Floating Photovoltaic System on Kranji Reservoir – Environmental Impact Assessment (EIA)

Volume 1 – Main EIA

Version 1.0 (Final)

May 2024

Project No.: 0566575

Sustainability is our business

ERM

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ACRONYMS AND ABBREVIATIONS

2-MIB	2-Methylisoborneol
AADT	Annual Average Daily Traffic
AAQT	Ambient Air Quality Targets
AC	Alternating Current
Al	Aluminium
ALARP	as low as reasonably practicable
AOI	Area of Influence
APCP	Air Pollution Control Plan
As	Arsenic
ASR	Air Sensitive Receptors
ASTM	American Society for Testing and Materials
B	Boron
Ba	Barium
BBOP	Business and Biodiversity Offsets Programme
BCNH	Black-crowned night heron
BIA	Biodiversity Impact Assessment
BOD5	Biochemical oxygen demand
BQISING	Benthic Quality Index
CCS	Central Control System
CCTV	Closed-circuit television
Cd	Cadmium
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CO	carbon monoxide
COD	Chemical oxygen demand
COLREG	Convention on the International Regulations for Preventing Collisions at Sea
COPPC	Code of Practice for Pollution Control
CPT	cone penetration test
Cr	Chromium
CR	Critically Endangered
CT	Contractor
Cu	Copper
DC	Direct Current
DD	Data Deficient
DEFRA	Department for Environment Food and Rural Affairs
DO	Dissolved Oxygen

DOC	Dissolved organic carbon
EBS	Environmental Baseline Study
EC	Environmental Consultant
ECB	erosion control blankets
ECD	Ecological Character Description
ECM	Erosion Control Measure
ECO	Environmental Control Officer
EDB	Economic Development Board
EHS	Environmental, Health and Safety
EIA	Environmental Impact Assessment
EM	Environmental Manager
EMMP	Environmental Management and Monitoring Plan
EN	Endangered
EPD	Environmental Protection Division
EPHA	Environmental Public Health Act
EPM	Environmental Protection and Management
EPMA	Environmental Protection and Management Act
ERM	Environmental Resources Management (S) Pte Ltd
ESA	Environmental Site Assessment
ESMAP	Energy Sector Management Assistance Program
Fe	Iron
FPV	Floating Photovoltaic
GHG	Greenhouse Gas
GI	Geotechnical Investigations
HDPE	high-density polyethylene
Hg	Mercury
IA	Impact Assessment
IAQM	Institute of Air Quality Management
IDA	Infectious Diseases Act
IFC	International Finance Corporation
IUCN	International Union for Conservation of Nature
JTC	Jurong Town Corporation
LAC	Limits of Acceptable Change
LC	Least Concern
LEDS	Low-Emissions Development Strategy
LOI	Loss on Ignition

LV	Low Voltage
Mn	Manganese
MND	Ministry of National Development
Mo	Molybdenum
MSDS	Material Safety Data Sheet
MSS	Meteorological Service Singapore
MV	Medium Voltage (11kV to 33kV)
MWac	Mega Watt AC capacity
MWdc	Mega Watt DC capacity
NBSAP	National Biodiversity Strategy and Action Plan
NCMP	Nature Conservation Master Plan
NDC	Nationally Determined Contribution
NDVI	Normalised Difference Vegetation Index
NE	Presumed Nationally Extinct
NEA	National Environment Agency
NG	Nature Groups
NGO	Non-Government Organisations
NH_3-N	Ammonia
Ni	Nickel
NMP	Noise Management Plan
NO_3-N / NO_2-N	Nitrate
NOX	oxides of nitrogen
NParks	National Parks Board
NSR	Noise Sensitive Receptors
NSRCC	National Service Resort & Country Club
NT	Near Threatened
NTU	Nephelometric Turbidity Units
O&M	operational and maintenance
PAR	Photosynthetically Active Radiation
Pb	Lead
PCD	Pollution Control Department
PCU	Power Conversion Units
PM	particulate matter
PO4-P	Phosphate
PPV	Peak Particle Velocity
PSD	Particle Size Distribution

PUB	Public Utilities Board
QECP	Qualified Erosion Control Professional
REC	Recognized Environmental Conditions
RFI	Request for Information
RMU	Ring Main Unit
Sb	Antimony
SBNP	Sungei Buloh Nature Park
SBWR	Sungei Buloh Wetland Reserve
SCADA	Supervisory Control and Data Acquisition
SCDF	Singapore Civil Defence Force
SDA	Sewerage and Drainage Act
Se	Selenium
SERIS	Solar Energy Research Institute of Singapore
SFA	Singapore Food Agency
SIDS	Silt Imagery Detection System
SME	Subject Matter Expert
SO2	sulphur dioxide
SOP	Standard Operating Procedures
SP	Singapore Power
SPT	standard penetration test
SRDB	Singapore Red Data Book
SWL	sound power levels
TAQMMS	Telemetric Air Quality Monitoring and Management System
TDS	Total dissolved solids
TIW	Toxic Industrial Waste
TN	Total nitrogen
TOC	Total organic carbon
TP	Total phosphorous
TPZ	Tree Protection Zone
TR	Technical Reference
TSP	Total Suspended Particulate
TSS	Total Suspended Solids
UNCBD	United Nations Convention on Biological Diversity
UNFCCC	United Nations Framework Convention on Climate Change
URA	Urban Redevelopment Authority
UV	Ultra-violet

VOC	volatile organic compounds
VPS	Vantage point surveys
VSR	Vibration Sensitive Receptors
VU	Vulnerable
WHO	World Health Organization
WP	Watt Peak
Zn	Zinc

GLOSSARY

Terminology	Definition
Adaptive Management	It is a practical approach to managing uncertainty, where implementation of mitigation and management measures are responsive to changing conditions and the results of monitoring throughout the project's lifecycle.
Alien Species	A species, subspecies or lower taxon, introduced outside its natural past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce.
Alternating Current (AC)	Alternating current (AC) is an electric current which periodically reverses direction and changes its magnitude continuously with time in contrast to direct current (DC) which flows only in one direction. AC is used by Singapore's national electricity grid.
Anoxic	Refers to conditions depleted of oxygen.
Aquifer	A rock formation that is sufficiently porous and permeable to yield a significant quantity of water to a borehole, well or spring. The aquifer may be unconfined beneath a standing water table, or confined (and therefore under pressure) by a lower permeability (hydraulic conductivity) horizon, or aquitard.
Area of Influence	The primary Project site(s) and related facilities and the additional areas in which aspects of the environment could conceivably experience significant impacts, such as: ■ associated facilities that are not developed and funded as part of the Project but are essential for the Project and without which the Project cannot proceed, and the associated additional areas in which aspects of the environment could conceivably experience significant impacts; ■ areas potentially affected by cumulative impacts resulting from other developments known at the time of the impact assessment, further planned phases of the Project or any other existing circumstances; and ■ areas potentially affected by impacts from predictable (but unplanned) developments as a result of the Project (i.e., induced activities), occurring at a later stage or at a different location.
Avoided Greenhouse Gas (GHG) Emissions	Avoided emissions are emission reductions that occur outside of a product's life cycle or value chain, but as a result of the use of that product.
Background Noise Level	It is a constant part of the noise environment of a location and should exclude short term extraneous noise events such as wind gusts, dogs barking or a plane flying overhead.
Baseline	The physical, biological, cultural and human conditions that will prevail in the absence of the Project, including interactions amongst them. The Baseline includes information on all receptors and resources that were identified during scoping (or at a later stage in the impact assessment process) as having the potential to be significantly affected by the Project.
Benthic	Bottom-dwelling; living on or under the sediments or other substrate.
Biodiversity	'Biological diversity' means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems.
Biota	The animal and plant life of a particular region and/or habitat.
Contamination	The introduction of pollutants (whether chemical substances, or energy such as noise, heat, or light) into the environment to such an extent that its effects become harmful to human health, other living organisms, or the environment.
Correction Factor (Noise)	Where corrections are applied to the maximum permissible noise level to account for existing background noise levels. Correction Factor is quantified in dB(A).
Cumulative Impact	An impact that arises as a result of an impact from the Project interacting with an impact from another activity to create an additional impact. How we assess such impacts and effects is strongly influenced by the status of the other activities (e.g., already in existence, approved or proposed) and how much data are available about them.
Decibel (dB)	The units of sound level and noise exposure measurement where a step of 10 dB is a ten-fold increase in intensity or sound energy.

Direct Current (DC)	Direct current (DC) is one-directional flow of electric charge. The electric current flows in a constant direction, distinguishing it from alternating current (AC).
Discharge	Release of water to surface waters or the ground from groundwater either via groundwater flow or by abstraction and subsequent discharge to ground, groundwater or surface water.
Ecological Character Description (ECD)	A conceptual framework developed by the Convention on Wetlands (Ramsar) to inform the management of Ramsar Wetlands. ECD is a combination of the ecosystem components, processes and benefits/services (both biotic and abiotic) that characterise the ecosystem at a given point in time.
Effect/ Impact	The specific consequence (to a resource/ receptor) arising from an alteration of existing conditions caused by the Project.
EIA Study Area	The area that needs to be studied in order to adequately understand and describe the Baseline likely to be affected by the Project. At a minimum, the EIA Study Area will encompass the Project footprint and the Area of Influence, and in some cases it may extend farther to further establish the context for the Baseline.
Embedded Controls	Physical or procedural controls that are planned as part of the Project design (i.e., not added solely based on a mitigation need identified by the impact significance assignment process). These are described from the very start of the IA Process as part of the Project (i.e., in the Project Description and Environmental Legislation, Policies, Standards and Criteria chapters).
Eutrophic	The increase in additions of nutrients to freshwater or marine systems, which leads to increases in plant and algae growth (biological production) and often to undesirable changes in ecosystem structure and function.
FPV System	Floating Photovoltaic Plant or system are solar panels mounted on a structure that floats on a body of water, typically a reservoir or a lake.
Greenhouse Gas	Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the earth's surface, the atmosphere itself, and by clouds. It is usually measured in Tonnes of Carbon Dioxide Equivalent (tCO_2e).
Groundwater	Water which is held in the pores or interstices of rock or alluvial deposits beneath the ground surface, forming an aquifer.
Groundwater abstraction	The removal of water from an aquifer, usually by pumping.
Habitat	Habitat means the place or type of site where an organism or population naturally occurs.
Impact Assessment Process	A systematic process that predicts the impacts of the Project and evaluates the resulting effects it is likely to have on elements of the physical, biological, cultural and human environment. It identifies measures that the Project will take to avoid, reduce, abate, remedy or compensate for adverse impacts/effects, and to enhance positive impacts/effects.
Lentic	Standing waters such as lakes and ponds, or swamps and marshes.
Limits of Acceptable Change (LAC)	LAC is the degree of change or impact that will be tolerated for the resource in use. LACs may indicate that the ecological character could be approaching a tipping point where significant impacts can occur.
Littoral zone	The nearshore part of the reservoir characterised by light penetration to the bottom. Light penetration is within the first 3m of water depth, below which light levels were negligible.
Megawatt Alternating Current (MWac)	It is the AC system capacity of a solar PV plant utility Scale from the Power Conversion Unit side (Megawatt - AC).
Megawatt Direct Current / peak (MWdc / MWp)	Is the DC system capacity of a solar PV plant measured on the DC side through the total # of Watts per # of solar panels.
Mitigation Hierarchy	The types (in order of preference) of mitigation that can be applied to address an impact. The **Mitigation Hierarchy** is as follows: • **Avoid at Source; Reduce at Source:** avoiding or reducing at source through the design of the Project (e.g., avoiding by siting or re-routing activity away

	from sensitive areas or reducing by restricting the working area or changing the time of the activity). • **Abate on Site:** add something to the design to abate the impact (e.g., pollution control equipment, traffic controls, perimeter screening and landscaping). • **Abate at Receptor:** if an impact cannot be abated on-site then control measures can be implemented off-site (e.g., noise barriers to reduce noise impact at a nearby residence or fencing to prevent animals straying onto the site). • **Repair or Remedy***:* some impacts involve unavoidable damage to a resource (e.g. agricultural land and forestry due to creating access, work camps or materials storage areas) and these impacts can be addressed through repair, restoration or reinstatement measures. • **Compensate in Kind; Compensate Through Other Means:** where other mitigation approaches are not possible or fully effective, then compensation for loss, damage and disturbance might be appropriate (e.g., planting to replace damaged vegetation, financial compensation for damaged crops or providing community facilities for loss of fisheries access, recreation and amenity space).
Mitigation Measure	A feature, procedure or other action that the Project commits to implement to avoid or reduce the magnitude of an adverse impact, or to enhance the magnitude of a positive impact.
Particulate Matter (PM)	It is a mixture of solid particles and liquid droplets found in the air. For example, dust, dirt, soot, or smoke. It is usually measured by PM10 (inhalable particles, with diameters that are generally 10 micrometers and smaller) and PM2.5 (fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller).
Pelagic zone	The open water part of the reservoir.
Photic zone	Where light intensity is above 1% of the surface light and where light availability is high enough to allow photosynthesis.
Precautionary Principle	The Precautionary Principle is an environmental approach that recommends for anticipatory action to be taken, when an activity possesses potential to cause harm and there is scientific uncertainty on the subject, including instances where there is a lack of available scientific information.
Project	The features and activities that are a necessary part of the Project Proponent's development, including all associated facilities without which the Project cannot proceed.
Project Engineer	Engineering team who is in charge of the engineering design of the floating photovoltaic system.
Project-specific Alternative	A particular approach for the Project (e.g., concept level alternatives, such as site location, technology, etc. or detailed alternatives, such as geotechnical investigation method) that could potentially be employed.
Receptor	Humans and other animals which can be impacted by Project activities.
Reservoir Study Area	The area of the reservoir agreed with the relevant technical agencies/ government authorities for the deployable area that needs to be studied in order to adequately understand and describe the Baseline likely to be affected by the Project.
Resource	An element of the physical, biological, cultural or human environment which is not a human or other animal (these are referred to as receptors) which can be impacted by the Project activities. Typical resources include, but are not necessarily limited to:

	■ In the physical environment: geological resources; sediments; land; water quality; water supply; air quality; noise level; vibration levels; light. ■ In the biological environment: terrestrial, freshwater and marine habitats; flora; biodiversity at the community, species and genetic levels; protected areas; ecosystem services. In the human or cultural environment: subsistence resources; community health, welfare, amenity and safety; employment and incomes; business and economic activity; land use; traffic; sites and features of archaeological, historic, traditional, cultural or aesthetic interest.
Sound Power Level (SWL)	A measure of the total power radiated by a source. The Sound Power of a source is a fundamental property of the source and is independent of the surrounding environment.
Sound Pressure Level (SPL)	The level of sound pressure; expressed in decibels, as measured by a standard sound level meter with a microphone. This differs from Sound Power Level (SWL) in that this is the received sound as opposed to the sound 'intensity'.
Species abundance	The total number of individuals of a taxon or taxa in an area, population, or community. Relative abundance refers to the total number of individuals of one taxon compared with the total number of individuals of all other taxa in an area, volume, or community.
Species Conservation Status	Species are classified into seven categories to determine their relative risk of extinction. The categories are arranged from high risk to low risk: Presumed Nationally Extinct (NE), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD).
Species of Conservation Concern/ Significance	These are defined as nationally or globally Critically Endangered (CR), Endangered (EN) or Vulnerable (VU) species.
Species richness	The number of species within a given sample, community, or area.
Stratification	Stratification is the division of the water column into layers with different densities caused by differences in temperature or salinity or both.
Thermocline	A thermocline is the transition layer between the warmer mixed water at the surface and the cooler deep water below.
Unplanned Event	A reasonably foreseeable event that is not planned to occur as part of the Project, but which may conceivably occur as a result of Project activities (e.g., accidents), even with a low probability.

1. INTRODUCTION

1.1 Purpose of this Report

This document presents the Environmental Impact Assessment (EIA) for the proposed Floating Photovoltaic (FPV) System on Kranji Reservoir (the System or Project). The assessment covers the construction and operation phases of the Project.

This EIA report comprises the following:

- Describes the project to be assessed in the EIA;
- Outlines the administrative framework;
- Provides an overview of the EIA methodology and scoping process related to the project activities and identification of potential impacts;
- Establishes the stakeholder engagement process;
- Assesses the potential impacts on environmental aspects; and
- Formulates the Environmental Management and Monitoring Plan (EMMP) for the proposed project phases.

This EIA has been prepared for Environmental Resources Management (S) Pte Ltd's (ERM) Client, the Renewable Energy User selected by EDB, Malkoha Pte Ltd (otherwise known as "Project Proponent"). Upon approval of the EIA, the Project Proponent will select and appoint a Developer/ Owner, who will own, design, build, install, operate and maintain the FPV System on Kranji Reservoir.

1.2 Project Background

1.2.1 Kranji Floating Solar Photovoltaic System Project

In December 2018, Singapore Government's Economic Development Board (EDB) launched a Request for Information (RFI) to explore the possibility of a large-scale floating solar photovoltaic system for private sector consumption on Kranji Reservoir (EDB, 2018).

The RFI identified that increasingly, as companies turn to renewable energy to reduce their carbon footprint, the availability of renewable energy in Singapore is viewed as a favourable consideration for business investments and expansions. It was envisaged by EDB that the selected proposer (i.e. the Project Proponent) of the project would commit to off-take (i.e. use) all the electricity generated by the project for their business needs.

Singapore Government adopted a two-stage model for the project:

- An Exploratory Stage – to determine the Renewable Energy User (i.e. the "selected proposer" or Project Proponent); and
- An Evaluation Stage:
  - Stage 1 – to determine the technical feasibility and environmental impacts of the project (this is the current stage of the project which the EIA is under); and
  - Stage 2 – to select a system builder and owner to own, design, build, install, operate and maintain the project (i.e. the "solution provider" or Developer/ Owner), from whom the Project Proponent will off-take the electricity generated.

It is recognised that while there has been strong interest in FPV systems globally, the sector is relatively nascent and few such systems have been deployed commercially. Therefore, the potential deployment of the project in Singapore presents a unique opportunity for local and regional companies to acquire the relevant project development and engineering capabilities that could support the growth of the sector in Singapore and the region (EDB, 2018).

Singapore Government identified Kranji Reservoir as the location for this project, with implementation being contingent on the outcome of environmental studies (i.e. this EIA).

1.2.2 Singapore Green Plan

In February 2021, Singapore Government launched the Singapore Green Plan (SG Green Plan, n.d.) which seeks to galvanise a whole-of-nation movement and advance Singapore's national agenda on sustainable development. The main programmes of the Green Plan include the Energy Reset. This programme recognises that whilst space for large-scale renewable energy projects is not readily available, Singapore is committed to quadrupling its solar energy deployment, thus increasing solar energy deployment by five times by 2030 (from the 2021 levels) to 2 GWp (gigawatt peak, i.e. 2,000 megawatt peak).

This FPV System on Kranji Reservoir utilises the limited readily available space for large-scale renewable project development, and contributes to achieving Singapore's target of 2GWp from solar deployment by 2030.

1.2.3 Singapore's Energy Story

Singapore has recognised that one of its biggest challenges in the next 50 years is ensuring a clean, affordable and reliable energy future. In order to achieve this, Singapore has laid out an 'Energy Story' plan (EMA, n.d.) which bases Singapore's energy sources on "4 Switches". These 4 switches refer to natural gas, solar, regional power grids and emerging low-carbon alternatives. The FPV System on Kranji Reservoir would contribute to these switches as part of the effort to achieve the solar target of 2GWp by 2030.

1.2.4 Energy Security and Resilience

In 2022, Singapore imported majority of its energy needs, with around 92% of electricity in Singapore being produced using imported natural gases (EMA, 2023). Having a secure and reliable energy supply is critical to Singapore's resilience and economic competitiveness. In view of the developments in the global energy sector, Singapore is taking temporary pre-emptive measures to safeguard its energy security and resilience (EMA, 2021). It is considered that this domestic solar project will support these national goals.

1.2.5 National Climate Change and Action Plan

Singapore has submitted its enhanced Nationally Determined Contribution (NDC) and its Long-Term Low-Emissions Development Strategy (LEDS) to the United Nations Framework Convention on Climate Change (UNFCCC). In 2022, Singapore announced that it will raise its national climate target to achieve net zero emissions by 2050 and reduce emissions to around 60 $MtCO_2e$ (million tonnes of carbon dioxide equivalent) in 2030 (NCCS, 2022). Increasing the share of non-fossil fuels in Singapore's electricity mix, and more renewable energy (such as this Project), are identified as main actions necessary to achieve these targets.

1.3 Overview of Project

The Project is to deploy an approximately 112.5 MWac (or 141 MWp)[1] (+/- 10%) FPV System on the north and central areas of the Kranji Reservoir. The FPV System will be connected to an integrated Project Substation located on Kranji Reservoir's eastern shoreline within the existing Sungei Kadut Industrial Estate, see *Section 2* for further details. The Project will be a fully operational FPV system, consisting of an in-reservoir FPV system (including PV panels, mounting systems, power conversion units, mooring and anchoring systems and connector cables), an operational and maintenance (O&M)

[1] MWp (or MWdc) is a measure of the Direct Current (DC) output of PV panels. MWac is a measure of the power output from PV panels after its DC output has been converted to Alternating Current (AC). This conversion is necessary as Singapore's power grid and most of Singapore's equipment/ systems/ appliances run on AC.

berthing facility (location subject to approval from agencies) for the Project's work boats, a power grid connection via connector cables and an integrated Project Substation, as well as associated O&M facilities (which may include control centre, office facilities, visitor centre and equipment storage). The EDB is the lead government agency for the Project.

1.4 Project's Environmental Benefits

1.4.1 Avoided Greenhouse Gases (GHG)

This Project is expected to have a capacity of 112.5 MWac (or 141 MWp) (+/- 10%). This is equivalent to producing 197 GWh (gigawatt hours) per year (or 4,637 GWh over its 25-year operational life). This Project will be the largest FPV system in Singapore and contribute to 7.1% of Singapore's target of achieving 2GWp of solar generation by 2030.

As summarised in *Figure 1-1*, based on GHG accounting guidance and methodologies from IFI (2019 and 2022) for grid connected renewables and grid emissions factors, it is estimated the Project will contribute to the avoidance of approximately 76,785 tonnes (t) carbon dioxide equivalent (CO_2e) per year, and a total of approximately 1,919,625 t CO_2e over its 25 years operation.

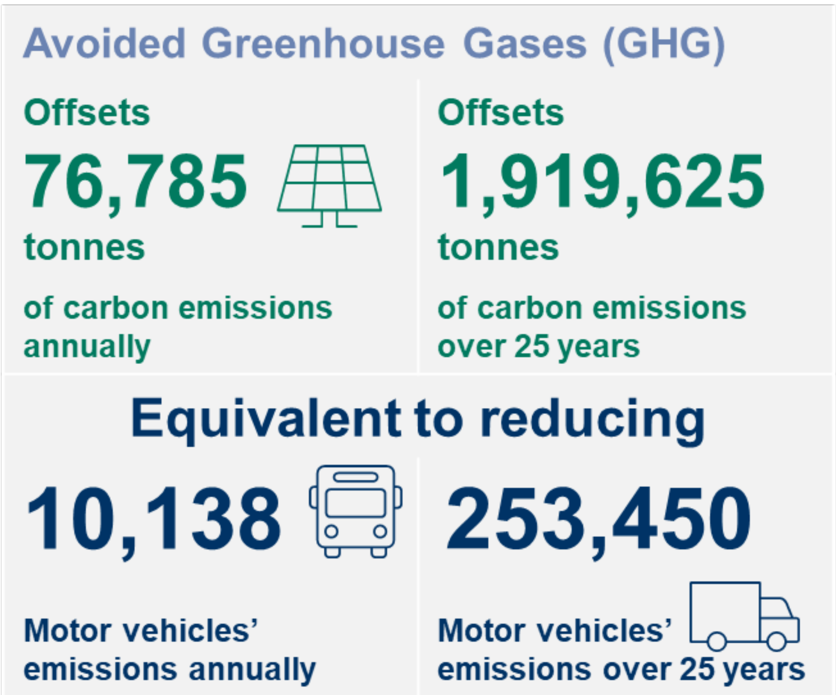


Figure 1-1: Estimated Avoided Greenhouse Gas Emissions from the Project[2]

1.4.2 Potential Water Conservation through Reduced Evaporation

The Floating Solar Handbook for Practitioners (World Bank Group, ESMAP and SERIS, 2019) refers to the potential for reduced evaporation from FPV projects depending on the system design, such as the configuration of FPV panels. Various internationally published studies in tropical/ sub-tropical regions (Melvin and Xiang, 2015; Rosa-Clot *et al.*, 2017; Gonzalez Sanchez *et al.*, 2021; Mamatha & Kulkarni, 2021; Farrar *et al.*, 2022) have estimated evaporation rates related to FPV projects via various means. Depending on the coverage and configuration of FPV panels, a number of these studies indicate evaporation rates below FPV panels could reduce by 40–80% compared to non-FPV

[2] Indicative, based on 2018 motor vehicle statistics from Singapore (NEA, 2022). Estimations do not consider the lifecycle emissions of the Project.

areas (Farfan *et al.*, 2018; Gonzalez Sanchez *et al.*, 2021; Farrar *et al.*, 2022). For this Project, the potential for reduced evaporation will be reviewed/ studied as the Project progresses, where appropriate, subject to further discussions between PUB and the Developer/ Owner on requirements and monitoring approaches.

1.5 Objectives of this EIA Study

The overall objective of the EIA is to evaluate the existing pre-construction baseline environmental status around the Project Sites and carry out an objective assessment of the various impacts on the environment which may result from the construction and operational activities of the Project, with reference to the applicable legislation and guidelines. The specific objectives of the EIA are:

- To identify and describe the elements of the environment likely to be affected by the Project's construction and operational activities;
- To describe the existing baseline environmental conditions of the Project Sites and surrounding areas;
- To identify, quantify and assess potential impacts and determine the significance of impacts on sensitive receptors and potentially affected uses according to the defined criteria;
- To propose mitigation measures to minimise any significant impacts during Project's activities;
- To identify, predict and evaluate the residual environmental impacts (after practicable mitigation), and the cumulative effects expected to arise during Project activities and other known concurrent projects in the immediate vicinity of the Project sites (see *Section 4.3.1*), in relation to the sensitive receptors and potentially affected uses; and
- To detail the specific mitigation and monitoring measures, and implementation roles and responsibilities for the Project's phases in an EMMP.

1.6 Scope of the Assessment

The scope of the EIA was determined through engagements with EDB, Ministry of National Development (MND), Urban Redevelopment Authority (URA), Public Utilities Board (PUB), and relevant Technical Agencies including National Parks Board (NParks) and the National Environment Agency (NEA). On this basis, the impacts to the following aspects were identified for assessment during the construction and/ or operation phases in this EIA (see *Sections 6 to 11* for further details):

- Surface Water Quality (including reservoir sediment);
- Biodiversity;
- Air Quality;
- Airborne Noise and Vibration;
- Soil & Groundwater; and
- Vector Control.

Excluded from the scope of the Project (and EIA) is the connection from the integrated Project Substation to the nearest feasible Singapore Power (SP) grid connection point [3], for onward transmission of the electricity; this connection (and any related studies) from the integrated Project Substation to the SP grid will be carried out by the relevant parties.

[3] Location to be confirmed during final design stage.

1.7 Limitations of the Report

A conservative approach has been carried out for the assessment of impacts to set out the parameters or boundary limits of the Project, i.e. the environmental limits within which the Project's impacts are as low as reasonably practicable. This conservative approach is based on the following:

1.7.1 Concept Engineering Design at Feasibility Study Stage

This EIA was undertaken at the technical feasibility stage of the Project, and therefore assesses the site layout and features of the concept design available at the time of preparing the EIA. Where detailed engineering design information was not available to inform the study, reasonably conservative assumptions were made based on ERM's internal subject matter experts' expertise and in consultation with the Project Proponent, the Project engineers and relevant Government and Technical Agencies (where appropriate) based on similar projects. This EIA has considered the conservative scenarios in the undertaking of the impact assessment, and the development of mitigation measures and monitoring plans for the construction and operation stages of the Project. Measures related to Project engineering design, which were identified through the EIA process, will be passed on to the Developer/ Owner for incorporation into the detailed design and construction approaches. A Developer/ Owner will be selected after the approval of the EIA, with the role to ensure that the detailed design is developed within the parameters and limits (e.g. adhering to mitigation measures) identified through the EIA process. The Developer/ Owner is to demonstrate to relevant agencies that the final design conforms to the EIA.

1.7.2 Use of Precautionary Principle

Where appropriate, the Precautionary Principle has been adopted in this EIA report. The Precautionary Principle is an approach that recommends for anticipatory action to be taken, when an activity possesses potential to cause harm and there is scientific uncertainty on the subject, including instances where there is a lack of available scientific information. The principle was adopted to overcome the lack of local or international standards/ guidelines or scientific studies to allow for an assessment of impacts, such as impacts to biodiversity due to operation of the FPV on the reservoir waterbody. This also resulted in the adoption of a conservative approach in undertaking the assessment, and assigning residual (post-mitigation) impact significance. For example, in some instances, despite mitigation, pre-mitigation impact significance levels may be retained after applying mitigation where there are limited baseline or study data or uncertainties of impacts over the longer term. Residual impact significance levels are to be validated through the establishment of an extensive long-term EMMP requiring monitoring and dataset analysis through pre-construction, during construction and post-construction (see *Section 12, Environmental Management and Monitoring Plan)*.

1.8 Report Structure

The remainder of this report is structured as follows:

- Section 2: Project Description;
- Section 3: Administrative Framework;
- Section 4: Overview of EIA Methodology and Scoping;
- Section 5: Stakeholder Engagement;
- Section 6: Surface Water Quality;
- Section 7: Biodiversity;
- Section 8: Air Quality;
- Section 9: Airborne Noise and Vibration;
- Section 10: Soil and Groundwater;

- Section 11: Vector Control;
- Section 12: Environmental Management and Monitoring Plan (EMMP);
- Section 13: Conclusion; and
- Section 14: References.

2. PROJECT DESCRIPTION

This Section sets out an overview of the:

- Project's site and surroundings;
- Proposed FPV System, and associated facilities;
- Project-specific alternatives identified during this initial feasibility stage for the Project;
- Pre-construction, construction, and operation and maintenance (O&M) activities;
- Indicative pre-construction and construction schedule and O&M timeline; and
- Embedded controls already planned to be put in place as part of the Project design, construction and operation from the outset, for example, to ensure Project's compliance to environmental, health and safety requirements and reservoir operational requirements from PUB.

2.1 Project Site and Surroundings

The Project's FPV system is proposed to be located in the north and central areas (the Reservoir Project Site) of the Kranji Reservoir situated in the north west of Singapore. During construction, a temporary staging/ launching area and temporary launching ramp are proposed on the eastern shoreline of the Kranji Reservoir within Sungei Kadut Industrial Estate. During operation, the in-reservoir FPV will be connected to a permanent integrated Project Substation (with O&M facilities) within the boundary of the temporary staging/ launching area on the eastern shoreline of the Kranji Reservoir within Sungei Kadut Industrial Estate. An in-reservoir O&M Berthing Facility (location subject to approval from agencies) for the Project's work boats will be located in close proximity to the integrated Project Substation (i.e. within the area of the temporary launching ramp). These Project components represent the Project Sites, and their locations are indicated in *Figure 2-1.* The need for additional buildings for O&M warehousing/ facilities within the existing Sungei Kadut Industrial Estate, if any, will be determined during the detailed design by the Developer/ Owner, and relevant Government agencies will be consulted as appropriate.

To the north of these main Project Sites are the Kranji Reservoir Park A and B, Sungei Buloh Wetlands Reserve, the Johor Straits, Mandai Mangrove and Mudflats, and over 1.1 km away is the international boundary in Johor Straits; to the east is the Sungei Kadut Industrial Estate as well as a Future Kranji Reservoir Eastern Park; to the south are the remaining areas of Kranji Reservoir and an area for military training; and to the west is the National Service Resort and Country Club (NSRCC) Kranji Sanctuary Golf Course, the Kranji Marshes, and Government Land (*Figure 2-1*).

Figure 2-1: Proposed Project Sites

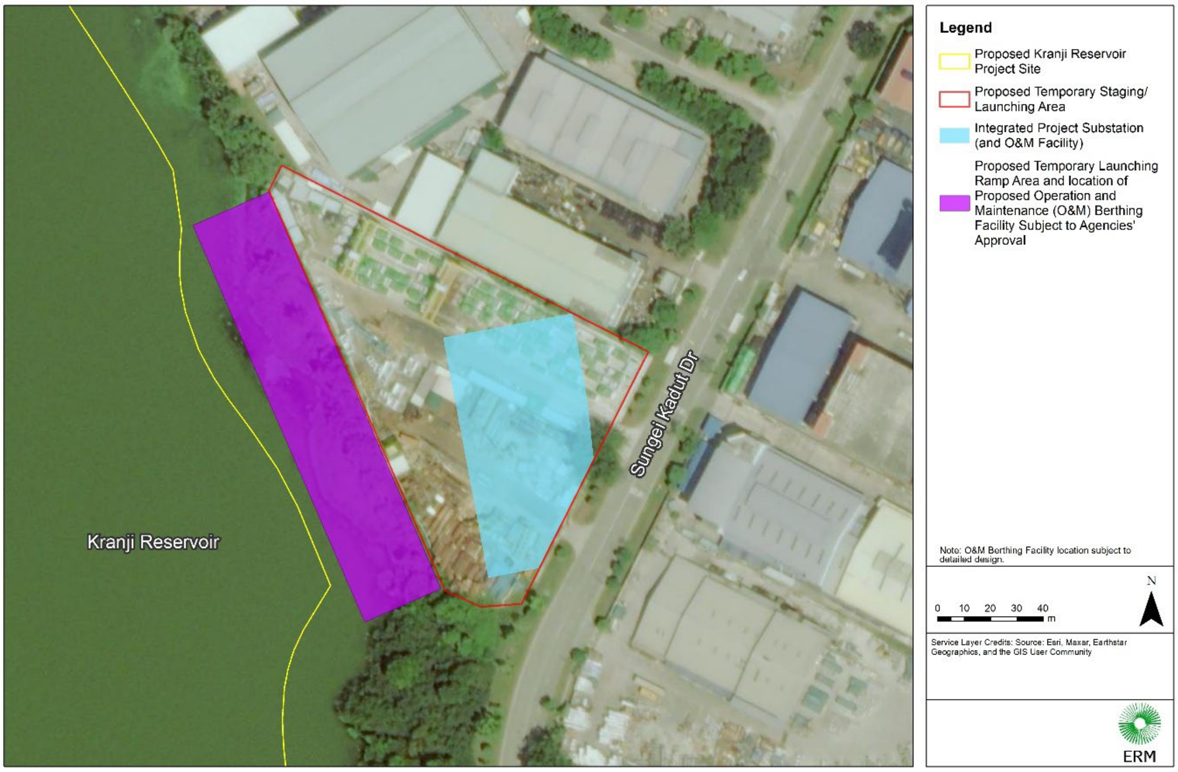


Figure 2-2: Zoom in of the Proposed Temporary Staging/ Launching Area and Permanent Integrated Project Substation Site

2.2 Proposed FPV System

2.2.1 Design Basis for Impact Assessment

Further to *Section 1.7.1 and 2.1,* this Project Description in some instances describes a range of design and construction options upon which the impact assessment is based, and which will be considered at the later detailed design stage of the project. Design parameters are based on available techniques and technology in the market at the time of writing.

Based on ERM's internal subject matter experts' expertise, consultation with the Project Proponent and the Project engineers, and relevant Government and Technical Agencies (where appropriate) based on similar projects; a conservative approach has been taken to the impact assessment of the design, construction and operation of the Project. For example, assessing the impacts of the maximum reasonable coverage (or footprint) of FPV over the reservoir for surface water quality and biodiversity impacts to understand if significant surface water quality or biodiversity impacts are anticipated and thus the mitigation that should be considered.

Design and construction approaches will be finalised during the detailed design by the Developer/ Owner and should be within the Project's parameter and boundary limits established in this EIA.

Project-specific alternatives which were reviewed and not considered viable solutions for the Project are presented in *Section 2.3*.

In general, the options for the design and placement of the Project components have considered a range of aspects:

- Technical;
- Engineering;

- Economic;
- Environmental;
- Stakeholder concerns; and
- Other considerations, including (amongst others): maintaining PUB's reservoir operations and vessel access; location, availability (e.g. tenure) and accessibility (e.g. connectivity to infrastructure) of land; right-sizing of construction and operational areas; and construction and operational requirements.

Design, construction and operations will be in accordance with relevant Singapore codes and standards and international standards, for example Singapore's TR 100: 2022 Technical Reference on Floating Photovoltaic Power Plants – Design Guidelines and Recommendations, published in 2022.

Details of the Project components and main construction and operation activities that are considered to potentially have notable interactions with the environment and receptors in the vicinity are elaborated further in the subsequent sections.

2.2.2 Overview of FPV System

The Project will involve the deployment of up to approximately 112.5 MWac (or 141 MWp)[4,5] (+/- 10%) FPV System on Kranji Reservoir.

An indicative layout of the FPV System components, including in-reservoir FPV islands, is presented in *Figure 2-3.* The main permanent Project components are described in *Table 2-1*. A schematic overview of a large-scale FPV System is presented in *Figure 2-2.* The reservoir-based and land-based project components, as well as the detailed FPV layout, are subject to detailed design (by the selected Developer/ Owner) and Planning Approval.

An artist's impression visualising future FPV panels from various viewing points in publicly accessible locations around Kranji Reservoir (namely (A) Kranji Fishing Ground B (B) Kranji Reservoir Park A and (C) Kranji Marshes Raptor Tower at Kranji Marshes) can be found in *Figure 2-5*.

See *Section 2.4* for an overview of pre-construction, construction and operation and maintenance activities associated with the Project.

[4] Subject to final detailed design and technologies available at the time of construction, e.g. PV panel capacities are continually improving and becoming more efficient, thus more capacity (i.e. MWac) may be achieved within the same size PV module and footprint.

[5] MWp (or MWdc) is a measure of the Direct Current (DC) output of PV panels. MWac is a measure of the power output from PV panels after its DC output has been converted to Alternating Current (AC). This conversion is necessary as our power grid and most of our equipment/ systems/ appliances run on AC.

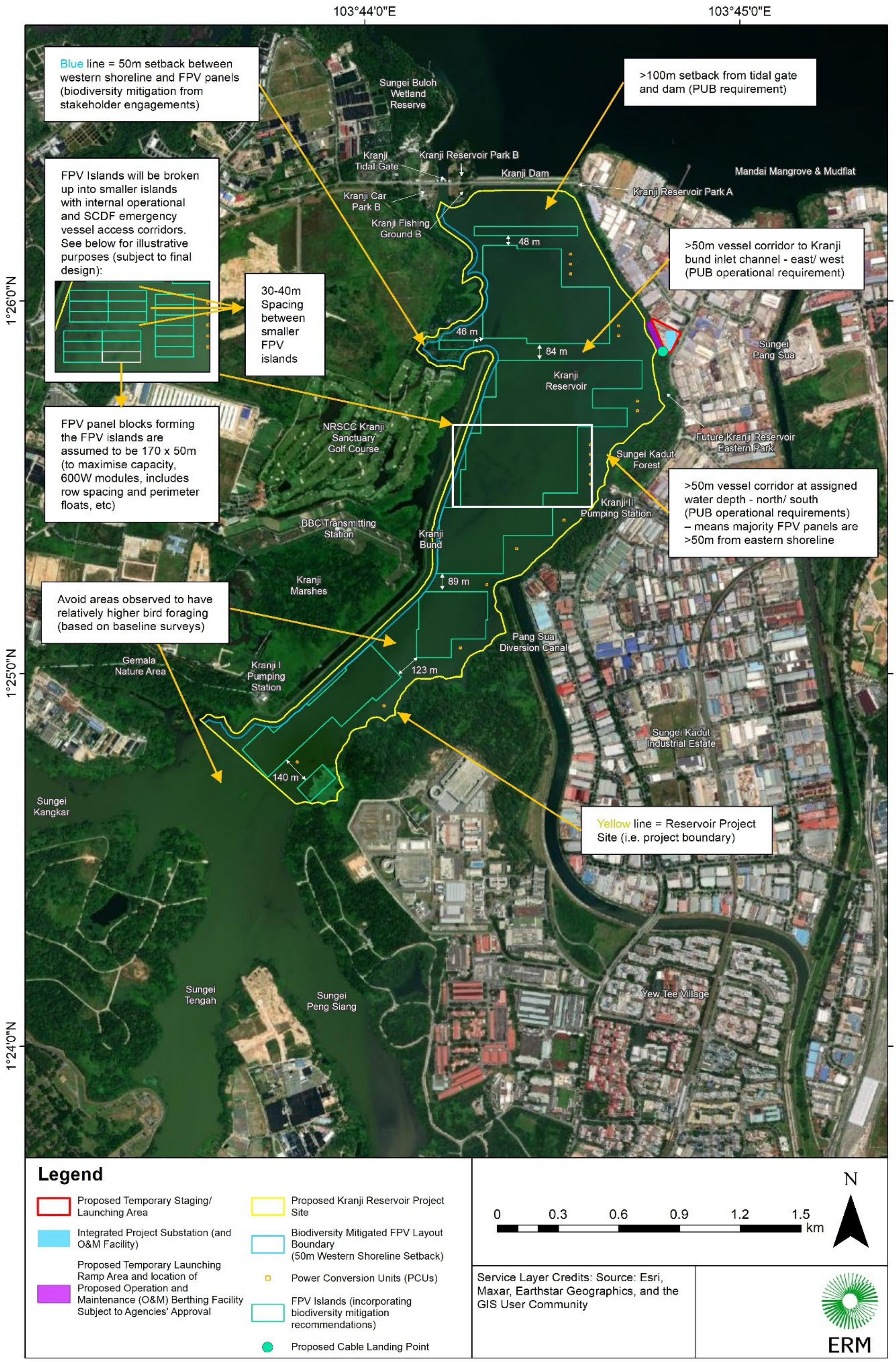


Figure 2-3: Indicative Layout of Main Project Components & FPV Layout Considerations

Table 2-1: Main Permanent In-Reservoir and Land-based Project Components

<table>
<tr><th>S/N</th><th>Main Component</th><th>Sub-Components</th><th>Descriptor</th></tr>
<tr><td>1</td><td>FPV System (in-reservoir)</td><td>

PV Panels/ Modules
Mounting System – floats/ fixed systems.
Power Conversion Units (PCUs):
Transformers
Central inverter
Ancillary equipment – e.g. switchgear, weather station etc
Mooring and Anchoring Systems – bottom anchoring and/or piles.
Connector Cables – laid on the reservoir bed between FPV islands, and the eastern shore (to connect to integrated Project Substation).
</td><td>
Capacity: 112.5 MWac (or 141 MWp) (+/- 10%)
<table>
<tr><th>S/N</th><th>Description of surface area coverage[a]</th><th>Hectares</th><th>% of Kranji Reservoir Area</th></tr>
<tr><td>1</td><td>Kranji Reservoir area[b]</td><td>522</td><td>-</td></tr>
<tr><td>2</td><td>Reservoir Project Site area</td><td>201</td><td>38.5%</td></tr>
<tr><td>2a</td><td>Reservoir Project Site area directly covered by FPV infrastructure footprint (i.e. large FPV islands and PCUs etc)</td><td>112</td><td>21.5%</td></tr>
<tr><td>3</td><td>Kranji Reservoir area <u>not covered</u> by FPV infrastructure footprint</td><td>410</td><td>78.5%</td></tr>
</table>
Note:
(a) The Developer/ Owner will carry out necessary surveys and designs to verify actual coverage areas.
(b) Area determined based on discussions with PUB.

FPV panel blocks (which form the FPV islands) assumed to be approximately 170m x 50m.
PCU/ Central inverters: approximately 18 to 36 number.
Connector cables: medium voltage, 11 - 33kV, with a shoreline landing point near the integrated Project Substation.
</td></tr>
<tr><td>2</td><td>Integrated Project Substation (with O&M facilities) (land-based)</td><td>

Connector Cables – land-based connection to the integrated Project Substation.
Integrated Project Substation:
Control centre / SCADA[6] system
Transformers
Ancillary equipment – e.g. switchgear, spare equipment.
Other potential integrated O&M facilities[a]:
FPV System control centre
Office/ staff facilities
Visitor centre
Maintenance/ spare equipment store to support regular inspections and maintenance activities.
</td><td>

Site: approximately 0.44 ha.
Building: 9m high with 3.5 m deep basement.
Location: on eastern shoreline in Sungei Kadut Industrial Estate.
</td></tr>
<tr><td>3</td><td>O&M Berthing Facility (in-</td><td>
Berthing facility to facilitate mooring of O&M work boats.</td><td>

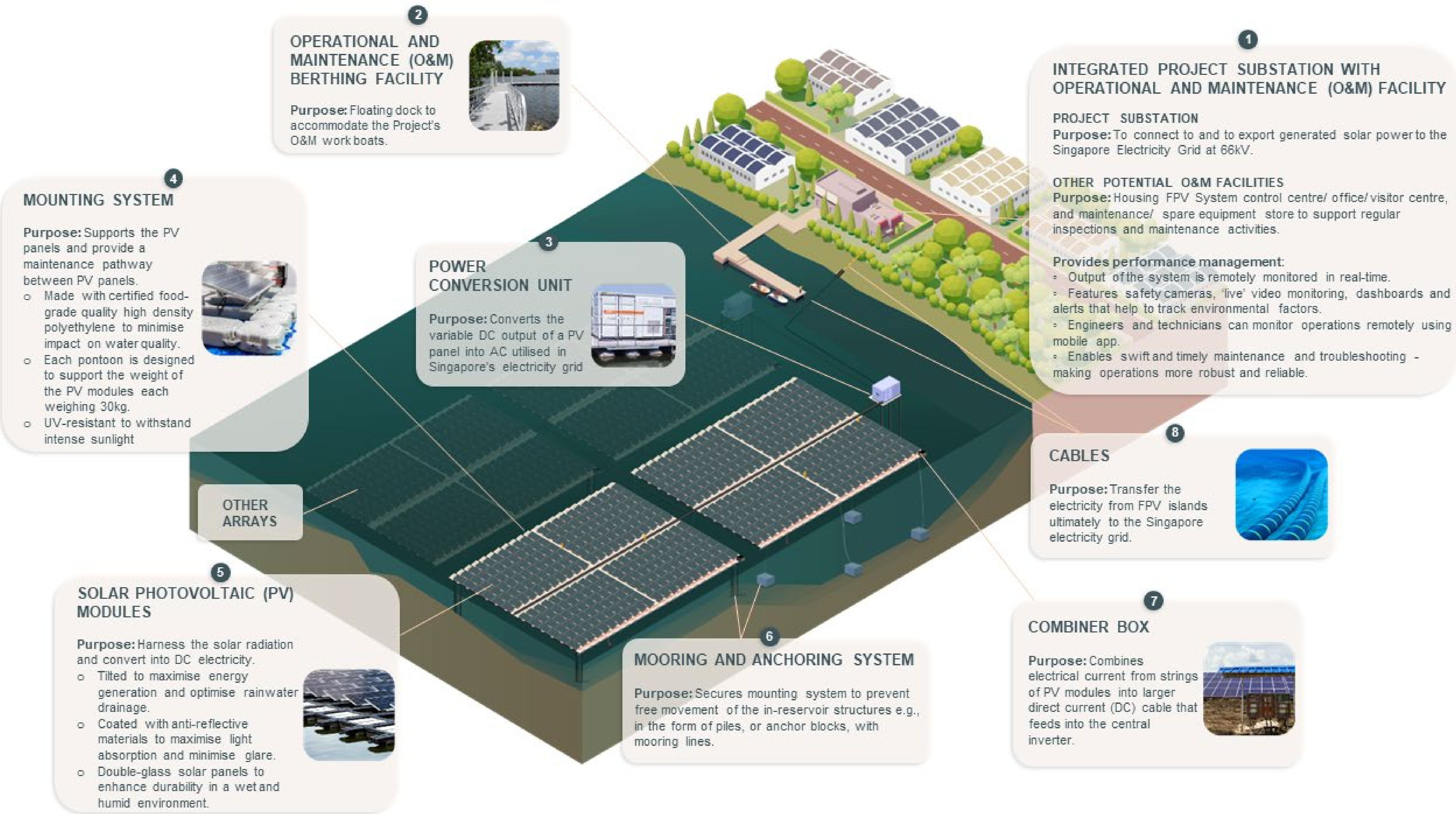
Size: approximately 20m x 5m.
Location: on eastern shoreline in close proximity to integrated Project Substation.
</td></tr>
</table>

[6] SCADA system = Supervisory Control and Data Acquisition system

S/N	Main Component	Sub-Components	Descriptor
	reservoir) (location subject to approval from agencies)		

Note: All main components listed above are indicative and subject to change during detailed design.

(a) The need for additional buildings for O&M warehousing/ facilities within the existing Sungei Kadut Industrial Estate, if any, will be determined during detailed design by the Developer/ Owner, and relevant Government agencies will be consulted as appropriate.



Source: Adapted from Sembcorp, 2021

Figure 2-4: Schematic Overview of a Large-scale FPV System

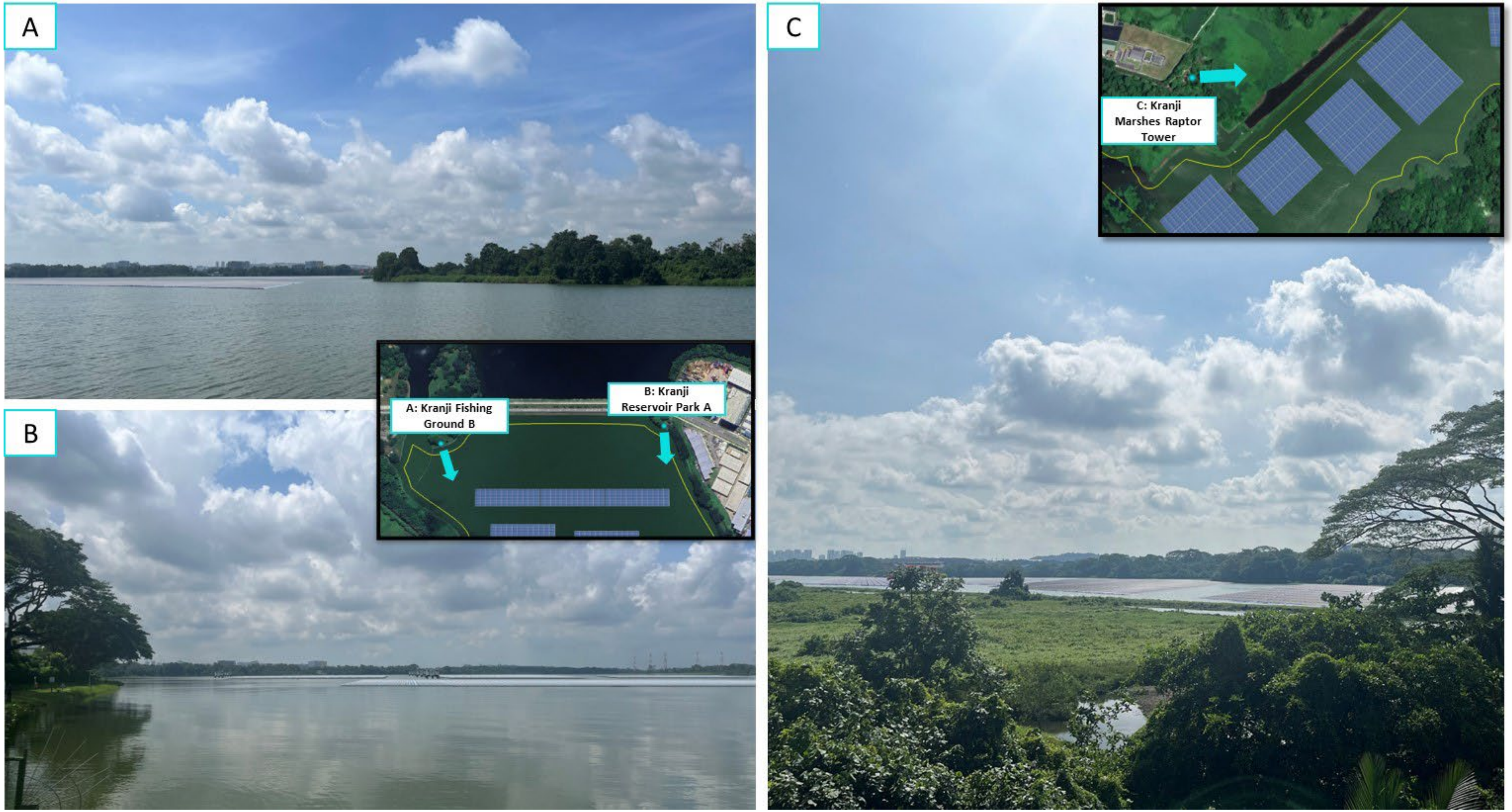


Figure 2-5: Artist Impression of FPV from the directions of (A) Kranji Fishing Ground B, (B) Kranji Reservoir Park A and (C) Kranji Marshes Raptor Tower

2.3 Project-specific Alternatives

During development of the concept engineering design options various technical, engineering, economic, environmental, stakeholder concerns and other considerations, were taken into account. In addition to the project design options presented within this Section and assessed in the EIA, a number of alternatives were considered for the Project, some of which, upon review, were not considered viable. Note, the Kranji Reservoir Project Site boundary was demarcated by Government for this Project, hence only alternatives within the limits of this site boundary are considered. *Table 2-2*: discusses the project-specific alternatives considered.

Table 2-2: Project-specific Alternatives Considered

S/N	Main Component	Sub-Components/ Description
1	FPV System - Technologies	■ The MW capacity of the FPV system is based on current technologies. PV panel capacities are continually improving and becoming more efficient. Improvements in technology, for example, more capacity (i.e. MWac), may be able to be achieved per PV module in the future. Therefore, in the future, more capacity may be able to be achieved within the same FPV footprint. ■ Technology improvements, such as MW capacity, that do not exceed the boundary limits established and assessed in this EIA, e.g. FPV layout/ footprint presented in the EIA, are not anticipated to significantly adversely alter the impact assessments herein.
2	FPV System – Layout	■ Various FPV layout iterations have been carried out in consultation with Government agencies to evolve from a “no constraints” scenario that assumed no layout constraints (e.g. no PUB reservoir operational constraints), to the FPV layout(s) assessed in this EIA. These iterations considered: - Maintaining PUB’s reservoir operations and vessel access requirements. - Right-sizing of construction and operational areas. - Environmental constraints and opportunities, particularly biodiversity and surface water quality. ■ Conservative FPV layout scenarios were assessed across the different environmental aspects of surface water quality and biodiversity: - Surface water quality – a more conservative, larger FPV layout has been modelled and assessed in this EIA (equivalent to 122 ha of FPV coverage (see *Section 6*, *Figure 6-3*) – vs the 112 ha presented for approval in this EIA (*see Figure 2-3*)). The FPV layout assessed in the water quality model assumed: (i) no breaking up of the large FPV islands, and (ii) included a southern FPV extension (which was originally considered, and later removed due to biodiversity concerns). This has resulted in a more conservative modelling approach (larger coverage of FPV), and thus greater confidence in the surface water quality impact assessment and the understanding of the maximum extent of FPV layout that is acceptable in terms of surface water quality. - Biodiversity alternatives and considerations included: ○ Consideration of a southern FPV extension – the feasibility of an extension of the original FPV layout south (“southern extension”), beyond the Reservoir Project Site, was initially considered during the preliminary concept design development for this EIA (see *Figure 6-3*). However, further to the analysis of bird baseline survey data in particular, the Project decided to retain the southern areas as “no build” to avoid impacts to these higher bird usage areas. ○ Preservation of an area in the central west shoreline area of the reservoir, adjacent to Kranji Marshes, where relatively higher bird foraging was observed from baseline surveys. This was achieved through a reduction in the FPV coverage area and re-orientation of the FPV islands to accommodate preserving the central west shoreline area. ○ Setbacks from shoreline to FPV panels:

S/N	Main Component	Sub-Components/ Description
		▪ A setback distance of 25m from the FPV layout to Kranji Reservoir western shoreline was originally established to identify the maximum power production boundary ("unmitigated maximum FPV layout") for the project, for the biodiversity impact assessment to assess a conservative (larger) development scenario and thus through the EIA: (i) understand the potential impacts of the Project's extent on biodiversity, (ii) determine biodiversity mitigation to reduce impacts as low as reasonably practicable, and (iii) establish the Project boundaries within which the Developer/ Owner must design, build and operate the Project. ▪ A setback distance of 50m from the FPV layout to the western shoreline of Kranji Reservoir, where relatively higher bird foraging was observed, has been suggested by stakeholders and have been taken forward as a biodiversity mitigation in this EIA. ▪ As a result, a "mitigated biodiversity FPV layout" has been recommended in this EIA for approval (see *Figure 2-3*), incorporating both: (i) reduction in the FPV coverage area and re-orientation of the FPV islands away from the central west observed higher bird foraging area (see *Section 7, Table 7-18*); and (ii) a setback distance of 50m from the Kranji Reservoir western shoreline to the FPV layout. In addition, it is proposed that the final FPV layout design by the Developer/ Owner will further break up the large FPV islands (presented in this EIA) with 30-40m intra-island vessel corridors for O&M and emergency vessel access corridors. ○ Based on the above alternatives and considerations, including inputs from stakeholders, the biodiversity impact assessment has resulted in the recommendation for a "mitigated biodiversity FPV layout" to be taken forward for approval in this EIA (see *Figure 2-3*). ■ Detailed design, construction and/ or operational boundary limits that are smaller than, or equal to, those assessed in this EIA are not anticipated to significantly adversely alter the impact assessments herein. A comprehensive EMMP (*Section 12*) is recommended to verify the significance of impacts assessed in this EIA.
3	FPV System – Inverters	■ Consideration was given to use of string inverters: - Typically more string inverters are required versus larger central inverters. - String inverters are smaller and lighter than central inverters, and would be distributed on the FPV islands (rather than within separate individual Power Conversion Units), and thus would not add additional footprint to the Project. ■ As string inverters would have minimal impact, the larger central converter option (as individual Power Conversion Units) was selected for assessment in this EIA as a conservative scenario. Therefore should string inverters be selected for this Project, they are not anticipated to adversely alter the impacts assessed in this EIA.
4	Connector Cable – Installation method	■ Various cable installation methods were considered in-reservoir, including burial in the reservoir bed, laying on reservoir bed, floating cables mid-depth in the water column, and floating cables on the surface. ■ Burial of cables in the reservoir bed are not considered viable due to potential suspension of reservoir bed sediments into the water column. ■ Floating cables mid-depth in the water column, or floating cables on the surface are not considered viable given the number of operational vessel movements and vessel access corridors required within the reservoir, resulting in high risks to floating cables from damage from vessels, and vice versa. ■ Laying of cables on the reservoir bed is considered the most viable option for cable installation and is considered in this EIA.
5	FPV System – Proposed Temporary	■ The western shorelines of Kranji Reservoir with biodiversity interests, and southeastern military areas were not considered viable for the proposed

S/N	Main Component	Sub-Components/ Description
	Staging/ Launching Areas, O&M Berthing Facility (location subject to approval from agencies) and Integrated Project Substation (with O&M facilities)	temporary Staging/ Launching areas, integrated Project Substation and O&M facilities. ■ Various locations have been considered to the north and east of the Kranji Reservoir for proposed temporary Staging/ Launching areas, including Kranji Car Park B, Kranji Fishing Ground B and Kranji II Pumping Station (see *Figure 2-1*). These were not considered viable due to: - Lack of space and accessibility to reservoir, requiring multiple small Staging/ Launching areas (e.g. resulting in construction schedule and logistics concerns). - Future planned developments in the area. - Potential impacts on reservoir operations & recreational activities. - Environmental considerations, such as surface water quality and biodiversity. ■ Consultations with Government agencies identified the currently proposed temporary Staging/ Launching areas, integrated Project Substation (with O&M facilities) location and thus the O&M berthing facility location, which are on existing Sungei Kadut Industrial Estate land outside of forested areas with appropriate road and reservoir shoreline frontage accessibility. No other viable options have been identified for the Project by Government agencies for the proposed temporary Staging/ Launching areas, O&M berthing facility and Integrated Project Substation (with O&M facilities).

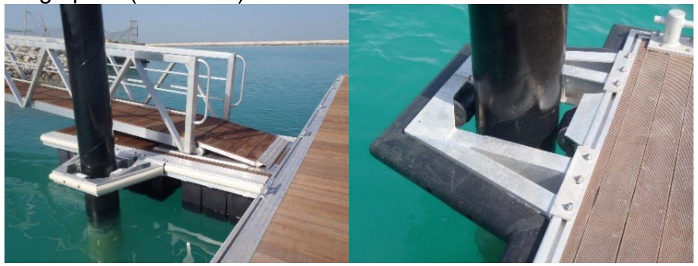
2.4 Project Activities

This section outlines the main project activities during pre-construction, construction and operation and maintenance phases of the project, see *Table 2-3.* The final designs and construction approaches by the Developer/ Owner will be determined through: considering the boundary limits established in this EIA, Government agency consultation and detailed design studies to optimise the Project while minimising impacts on the nearby surroundings, landowners and reservoir itself, as well as maintaining compliance with all agreements and approvals.

Table 2-3: Overview of Project Activities

S/N	Project Activities	Sub-Activities	Description	Illustration/ Example
Pre-Construction				
1	Geotechnical Investigations (GI)	■ Land-based GI ■ In-reservoir GI	■ To inform the detailed design and construction of in-reservoir FPV system anchoring and piling, and O&M berthing facility piles (location subject to approval from agencies); as well as and land-based integrated Project Substation (O&M Facility) foundations. ■ Temporary GI works are considered to be smaller scale activities than the piling described in item 4 below. GI works are assessed further in the EIA, where appropriate.	In-reservoir GI:  Land-based GI:  *Source: Ground Instrumentation & Engineering Pte Ltd (in-reservoir GI) and FOSTA Pte Ltd (land-based GI)*

S/N	Project Activities	Sub-Activities	Description	Illustration/ Example
Construction				
2	FPV System – proposed temporary Staging/ Launching	■ Preparation of the proposed temporary Staging/ Launching Area(s) (land-based)	■ Approximately 1.1 hectare site will be cleared and prepared (including minor grading). ■ Clearance of vegetation along the approximately 150m shoreline to establish temporary launching ramp into the reservoir and construction of permanent O&M berthing facility extending approximately 20m into the reservoir. ■ Establishment of areas and facilities, e.g. for construction trailers, truck loading and unloading facilities, fabric buildings, office area, portable sanitary facilities, temporary shelters for workers during rest breaks and meals, and laydown areas for storage of raw materials, equipment and wastes. ■ Material delivery will likely need to be spaced out over the FPV assembly period. The use of heavy haulers will be needed almost continuously during this period of construction.	Temporary Staging/ Launching Area and Launching Ramp:  *Source: Ciel & Terre International, 2016*

S/N	Project Activities	Sub-Activities	Description	Illustration/ Example
3	FPV System	■ Assembly of FPV System (land-based)	■ Unpackaging of materials, staging of materials, connecting the rows of floats to form a floating platform, mounting PV panels on the floating platform/ pile system assembly and testing of FPV arrays, and launching of the FPV islands and other FPV system components.	Assembly of FPV on Launching Ramp:  *Source: Ciel & Terre International, 2016*
4		■ Deployment of Anchoring and Mooring System (in-reservoir) (see *Appendix 2.1* for further details on these Options)	■ ***PCU/ central inverters:*** on fixed large piles with platform above top water level of reservoir. ■ ***O&M berthing facility*** *(*location subject to approval from agencies*)*: on fixed large piles with roller connections to enable it to rise and fall with the water levels. ■ ***FPV mounting system (Option 1):*** Either all FPV on: - large (300-600mm diameter) piles with roller connections; OR - anchor blocks (2m (L) x 2m (W) x 1m (H)). ■ ***FPV mounting system (Option 2):*** Either: - Shallow area FPV (predominantly western waters) on small (150-300 mm diameter) piles, with fixed frame; AND - Remaining FPV on large (300-600mm diameter) piles with roller connections; OR anchor blocks (2m (L) x 2m (W) x 1m (H)). Note: see *Appendix 2.1* for details of Anchoring and Mooring System Option assumptions.	Large piles (indicative) with roller connections:  *Source: Marina Technology and Construction* Illustration of anchor block:  *Source: Drimoleague Concrete Works*

S/N	Project Activities	Sub-Activities	Description	Illustration/ Example
			■ Anchor blocks and piles (whether screw type or percussive, driven piles) will require barges (or similar), piling equipment and winches. ■ Anchor blocks and piling are anticipated to be pre-cast and fabricated off-site. ■ No dredging and excavation of reservoir sediment are anticipated to be required for above anchoring options.	Small piles with fixed frame PV connections:  *Source: Ningbo Raytech New Energy Materials Co., Ltd* Anchor block (left) and piling (right) deployment:  *Source: Sembcorp Floating Solar Press Release, 2021*
5		■ Launching/ Arrangement of FPV system & connector cables (in-reservoir)	■ Launching equipment via ramps or cranes along the 150m staging area shoreline. ■ 4-8 work boats will operate within the reservoir to move equipment and personnel. ■ Barges (or similar) may be used to store materials and equipment prior to installation. ■ Cranes, or potentially helicopters, may be required to move large equipment e.g. PCU's into the reservoir and final installation location.	Launching of FPV off Launching Ramp (left) and by crane (right): 

S/N	Project Activities	Sub-Activities	Description	Illustration/ Example
				Towing FPV into position (left) and installation of PCU (right):   *Source: Sembcorp Floating Solar Press Release, 2021 and Sembcorp Energy, 2021* Work boats (left) and cables on bed of waterbody (right):   *Source: Roslan Rahman/ AFP, 2021 (left) and Xlinks (right)*
6	O&M Berthing Facility (location subject to approval from agencies)	■ Installation of O&M Berthing Facility (in-reservoir)[(a)]	■ Further to the in-reservoir piling (see item 4 above), a simple floating dock will be installed.	O&M Berthing Facility:  *Source: Bellingham Marine,2013*

S/N	Project Activities	Sub-Activities	Description	Illustration/ Example
7	Integrated Project Substation	■ Construction of Project Substation (land-based) ■ Installation of Connector Cables (land-based)	■ Approximately 7,000 to 10,000m^3 of spoil material is anticipated to be removed from site during site clearance, grading, excavation, etc. ■ Typical construction activities, such as site clearance, foundations, utilities, ancillary equipment etc to be carried out at the integrated Project Substation site. ■ Connector cables will be installed in ducts laid underground. Typical utilities construction methods will be used, such as open cut trenching with an excavator. ■ Testing and commissioning will be carried out prior to commercial operation of the FPV system.	Substation:  *Source: ECAS Consultants Pte Ltd, 2022*
8	General	■ General Construction	■ **Equipment** – typical construction equipment will be used throughout construction, including in-reservoir barges (or similar), winches and work boats (up to approximately 8 no. work boats). See *Section 9.6.1.2 (Airborne Noise and Vibration)* for indicative list of construction equipment to be utilised during the construction phase (subject to detailed design). ■ **Manpower** – workers will be housed at temporary quarters outside the Project area and transported by vehicles to the worksites on a daily basis. The number of workers present on site would be dependent on the stage of the Project construction. ■ **Fuel, Chemicals and Raw Materials** – will be stored at the land-based laydown area in the Staging/ Launching area, and typically include chemicals and hazardous substances, e.g. diesel, thinner, paint, lubricants, hydraulic oil, solvents; compressed gases such as acetylene and oxygen; and raw material such as cement and aggregates for concrete works and road works, crushed stone, asphalt and bituminous materials. ■ **Power Supply** – electrical power will be sourced from the national electricity grid or generators. ■ **Water Supply** – use of water for dust suppression, potable use, sanitary facilities etc. Water required for construction will be drawn from the mains in accordance with approvals from the authorities. ■ **Waste Management** – various types of waste may arise from construction activities including spoil from earthworks and excavations, general construction waste (e.g. materials packaging), chemicals, fuel, domestic wastes (e.g. food, paper, plastics etc), portable sanitary facilities. Waste, including chemicals/ fuel, will be managed in accordance with local regulations (see *Section 3.2*) and industry good practices to avoid discharge to the Reservoir from land worksites. Appropriate measures will be put in place to manage chemical and fuel use in the Reservoir with appropriate spill management protocols established (see *Section 6: Surface water quality*). The Project will provide adequate waste collection bins, skips and storage areas with appropriate containment measures; as well as segregated collection of hazardous, general and recyclable waste. Licensed waste collectors will be contracted in accordance with local regulations.	

S/N	Project Activities	Sub-Activities	Description	Illustration/ Example
			■ **Aquatic Vegetation Trimming** - to enable construction vessel movement, aquatic vegetation within the top 1 m of water column will be trimmed and will be collected and disposed appropriately offsite. Similar aquatic vegetation removal activities and disposal are currently carried out by PUB in the reservoir. Licensed waste collectors will be contracted in accordance with local regulations. ■ **Site Drainage** – groundwater or accumulated surface runoff from worksites will be collected by site drains, Earth Control Measures (ECMs) and discharged to the drainage and sewer system upon compliance with local discharge limits and guidelines set within the *Environmental Protection and Management (Trade Effluent) Regulations, 2011* and *Sewerage and Drainage (Trade Effluent) (Amendment) Regulations, 2022* for discharge into sewers and *Sewerage and Drainage (Trade Effluent) Regulation (Surface Water Drainage) Regulations* for discharges into surface drainage system. If discharge limits are not met, collection by a third party Contractor will be required for off-site disposal. No runoff into the reservoir from the proposed temporary Staging/ Launching area will be allowed. ■ **Timing of Construction Works** – works within the reservoir will be limited to daylight hours only due to health and safety concerns. 24 hour construction works may be required at the proposed land-based temporary Staging/ Launching Area and integrated Project Substation, which would be subject to relevant Government agency approvals.	
9	Unplanned events (see *Section 4.3.2*)	■ Failure of Erosion Control Measure(s) (ECM) ■ Environmental Spill ■ Fire and Explosion	■ During the feasibility stage, construction methodology and equipment were studied to identify any unplanned events which may occur during the Project construction phase. The impact assessment is to consider the potential likelihood of occurrence of the unplanned events, where relevant. Unplanned construction events considered include: - Failure of ECM – potential for spillage or overflow of site runoff and effluents into external surface water drains and water bodies. - Environmental Spill – accidental spills or leaks, fuel, oil, lubricants and chemicals to be stored and handled within the construction worksites, e.g. periodic refueling or lubrication or maintenance of equipment and machinery. - Fire and Explosion – a fire emergency may occur at the worksites.	
Operation and Maintenance (O&M)				
10	Operation	■ Normal Operations	■ Inclusion of the intra-island block spacing (i.e. breaking up large FPV islands with 30-40m corridors, as required for safe and viable operations, and firefighting access). ■ FPV system shall be remotely operated and monitored by onsite staff for security and maintenance purposes. ■ The FPV system and integrated Project Substation has minimal moving parts, which means that maintenance requirements are expected to be limited. Planned maintenance shall be scheduled accordingly and any unplanned maintenance would be performed as required or needed. Project maintenance that is anticipated to be performed onsite consists of monitoring, inspection and replacement of equipment. Maintenance shall occur during daylight hours. The FPV system will be designed to ensure safe and efficient access for required periodic O&M, e.g. designing for access ways between the rows of mounted PV. Qualified personnel will be appointed to carry out the O&M activities.	

S/N	Project Activities	Sub-Activities	Description	Illustration/ Example
			■ The energy production of the proposed FPV system will be optimised through the use of targeted spot cleaning of PV panels. It is not anticipated that the Project will experience high levels of dust accumulation on PV panels given high rainfall in Singapore (i.e. adequate to provide site-wide cleaning of the FPV system without any human intervention), but several clean-up events per year may be conducted depending on weather conditions and how wildlife (i.e. birds) might behave. Manual or robotic cleaning may be used to maintain the FPV system from the affects of bird droppings. ■ The operating hours for the Project are expected to be 24 hours a day, 365 days a year. Artificial lighting for operational safety and security is anticipated to be required.	
11	General	■ General O&M	■ **Fuel and Chemicals** – equipment maintenance and storage and handling of fuel, oil and lubricants, as well as refuelling of diesel powered equipment such as work boats (assumed to be 2 – 4 no.) are typical activities anticipated to be undertaken during routine operation. All fuel and chemicals will be stored and handled following relevant regulatory requirements. The chemical storage areas will be outside the reservoir, will be appropriately bunded and drained (not to the reservoir), and will also be roofed to avoid rainwater collection within the bunded areas. ■ **Power Supply** – electrical power will mainly be sourced from the national electricity grid, where required. ■ **Water Supply** – water will be supplied from the PUB mains supply such as for potable water for offices/ worker use etc. ■ **Firefighting** – design and construction and fire response plans will be in accordance with requirements of the relevant regulations. ■ **Waste Management** – general wastes, including domestic refuse such as food/ equipment packaging and toxic industrial waste (TIW) (e.g. chemicals, fuel etc), will be minimal. Licensed general waste collectors will be contracted in accordance with local requirements; operational PV and electrical waste management will be developed to allow for appropriate management and recycling of the main components of the FPV system at end of life.	
12	Unplanned events	■ Environmental Spill ■ Fire and Explosion	■ During the feasibility stage, operational equipment was studied to identify any unplanned events which may occur during the Project operational phase. The impact assessment is to consider the potential likelihood of occurrence of the unplanned events, where relevant. Unplanned operational events considered include: - Environmental Spill – accidental spills or leaks, fuel, oil, lubricants and chemicals to be stored and handled within the Project site, e.g. periodic refueling or lubrication or maintenance of equipment and machinery. - Fire and Explosion – a fire emergency may occur at the Project site.	

Note: above is indicative and subject to detailed design.

(a) A launching ramp of approximately 4 – 5 m wide will also be placed in the vicinity of the O&M berthing facility for use by SCDF's amphibious vehicles for emergency response situations.

2.5 Indicative Schedules

2.5.1 Pre-Construction and Construction

A description of the anticipated main construction activities are summarised in *Table 2-4*. An indicative programme for construction works and anticipated duration/ timeframe for these construction activities are summarised in *Table 2-5*. The pre-construction works of the Project will tentatively commence in 2025 (subject to Developer/ Owner selection), with construction to indicatively take up to approximately 3 years (156 weeks), including testing and commissioning.

Table 2-4: Description of Main Construction Activities

S/N	Main Construction Activity	Location	Description
1	Geotechnical/ Site Investigation and Studies	■ Land/ In-reservoir	■ Geotechnical/ Site investigation of the proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M Facility). ■ Geotechnical/ Site investigation of Reservoir Project Site, i.e. in footprint of FPV islands, PCU and O&M Berthing Facility.
2	Detailed Design Phase	■ N/A	■ Engineering design drawings and specifications.
3	Mobilisation/ Site Establishment	■ Land/ In-reservoir	■ Preparation of the proposed temporary Staging/ Launching Area: site clearance, minor grading, stabilised road base, construction of temporary work areas, temporary facilities, temporary FPV assembly areas, and temporary launching ramp for assembled FPV arrays. ■ Installation of surface water quality controls, vehicle and vessel traffic control, temporary berthing facility and launching water-based construction equipment.
4	FPV Anchors and Mooring	■ In-reservoir	■ Deployment of anchors/ piles (subject to detailed engineering design), and mooring lines.
5	FPV Floats and Modules	■ Land/ In-reservoir	■ Assembly of the FPV floats, modules, and cabling in modular sections. FPV islands assembled onshore and launched into the reservoir via the temporary launching ramp. ■ Towing and arrangement of the FPV islands within the Reservoir Project Site. ■ Attaching FPV islands to anchoring and mooring system.
6	In-reservoir Electrical Equipment	■ In-reservoir	■ Installation of reservoir-based ancillary plant/ equipment (e.g. in-reservoir PCUs, etc).
7	In-reservoir Connector Cables	■ In-reservoir	■ Installation of reservoir-based electrical and communications connector cables (i.e. between FPV islands and to landing point at integrated Project Substation).
8	O&M Berthing Facility (location subject to approval from agencies)	■ In-reservoir	■ Installation of O&M Berthing Facility.
9	Land-based Connector Cables	■ Land	■ Installation of land-based electrical and communications cables (e.g. shore to substation).
10	Integrated Project Substation (with O&M Facility)	■ Land	■ Construction of integrated Project Substation (with O&M Facility) and ancillary equipment.
11	Testing and Commissioning	■ Land/ In-reservoir	■ Testing and commissioning of the entire system, in coordination with the utility company.

Table 2-5: Indicative Schedule of Pre-Construction and Construction Works

			Year 1				Year 2				Year 3			
S/N	**Task Description**	**No. of Weeks**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
1	Geotechnical/ Site Investigation and Studies	12-16												
2	Detailed Design Phase	18-24												
3	Mobilisation/ Site Establishment	8-12												
4	FPV Anchors and Mooring	52-70												
5	FPV Floats and Modules	52-70												
6	In-reservoir Electrical Equipment	36-52												
7	In-reservoir Connector Cables	24-32												
8	O&M Berthing Facility (location subject to approval from agencies)	4-6												
9	Land-based Connector Cables	8-12												
10	Integrated Project Substation (with O&M Facility)	36-52												
11	Testing and Commissioning	8-12												

2.5.2 Operation Timeline

Based on the anticipated construction commencement and duration, operations of the FPV system is expected to commence in 2027/ 2028. The operating hours for the Project are expected to be 24 hours a day, 365 days a year. The operation lifetime of the Project is expected to be around 25 years.

Decommissioning of FPV system is not included in the scope of this EIA, given the 25 year operational lifetime; such requirements will be considered as appropriate prior to decommissioning.

2.6 Embedded Controls

Embedded controls are defined as measures (physical or procedural) that are planned to be put in place as part of the Project design, construction and operation from the outset. The project description presented herein already includes a number of embedded controls that will help protect against potential impacts to the environment. Embedded controls are predominantly based on, for example, regulatory and industry standard requirements, and reservoir operational requirements from PUB, as result of engagements with relevant Government agencies, amongst others. A list of the embedded controls are presented in *Appendix 2.2*.

3. ADMINISTRATIVE FRAMEWORK

3.1 National Plans

In addition to those Singapore Government plans discussed in *Section 1.2* the following national level plans are also of relevance to this project and for the management of land use in Singapore:

- **Nature Conservation Master Plan 2015** (NParks, 2015): sets out biodiversity conservation plans for the following five years to achieve the Singapore's vision of a City in a Garden.
- **National Biodiversity Strategy and Action Plan 2009** (NParks, 2019): sets out goals to conserve and enhance Singapore's biodiversity.
- **Sustainable Singapore Blueprint 2015** (NCCS, 2015): sets out targets to be achieved by 2030 for factors attributing to a sustainable, high quality living environment, i.e. green and blue spaces, mobility and air quality, and carbon footprint.
- **Parks and Waterbodies Plan** (URA, 2019): sets out land use plans for green areas and waterbodies for the next five years.

3.2 Local Legislation & Standards

Singapore adopts a systematic framework to determine and mitigate the potential impact of any new development on the environment. A rigorous evaluation process is in place for any new development to identify its impact on traffic, public health, heritage, and the environment. Development projects in close proximity to sensitive areas are also subject to thorough reviews, and environmental studies may be required to be conducted if necessary. Findings of the environmental studies (if deemed necessary) are carefully considered to determine the extent of potential impacts and the adequacy of proposed mitigation measures, before a development is allowed to proceed.

The relevant Acts and Regulations as well as local guidelines that will be reviewed and referenced, where applicable, in the EIA, are summarised in *Table 3-1*: Summary of Relevant Singapore Legislation and Guidelines below.

Table 3-1: Summary of Relevant Singapore Legislation and Guidelines

Subject	Legislation/ Regulations/ Guidebooks	Responsible Agency
Physical Environment		
Air emissions	■ Environmental Protection and Management (Vehicular Emissions) Regulations (Amendment), 2023 ■ Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021 ■ Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations, 2012 ■ Environmental Public Health Act (EPHA), (Amendment), 2022 ■ NEA Code of Practice for Environmental Control Officers for Construction Sites, 2021 ■ NEA Singapore Ambient Air Quality Targets (AAQTs), 2020	NEA

Subject	Legislation/ Regulations/ Guidebooks	Responsible Agency
Airborne noise pollution	■ Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021 ■ Environmental Protection and Management (Control of Noise at Construction Site) Regulations (Amendment), 2011 ■ Environmental Protection and Management (Boundary Noise Limits for Factory Premises) Regulations, 2008 ■ Environmental Protection and Management (Vehicular Emissions) Regulations (Amendment), 2023 ■ Environmental Public Health Act (EPHA), (Amendment), 2022 ■ NEA's Code of Practice for Environmental Control Officers for Construction Sites, 2021 ■ Singapore Standards SS602:2014 Code of Practice for Noise Control on Construction and Demolition Sites, 2014 ■ Singapore Standards SS593: 2013 Code of Practice for Pollution Control (COPPC) ■ LTA Guidebook for Best Environmental Practices Noise Control at LTA Sites (2013)	NEA
Vibration	■ N/A	-
Trade effluent, water resources and the prevention of water pollution	■ Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021 ■ NEA Allowable Limits for Trade Effluent Discharge to Watercourse or Controlled Watercourse under the Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021 ■ Environmental Protection and Management (Trade Effluent) Regulations, (Amendment), 2011 ■ Environmental Protection and Management (Hazardous Substances) Regulations, 2008 ■ Environmental Public Health Act (EPHA), (Amendment), 2022 ■ Environmental Public Health (Toxic Industrial Waste) Regulations (Amendment), 2022 ■ Environmental Public Health (General Waste Collection) Regulations (Amendment), 2019 ■ Fire Safety Act (Amendment), 2022 ■ Sewerage and Drainage Act (Chapter 294) (Amendment), 2021 ■ Sewerage and Drainage (Surface Water Drainage) Regulations, 2007 ■ Sewerage and Drainage (Trade Effluent) (Amendment) Regulations, 2022 ■ NEA's Code of Practice for Environmental Control Officers for Construction Sites, 2021 ■ PUB Code of Practice on Sewerage and Sanitary Works, 2nd Edition, 2019 ■ PUB Code of Practice on Surface Water Drainage, 7th Edition December, 2018 ■ PUB Guidebook on Erosion and Sediment Control at Construction Sites, 2018 ■ Singapore Standard SS 593: 2013 Code of Practice for Pollution Control (COPPC), 2013 PUB guideline criteria for reservoir water quality for this Project: ■ Temperature: to not increase more than 0.3°C throughout the whole water column. ■ Dissolved Oxygen (DO): to be more than 3 mg/L throughout the whole water column.	NEA, PUB, NParks

Subject	Legislation/ Regulations/ Guidebooks	Responsible Agency
	▪ Latest baseline data sets from PUB prior to construction will be considered as threshold criteria for other surface water quality variables (see *Section 12: EMMP*).	
Soil and groundwater quality	▪ Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021 ▪ Environmental Protection and Management (Hazardous Substances) Regulations (Amendment), 2021 ▪ Environmental Protection and Management (Trade Effluent) Regulations, 2008 ▪ Environmental Public Health Act (EPHA) (Amendment), 2022 ▪ Environmental Public Health (Toxic Industrial Waste) Regulations (Amendment), 2022 ▪ Environmental Public Health (General Waste Collection) Regulations (Amendment), 2019 ▪ Sewerage and Drainage Act (Surface Water Drainage) Regulations, 2007 ▪ Fire Safety (Petroleum and Flammable Materials) Regulations (Amendment), 2022 ▪ Fire Safety (Petroleum and Flammable Materials – Exemption) Order (Amendment), 2020 ▪ Singapore Standard SS593: 2013 Code of practice for pollution control (COPPC)	NEA, PUB
Waste management	▪ Environmental Public Health Act (EPHA) (Amendment), 2022 ▪ Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021 ▪ Environmental Protection and Management (Hazardous Substances) Regulations (Amendment), 2021 ▪ Environmental Public Health (Toxic Industrial Waste) Regulations (Amendment), 2022 ▪ Environmental Public Health (General Waste Collection) Regulations (Amendment), 2019	NEA
Vector control	▪ Environmental Public Health Act (EPHA) (Amendment), 2022 ▪ Infectious Diseases Act (IDA) (Amendment), 2022 ▪ Control of Vectors and Pesticides Act (Chapter 59) (Amendment), 2021 ▪ NEA's Code of Practice for Environmental Control Officers for Construction Sites, 2021	NEA
Light	▪ N/A	-
Biotic Environment		
Parks, tree, and flora protection	▪ Parks and Trees Act (Amendment), 2021 ▪ Public Utilities (Reservoir and Catchment Areas and Waterway) Regulations, 2018 ▪ National Parks Board Guidelines on Greenery Provision and Tree Conservation for Developments, 2018	NParks, PUB
Animal/ wildlife/ fauna protection	▪ Wildlife Act, 1965 (Revised edition 2020) ▪ National Biodiversity Strategy and Action Plan (NBSAP), 2019 ▪ Nature Conservation Master Plan (NCMP), 2015 ▪ Biodiversity Impact Assessment (BIA) Guidelines, 2020 ▪ Singapore Red Data Book (2nd Edition, 2008; and 3rd edition, 2023 in preparation, latest access 28 July 2023)	NParks
Note: Selection of a standard/ guideline for instance, will depend on several details which will be identified as the studies progress, such as the environmental baseline; the sensitivities identified; and the engineering design. The relevant regulatory framework is described in the relevant impact assessment section.		

3.3 Other Guidance Documents

Other international guidance documents reviewed to inform this study are summarised as follows:

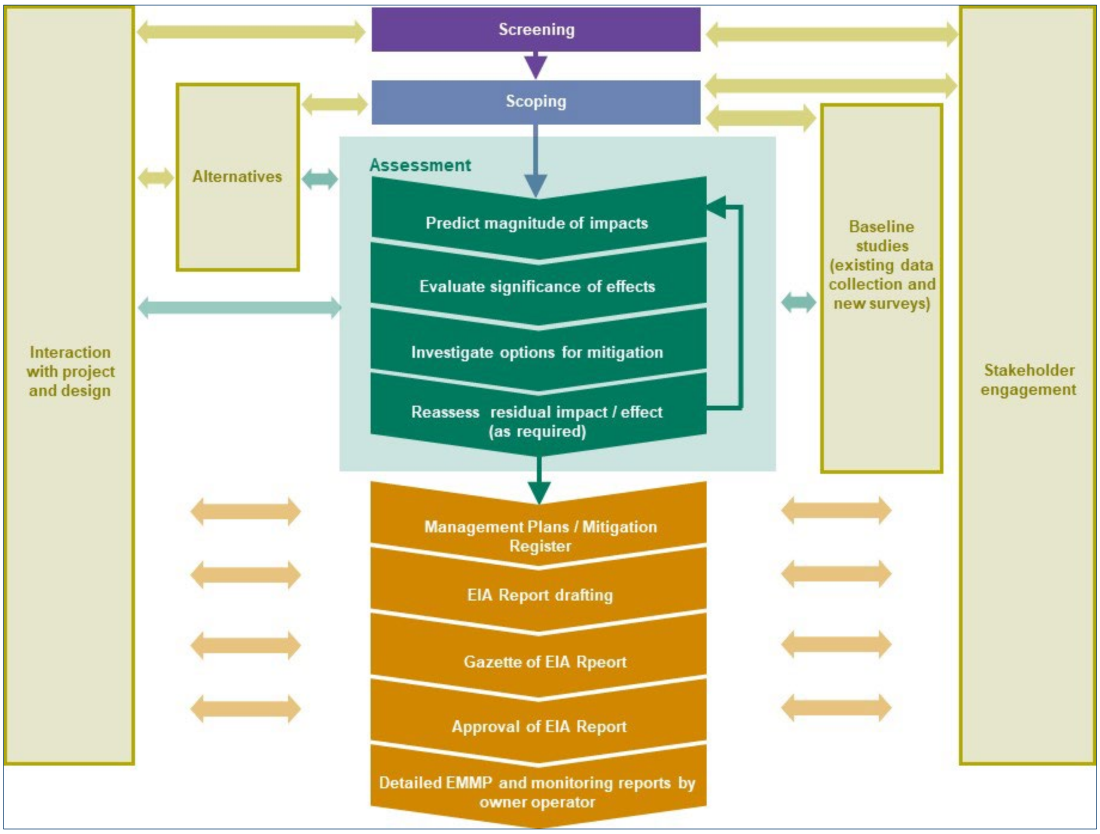
- Noise and Vibration:
  - British Standard 5228:2: Code of Practice for Noise and Vibration Control on Construction and Open Sites – Part 1: Noise (2014); and
  - British Standard 6472-1:2008 Guide to evaluation of human exposure to vibration in buildings – Part 1: Vibration sources other than blasting (2008).
- Air Quality:
  - World Health Organisation Air Quality Guidelines (WHO AQG) (2021);
  - Guidance on Monitoring in the Vicinity of Demolition and Construction Sites (IAQM, UK) (2018);
  - Land-Use Planning & Development Control: Planning for Air Quality (IAQM, UK) (2017);
  - Guidance on the Assessment of Dust from Demolition and Construction (Institute of Air Quality Management, IAQM, UK) (2014); and
  - Local Air Quality Management –Technical Guidance (Department for Environment Food and Rural Affairs, DEFRA, UK) (2009).
- Biodiversity:
  - International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN) (2023); and
  - United Nations Convention on Biological Diversity (UNCBD) (1993).

4. OVERVIEW OF EIA METHODOLOGY AND SCOPING

4.1 Overview

This EIA is conducted following ERM's Impact Assessment (IA) Standard. Our IA Standard has been developed based on ERM's extensive experience across a wide variety of different projects and developing EIA legislation, frameworks and guidelines for government bodies over the last 50 years. It is generally consistent with most international standards, such as the World Bank and International Finance Corporation (IFC) Performance Standards with regard to environmental, social and health performance, and represents best practice. It deliberately provides overarching guiding principles that can be tailored to specific IA cases and countries. Over the last two decades, ERM has successfully applied the ERM IA Standard to numerous EIAs projects in Singapore.

The IA has been undertaken following a systematic process that predicts and evaluates the potential impacts from the Project on aspects of the physical and biological environment, and identifies measures that the Project will take to avoid, minimise/ reduce, mitigate, offset or compensate for adverse impacts; and to enhance positive effects where practicable. The stages of the IA process from ERM's IA Standard which will be applied to the Project are described below in *Figure 4-1*.



Note: "Management plans/ mitigation register" encompasses a range of environmental management plans and environmental monitoring plans depending on the assessment outcome and country-specific legislative requirements.

Source: ERM

Figure 4-1: Impact Assessment Stages

4.2 Screening

In early 2020, the Project Proponent conducted a consultation process with Government and Technical Agencies. This step was conducted utilising a high level description of the Project and its associated facilities. It was assessed that an environmental study was required for the Project; and agencies were consulted in the scoping of the EIA study.

4.3 Scoping

Scoping was undertaken to identify the EIA Study Area. The EIA Study Area refers to the area that needs to be studied in order to adequately understand and describe the baseline conditions likely to be affected by the Project. At a minimum, the EIA Study Area encompasses the Project footprint and the Area of Influence (AOI). The AOI is defined broadly as the area that is likely to be affected due to direct, indirect and cumulative effects from the Project.

The AOI (and thus the EIA Study Area) varies across different resources (also referred to as environmental aspects), depending on the nature of the specific impacts to potential receptors or resources. For this reason, the EIA Study Area has been defined for each environmental aspect (i.e. surface water quality, biodiversity, air quality, airborne noise and vibration, soil and groundwater etc) and assessed respectively in the subsequent sections. Typically the AOI may cover land uses within a distance of 250 m of the Project footprint. In some cases, for example surface water quality, the Reservoir Study Area is referred to, given that the specific affected area for this aspect incorporates the Reservoir Project Site and broader Kranji Reservoir. The Reservoir Study Area sits within the broader EIA Study Area.

The scoping exercise was also undertaken to identify potential interactions between the Project's construction and operational activities and sensitive environmental resources/ receptors in the AOI; the impacts that could result from these interactions; and to prioritise these impacts in terms of their likely significance. This scoping stage is intended to ensure that the IA focuses on those issues that are likely to result in significant effects.

Table 4-1 presents the environmental resources/ receptors considered in the scoping stage, together with the changes that might indicate a Project-related impact.

Table 4-1: Environmental Resources/ Receptors and Impacts Considered in Scoping

Resources/Receptors	Impacts
Physical	
Ambient Air Quality/ Dust Deposition	Change to the ambient air quality for substances including oxides of nitrogen (NO_X), sulphur dioxide (SO_2), particulate matter (PM), carbon monoxide (CO), volatile organic compounds (VOCs), etc.
Global Climate	Change to global climate
Airborne Noise	Change in airborne noise levels
Vibration	Change in vibration levels
Groundborne Noise	Generation of groundborne noise
Light	Change in light
Topography	Change in topography
Soil	Contamination of soil leading to changes in physical and chemical properties
Groundwater	Contamination of shallow or deep groundwater resources, change in groundwater resources
Surface Water Quality (including reservoir bed sediment quality)	Changes to physical, chemical or biological quality of surface water bodies including from impacts to reservoir bed sediments; effluent discharge
Biological	
Terrestrial Habitats	Changes in habitat quality and conditions, and subsequent effects on the ecosystem
Terrestrial Flora & Fauna	Changes to vegetation community, health, species abundance and diversity and impact on endangered species and changes to wildlife assemblages

Resources/Receptors	Impacts
Aquatic Habitats	Changes on the aquatic ecosystem within reservoir, streams and wetlands etc
Aquatic Flora & Fauna	Changes to aquatic vegetation community, health, species abundance and diversity and impact on endangered aquatic species
Protected Areas	Compatibility of activities within designated national park/ protection areas
Vectors	Changes to the environment or introduction of new environments ideal for the breeding of vectors such as the Aedes mosquito and rats

4.3.1 Sensitive Receptors & Planned Developments Identified during Scoping

The scoping exercise considers Sensitive Receptors. Sensitive Receptors are those existing users of current developments or land uses, as well as planned users of developments or land uses[7], who will be directly impacted due to their proximity to the Project and exposure to Project construction and operation activities. Current land uses were identified through desktop research of the EIA Study Area. Data gathered through the desktop study includes available online resources such as street directories, satellite imagery and databases maintained by the Singapore Government. Identified sensitive receptors based on desktop research are shown in *Table 4-2* and *Figure 4-2*. The existing receptors were confirmed and updated during a site reconnaissance conducted by ERM in October 2020, and re-verified in January 2023.

Other known planned developments in the immediate vicinity of the Project Sites are also detailed in *Table 4-2* below, and are considered in the IAs where appropriate, i.e. in terms of potential cumulative impacts (see *Section 4.6.5*), where sufficient information is deemed available.

Table 4-2: Existing and Known Future Potential Sensitive Receptors & Other Known Planned Developments

S/N	Name	Type	Receptor	Direction from Proposed FPV System/ Indicative Description
Existing and Known Locations of Potential Sensitive Receptors				
1	Kranji Reservoir	Waterbody	■ Biodiversity, visitors, recreational anglers, water supply for potable use	■ Within Project Site
2	Sungei Buloh Wetland Reserve	Nature Reserve	■ Biodiversity, visitors	■ North-west
3	Kranji Marshes	Nature area	■ Biodiversity, visitors	■ West
4	Mandai Mangrove & Mudflat	Nature area	■ Biodiversity, future visitors	■ North-east
5	Sungei Kadut Forest	Nature area	■ Biodiversity	■ East
6	Gemala Nature Area	Nature area	■ Biodiversity	■ South-west
7	Kranji Reservoir Park A	Park	■ Biodiversity, visitors, recreational anglers	■ North
8	Kranji Reservoir Park B	Park	■ Biodiversity, visitors, recreational anglers	■ North

[7] For example, developments for which formal planning approvals have been granted by the Singaporean Authorities, but which are not operating at the time of writing; as confirmed by relevant Government agencies.

S/N	Name	Type	Receptor	Direction from Proposed FPV System/ Indicative Description
9	Future Kranji Reservoir Eastern Park[8]	Park	■ Biodiversity, visitors	■ East
10	PUB Office	Utility	■ Workers	■ North
11	NSRCC Kranji Sanctuary Golf Course	Recreational	■ Visitors, golfers	■ West
12	Kranji I Pumping Station water intake	Utility	■ Workers, reservoir operations	■ East
13	Kranji II Pumping Station water intake	Utility	■ Workers, reservoir operations	■ West
14	Sungei Kadut Industrial Estate	Industrial area	■ Workers	■ East
15	Yew Tee Village	Residential area	■ Residents	■ South-east
Other Known Planned Developments and Future Potential Sensitive Receptors				
16	Round Island Route along Kranji Way	Nature Park	■ Biodiversity, visitors	■ North ■ By NParks ■ Timing TBC
17	Sungei Buloh Nature Park Network (NParks, 2020)	Nature Park	■ Biodiversity, visitors	■ East, north and west ■ By NParks ■ Timing TBC
18	Sungei Kadut Eco-District (JTC, n.d.)	Industrial	■ Workers	■ East, North and South ■ By JTC ■ 1st phase of redevelopment works have commenced on site ■ Progressive development over the next 20-30 years
19	Lim Chu Kang High-tech Agri-Food Cluster (SFA, 2020)	Agricultural	■ Workers	■ West ■ By SFA ■ From 2024 onwards
Note: Project information may be subject to change.				

[8] Depicted in URA Master Plan 2022 as per *Figure 4-3*.

Figure 4-2: Locations of Existing and Known Potential Sensitive Receptors

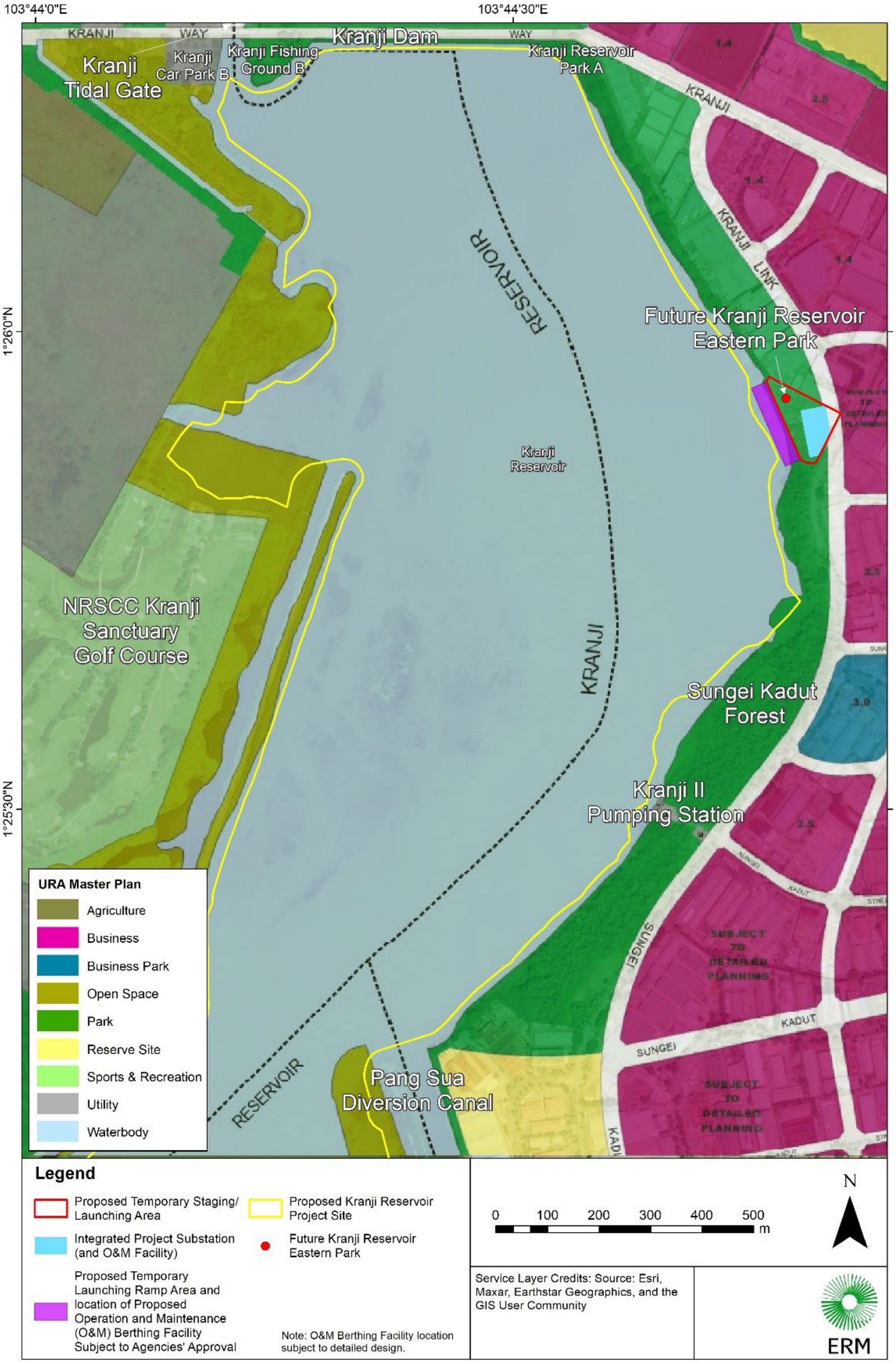


Figure 4-3: Location of Future Kranji Reservoir Eastern Park within URA Master Plan 2019 (indicative)[9]

[9] Relevant Government agencies have been engaged on, and agreed to, locating the proposed integrated Project Substation (with O&M facility) and O&M berthing facility at the proposed locations, subject to the necessary Government submissions and approvals.

4.3.2 Identification of Potential Unplanned Events

Unplanned events are defined as unintended occurrences for which engineering methods and equipment are designed to prevent during the Project construction and operation phases, e.g. a fire emergency, accidental fuel/ chemical storage. During the feasibility stage, a precautionary approach was used to review the proposed activities for the Project to identify any unplanned events which may occur during the Project phases. The following unplanned events were identified through the scoping:

- Failure of Erosion Control Measure(s) (ECM) during construction phase – there is a potential for spillage or overflow of site runoff and effluents into external surface water drains and water bodies during one of the following unplanned events occurring during the construction phase which could impact the quality of the surface water receptors:
  - Exceptionally heavy rainfall overwhelming the ECM system;
  - Failure of ECM outlet discharge pump resulting in overflow of sedimentation basin; and
  - Rupture due to accident or leakage due to wear and tear of ECM discharge pipeline.
- Environmental Spill during construction and operational phase – the construction and operational activities will require fuel, oil, lubricants, and chemicals to be stored within the construction worksites and operational area. Due to the nature and scale of the construction, hazardous chemicals such as diesel may be stored on-site. Accidental spills or leaks of such hazardous materials can occur during their handling as part of the Project construction e.g. periodic refuelling or lubrication or maintenance of equipment and machinery. A direct accidental leak or spill into the reservoir, or surrounding drains or through stormwater runoff could impact the quality of the surface water, biodiversity and soil and groundwater receptors.
- Fire and Explosion during construction and operation phases – a fire may occur at the worksites during construction works, or at the future Project Sites during operation phase which could impact the quality of the surface water, biodiversity and air receptors. This may occur due to:
  - Electrical shortage due to wear and tear or overloading of electrical equipment; and
  - Accidental ignition of flammable materials or components, such as diesel fuel or combustible waste stored at the construction worksite/ operational Project Sites.

Further details on assessment of unplanned events and their likelihood are provided in *Section 4.6.2.4*, and are assessed in *Sections 6 to 11*, where appropriate.

Embedded controls, i.e. measures that are planned to be put in place as part of the Project design, construction or operation from the outset, will be implemented during the design, construction and operational phases to prevent or minimise the risk of the occurrence of the abovementioned unplanned events. These embedded controls are summarised in *Appendix 2.2*.

Response plans will be established and appropriate measures will be implemented in the event that these unplanned scenarios occur, and will be incorporated into the Developer/ Owner's emergency response plan(s), and agreed with relevant Government agencies.

4.3.3 Scoping Outcomes

Government and Technical Agencies were further consulted on the scope of the EIA. See *Section 5* for further information on the other Stakeholder Engagement activities carried out for this Project, including engagement with Nature Group representatives on the baseline survey scopes, baseline findings, EIA approaches and outcomes.

The Project footprint, embedded controls that are planned to be put in place from the outset of the Project (see *Section 2*), and factors such as the spatial extent and duration of construction and operational activities were reviewed and assessed iteratively during the scoping and EIA process.

Activities associated with the construction and operational phases and environmental receptors within the EIA Study Area were classified into one of the following:

- No interaction: where the Project is unlikely to interact with the resource/ receptor (e.g. wholly terrestrial projects may have no interaction with the marine environment) – not to be considered or assessed in the EIA;
- Interaction likely, but not likely to be significant: where there is likely to be an interaction, but the resultant impact is unlikely to change baseline conditions in an appreciable/ detectable way – to be considered in the EIA, and embedded controls and standard practices to be detailed in the EMMP; and
- Significant interaction: where there is likely to be an interaction, and the resultant impact has a reasonable potential to cause a significant effect on the resource/ receptor(s) – to be assessed in detail in the EIA, where additional mitigation measures over and above embedded controls and standard practices will be identified as necessary, and included in the EMMP.

Where positive interactions were anticipated, these were also captured. The findings of scoping the construction and operational activities for the Project are detailed within the potential interactions matrix provided in *Appendix 4.1* and potential significant interactions, which are carried forward for further consideration in the EIA, are summarised in *Table 4-3* below.

Given the distance from the Project to the international boundary (over 1.1km), it is considered that no cross-border impacts are anticipated from this Project.

Table 4-3: Summary of Scoping Findings and Aspects to be Carried Forward for Assessment

Environmental Aspect	Scoping Findings
Surface water quality	**Pre-Construction/ Construction on land for the proposed temporary Staging/ Launching Area and integrated Project Substation:** *Potential Interactions:* There could be interactions between construction materials stored on-site, construction activities within the proposed temporary Staging/ Launching Area and integrated Project Substation construction worksite (including installation of land-based connector cables), resulting in site runoff and wastewater being washed into the reservoir. **Pre-Construction/ Construction for FPV on/ in-reservoir:** *Potential Significant Interactions:* Pre-construction/ construction works in the reservoir e.g. geotechnical investigation, deployment of the FPV anchoring system, launching/ towing/ installation of FPV and ancillary equipment, installation of in-reservoir connector cables, trimming of aquatic vegetation within top 1 m of water column and O&M berthing facility (location subject to approval from agencies) construction, may impact the surface water quality conditions (including sediment disturbance of the reservoir bed). **Operation of FPV on/ in-reservoir:** *Potential Significant Interactions:* Deployment of the FPV system may impact the surface water quality conditions in the reservoir over the Project's lifetime, related to a change of hydrodynamics, water quality and sediment disturbance from O&M activities (including FPV panel cleaning). Consequently, reservoir water quality at the PUB water intakes may be adversely affected. **Unplanned Event(s) during Construction and Operation:**

Environmental Aspect	Scoping Findings
	Potential Interactions from fire and explosion, failure of Erosion Control Measures (ECM) and environmental spill events on land and in-reservoir may impact surface water quality.
Biodiversity (terrestrial and aquatic)	**Construction works on land for the proposed temporary Staging/ Launching Area and integrated Project Substation:** *Potential Interactions:* Terrestrial habitat loss is currently anticipated with shoreline clearance for access at the proposed temporary Staging/ Launching Area and integrated Project Substation worksite. Disturbance of terrestrial fauna and introduction/ spread of invasive alien species, and impacts to flora from dust, may result from construction on land. **Construction of FPV on/ in-reservoir:** *Potential Significant Interactions:* Deployment of the FPV anchoring system, may impact the aquatic biodiversity conditions such as from benthic habitat/ fauna loss/ disturbance, elevated suspended sediments and pollutants and nutrients due to sediment disturbance, trimming aquatic vegetation within the top 1 m of water column and in-reservoir piling, and boat movements disturbing aquatic fauna. Terrestrial biodiversity may be impacted through disturbance to fauna (including birds) from piling in-reservoir, land-based night lighting, boat movements and use of helicopters. Introduction/ spread of invasive alien species may also result from construction and impact aquatic biodiversity. There may be impacts to the broader nearby protected areas of the Sungei Buloh Nature Reserve Network, including Kranji Marshes. **Operation of FPV on/ in-reservoir:** *Potential Significant Interactions:* Operational FPV coverage and O&M may impact benthic/ planktonic and fish communities. Terrestrial biodiversity may be impacted by reduced foraging opportunities for birds, bird/ bat collisions with FPV panels, and barrier/ fragmentation effects across the reservoir and at the integrated Project Substation site. Maintenance activities and introduction/ spread of invasive alien species may also occur during operations. There may be impacts to the broader nearby protected areas of the Sungei Buloh Nature Reserve Network, including Kranji Marshes. **Unplanned Event(s) during Construction and Operation:** *Potential Interactions* from fire and explosion and environmental spill events on land and in-reservoir may impact biodiversity.
Light	**Construction on land for the proposed temporary Staging/ Launching Area and integrated Project Substation, and in-reservoir for FPV:** *Potential Interactions:* Disturbance effects from artificial light to nocturnal aquatic and terrestrial fauna, including where 24 hour works may be required at the land-based proposed temporary Staging/ Launching Area and integrated Project Substation. **Operation of FPV on/ in-reservoir:** *Potential Interactions:* Disturbance effects from artificial light for operational safety and security to nocturnal aquatic and terrestrial fauna. Reduction in available daylight to support photosynthesis in the vicinity of FPV islands may impact aquatic flora, and indirectly benthic/ planktonic and fish communities.

Environmental Aspect	Scoping Findings
	Unplanned Event(s) during Construction and Operation: No significant interaction anticipated.
Air quality	**Construction on land for the proposed temporary Staging/ Launching Area and integrated Project Substation:** *Potential Interactions:* Dust generating activities from the proposed temporary Staging/ Launching Area and integrated Project Substation worksite during the construction phases (both PM_{10} and $PM_{2.5}$) may impact sensitive receptors in the vicinity. **Construction of FPV on/ in-reservoir:** No significant interaction anticipated. **Operation of FPV on/ in-reservoir, and land-based integrated Project Substation:** No significant interaction anticipated. **Unplanned Event(s) during Construction and Operation:** *Potential Interactions* from fire and explosion causing releases of ash or smoke.
Airborne noise	**Construction on land for the proposed temporary Staging/ Launching Area and integrated Project Substation:** *Potential Significant Interactions:* Construction activities on land related to site preparations, material deliveries, traffic and assembly of the FPV systems at the proposed temporary Staging/ Launching Area; as well as construction activities for the integrated Project Substation, such as excavation, piling, and installation of permanent structures may result in impacts to airborne noise. **Construction of FPV on/ in-reservoir:** *Potential Significant Interactions:* Airborne noise impacts may result from construction activities in the reservoir, such as piling (anchoring method and locations subject to detailed design). **Operation of FPV on/ in-reservoir:** No significant interaction anticipated. **Operation of integrated Project Substation:** *Potential Significant Interactions:* Airborne noise impacts may result from operation of the transformers in the substation. **Unplanned Event(s) during Construction and Operation:** *Potential Interactions* from fire and explosion causing instantaneous noise.
Vibration	**Construction on land for the proposed temporary Staging/ Launching Area and integrated Project Substation:** *Potential Interactions:* Disturbance effects from vibration related to the site preparations at the proposed temporary Staging/ Launching Area and piling for the integrated Project Substation. **Construction for FPV on/ in-reservoir:** *Potential Interactions:*

Environmental Aspect	Scoping Findings
	Disturbance effects from vibration through construction activities such as the installation of piles in the reservoir. **Operation of FPV in-reservoir and of land-based integrated Project Substation:** No significant interaction anticipated. **Unplanned Event(s) during Construction and Operation:** No significant interaction anticipated.
Soil and groundwater quality	**Construction on land for the proposed temporary Staging/ Launching Area and integrated Project Substation:** No significant interaction anticipated. **Operation of FPV in-reservoir and of land-based integrated Project Substation:** No significant interaction anticipated. **Unplanned Event(s) during Construction:** *Potential Interactions* from unplanned/ accidental environmental spill events may degrade soil and groundwater resources during land-based construction. No significant interaction is anticipated during operation of the FPV in-reservoir or the integrated Project Substation on land.
Vectors	**Construction for in-reservoir FPV and land-based proposed temporary Staging/ Launching Area and integrated Project Substation:** *Potential Interactions:* Various construction activities, works, storage of equipment and activities by the workforce (e.g. stagnant pools of water, organic waste creation etc) at in-reservoir and on land worksites may result in an increase in vector (rat and mosquito) populations. **Operation of FPV in-reservoir and of land-based integrated Project Substation:** No significant interaction anticipated. **Unplanned Event(s) during Construction and Operation:** No significant interaction anticipated.
Note: Interactions will need to be verified as the design, construction and operation progresses through the EMMP.	

4.4 Baseline Environment

To provide an environmental baseline against which the impacts of the Project can be assessed, this EIA provides a description of the current environmental conditions, which are assumed to prevail in the absence of the Project. The baseline includes information on receptors and resources identified as having the potential to be affected by the Project, as defined for each environmental aspect. The description of the baseline has the following objectives:

- To identify the existing environmental conditions in areas potentially affected by the Project and highlight those that may be vulnerable to activities of the Project;
- To describe and where possible, quantify, their characteristics (such as nature, condition, quality, extent) in the absence of the Project;
- To provide data to aid the prediction and evaluation of possible impacts; and

- To inform ERM's assessment of the significance of potential impacts.

The baseline environmental setting was developed from gathering and review of existing information (also referred to as secondary information) from various sources and field surveys (primary information). Existing information was gathered from in-house databases, online sources, publications, libraries, and Government and Technical Agencies such as NEA, NParks, PUB etc.

Comprehensive baseline surveys and monitoring as well as research of publicly available sources was conducted by ERM to understand the characteristics within the EIA Study Area related to:

- Ambient air quality;
- Airborne noise;
- Reservoir light penetration;
- Reservoir water quality;
- Reservoir bed sediment quality;
- Soil and groundwater;
- Biodiversity (terrestrial):
  - Flora;
  - Fauna:
    - Aculeate hymenopterans (bees and stinging wasps);
    - Odonates;
    - Butterflies;
    - Herpetofauna;
    - Birds;
    - Non-volant mammals; and
    - Bats.
- Biodiversity (aquatic habitat):
  - Aquatic vegetation;
  - Aquatic fauna; and
  - Benthic communities.
- Vector-borne diseases.

Baseline vibration measurements have been scoped out of the EIA Study. From a site reconnaissance of the land uses around the Project area, existing sources of vibration comprise heavy vehicles along Sungei Kadut Drive, Kranji Way and Neo Tiew Road; construction activities associated with future vegetable farms along Neo Tiew Harvest Lane and at construction facilities along Sungei Kadut Drive. These sources of vibration are highly localised in nature and are unlikely to contribute to any cumulative effects from the Project.

Field surveys were conducted between October 2020 and May 2022 for a total of 20 months, and works were carried out in accordance with the COVID-19 Government mandatory requirements at that time, with COVID-19 health and safety measures agreed with the relevant survey permitting authorities (e.g. NParks and PUB). Further details on the baseline methods, durations, parameters etc are provided in relevant sections and related appendices of this EIA, alongside the results and analysis of the baseline surveys and desktop research.

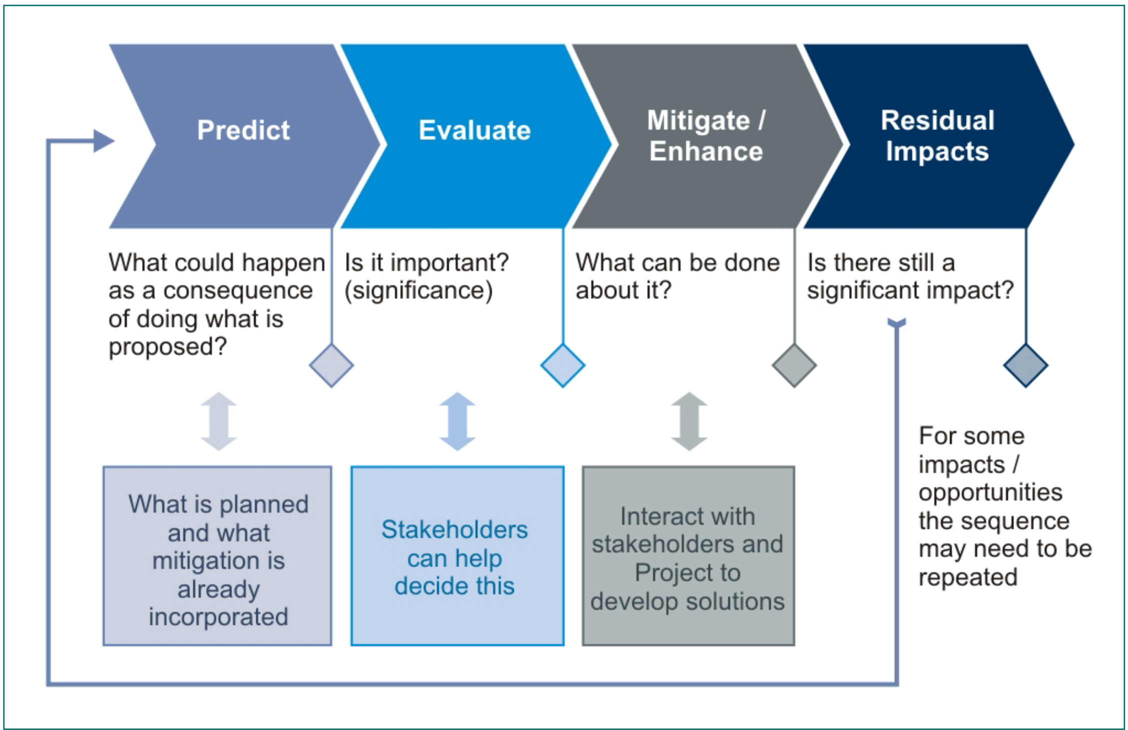
4.5 Stakeholder Engagement

An effective impact assessment process requires engagement with relevant stakeholders throughout the main EIA stages. This assists in understanding stakeholder views on the Project, in identifying issues that should be taken into account in the evaluation of impacts and in development of appropriate mitigation and enhancement measures, where appropriate. *Section 5* outlines the various stakeholder engagement activities carried out for the Project with Government agencies and stakeholders, such as the Nature Groups.

4.6 Impact Assessment

The assessment of impacts involved an iterative process considering four questions as illustrated in *Figure 4-4*. The below sections describe ERM's standard IA steps, comprising:

- Impact prediction: to determine what could potentially happen to resources/ receptors as a consequence of the Project and its associated activities;
- Impact evaluation: to evaluate the significance of the predicted impacts by considering their magnitude and likelihood of occurrence (for unplanned events), and the sensitivity, value and/ or importance of the affected resource/ receptor;
- Mitigation and enhancement: to identify appropriate and justified measures to mitigate negative impacts and enhance positive impacts, where appropriate; and
- Residual impact evaluation: to evaluate the significance of impacts assuming effective implementation of mitigation and enhancement measures.



Source: ERM

Figure 4-4: Process of Prediction, Evaluation and Mitigation of Impacts

4.6.1 Prediction of Impact Magnitude

Prediction of impacts is essentially an objective exercise to determine what is likely to happen to the environment as a consequence of the Project and its associated activities. From the potentially significant interactions identified in the scoping phase, the impacts to the various resources/ receptors are elaborated and evaluated.

The range of potential impacts considered in the impact assessment process resulted in a wide range of prediction methods being used, including quantitative, semi-quantitative and qualitative techniques. For example, for readily quantifiable impacts such as noise emissions, numerical values were used in this EIA to predict impact magnitude. For other topics, such as biodiversity, a more qualitative approach is undertaken.

It is important to note that impact prediction took into account any embedded controls i.e. physical or procedural controls that are planned to be put in place as part of the Project design, construction and operation from the outset.

4.6.2 Evaluation of Impact Significance

The next step in the assessment was to take the information describing the magnitude of an impact, and explain what this meant in terms of its importance to society and the environment by considering the assigned impact magnitude and the sensitivity of potential impacted receptors.

4.6.2.1 Impact Magnitude

Magnitude essentially describes the intensity of the change that is predicted to occur in the resource or receptor as a result of the impact, and is typically a function of some combination (depending on the resource or receptor in question) of the following impact characteristics: type, extent, duration, scale, and frequency.

The definitions for the impact characteristic definitions and designations and definition of impact types are shown in *Table 4-4* and *Table 4-5* respectively.

Table 4-4: Impact Characteristic Terminology

Characteristic	Definition	Designations
Type	A descriptor indicating the relationship of the impact to the Project (in terms of cause and effect).	Direct; Indirect; Induced
Duration	The time period over which a resource/ receptor is affected.	Temporary; Short-term; Long-term; Permanent
Extent	The “reach” of the impact (e.g. Projected for several kilometres, etc.).	Local; Regional; International
Scale	The size of the impact (e.g. the size of the area damaged or impacted, the fraction of a resource that is lost or affected, etc.)	[no fixed designations; intended to be a numerical value or a qualitative description of “intensity”]
Frequency	A measure of the constancy or periodicity of the impact.	[no fixed designations; intended to be a numerical value or a qualitative description]

Table 4-5: Impact Type Definitions

Designations	Definition
Type	
Direct	Impacts that result from a direct interaction between the Project and a resource/ receptor (e.g. between occupation of a plot of land and the habitats which are affected).

Designations	Definition
Indirect	Impacts that follow on from the direct interactions between the Project and its environment as a result of subsequent interactions within the environment (e.g. viability of a species population resulting from loss of part of a habitat as a result of the Project occupying a plot of land).
Induced	Impacts that result from other activities (which are not part of the Project) that happen as a consequence of the Project (e.g. influx of informal businesses (such as food stalls) resulting from the importation of a large Project workforce).

As discussed above, the magnitude designations themselves are universally consistent, but the descriptions for these designations vary on a resource/ receptor-by-resource/ receptor basis. The universal magnitude designations are:

- Positive;
- Negligible;
- Small;
- Medium; and
- Large.

In the case of a positive impact (i.e. benefit), no magnitude designation (aside from 'positive') is assigned. It is considered sufficient for the purpose of this EIA to indicate that the Project is expected to result in a positive impact, without characterising the exact degree of positive change likely to occur.

In the case of impacts resulting from unplanned events, the same resource/ receptor-specific approach to concluding a magnitude designation is utilised, but the 'likelihood' factor is considered, together with the other impact characteristics, when assigning a magnitude designation (See *Section 4.6.2.4)*.

4.6.2.2 Receptor Sensitivity

In addition to characterising the magnitude of impact, the other principal impact evaluation step is definition of the sensitivity, vulnerability or importance of the potentially impacted resource or receptor. A range of factors were taken into account when defining the sensitivity, vulnerability, or importance of the resource or receptor, such as legal protection, government policy, stakeholder views and economic value. The sensitivity, vulnerability, or importance designations used herein for all resources or receptors are:

- Low;
- Medium; and
- High.

4.6.2.3 Impact Significance

The impact magnitude and sensitivity of a resource or receptor were considered in combination to evaluate whether an impact was significant, and if so, its degree of significance. Impact significance was designated using the matrix shown in *Figure 4-5.*

		Sensitivity/Vulnerability/Importance of Resource/Receptor		
		Low	Medium	High
Magnitude of Impact	Negligible	Negligible	Negligible	Negligible
	Small	Negligible	Minor	Moderate
	Medium	Minor	Moderate	Major
	Large	Moderate	Major	Major

Figure 4-5: Matrix for Evaluation of Impact Significance

The matrix applies universally to all resources/ receptors, and all impacts to these resources/ receptors, as the resource/ receptor-specific considerations are factored into the assignment of magnitude and sensitivity/ vulnerability/ importance designations. *Figure 4-6* provides a context for what the various impact significance ratings signify.

An impact of **negligible significance** is one where a resource/ receptor will essentially not be affected in any way by a particular activity, or the predicted effect is deemed to be 'imperceptible' or is indistinguishable from natural background variations.
An impact of **minor significance** is one where a resource/ receptor will experience a noticeable effect, but the impact magnitude is sufficiently small and/or the resource/ receptor is of low sensitivity/ vulnerability/ importance. In either case, the magnitude should be well within applicable standards.
An impact of **moderate significance** has an impact magnitude that is within applicable standards, but falls somewhere in the range from a threshold below which the impact is minor, up to a level that might be just short of breaching a legal limit. Clearly, to design an activity so that its effects only just avoid breaking a law and/ or causing a major impact is not best practice. The emphasis for moderate impacts is therefore on reducing them to a level that is as low as reasonably practicable (ALARP). This does not mean that impacts of moderate significance have to be reduced to minor, but that moderate impacts are being managed effectively and efficiently.
An impact of **major significance** is one where an accepted limit or standard may be exceeded, or large magnitude impacts occur to highly valued/ sensitive resource/ receptors. An aim of impact assessment is to get to a position where the Project does not have any major residual impacts, certainly not ones that would endure into the long-term or extend over a large area. However, for some aspects there may be major residual impacts after all practicable mitigation options have been exhausted (i.e. ALARP has been applied). An example might be the visual impact of a facility. It is then the function of regulators and stakeholders to weigh such negative factors against the positive ones, such as employment or avoided emissions, in coming to a decision on the Project.

Figure 4-6: Context of Impact Significances

4.6.2.4 Likelihood (Unplanned Events)

The process of designating impact magnitude and receptor sensitivity as shown in *Figure 4-4* applies to planned events. It is noted that the reasonable worst-case scenario is considered in determining the consequences of the unplanned event. In the case of unplanned events an additional factor that is considered is likelihood. The likelihood of an unplanned event occurring is designated using a qualitative scale, as described in *Table 4-6.* The impact significance of an unplanned event is then designated using the matrix shown in *Figure 4-7*. Further details on likelihood of unplanned events is provided in *Appendix 4.2*.

Table 4-6: Definition of Likelihood Designation

Likelihood	Definition
Unlikely	The event is unlikely but may occur at some time during normal operating conditions.
Possible	The event is likely to occur at some time during normal operating conditions.
Likely	The event will occur during normal operating conditions (i.e. it is essentially inevitable).

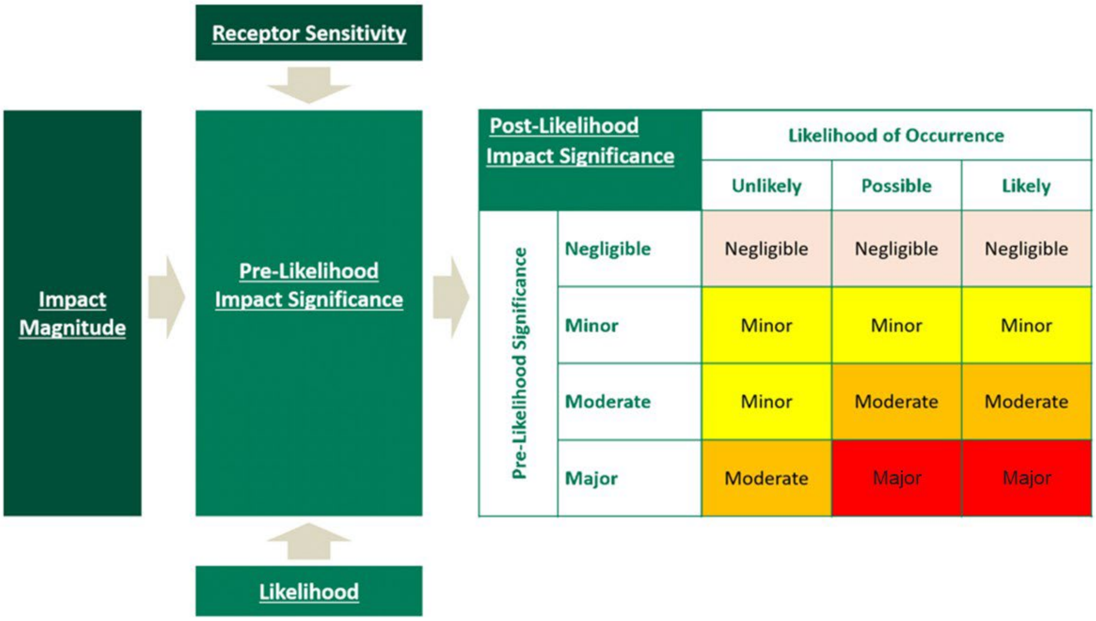


Figure 4-7: Matrix for Evaluation of Impact Significance (Unplanned Event)

4.6.3 Mitigation & Enhancement

Once the significance of the impacts had been characterised, the need for and type of mitigation and enhancement measures that were required to meet the applicable standards were considered. For the purposes of this EIA, where a significant impact was identified (considered to be moderate significance or higher), ERM has adopted the following mitigation hierarchy:

- **Avoid at source, reduce at source**: avoiding or reducing at source through the design of the Project;
- **Abate on-site**: add something to the design to abate the impact (e.g. pollution control equipment, traffic controls etc.);

- **Abate at receptor**: if an impact cannot be abated on-site, then control measures can be implemented off-site;
- **Repair or remedy**: some impacts involve unavoidable damage to a resource and can be addressed through repair, restoration, or reinstatement measures; and
- **Compensate in kind, compensate through other means**: where other mitigation approaches are not possible or fully effective, then compensation for loss, damage and disturbance might be appropriate.

4.6.4 Assessing Residual Impacts

Once mitigation and enhancement measures were identified, the next step in the impact assessment process was to assign residual impact significance. This is essentially a repeat of the impact assessment steps discussed above, considering the implementation of the proposed mitigation and enhancement measures.

4.6.5 Cumulative Impacts

A cumulative impact can be defined as, an impact that arises as a result of an impact from the Project interacting with an impact from another activity to create an additional impact. For example, a residential property positioned between the Project's construction worksite and other developments would result in the residential receptors experiencing the combined effect of the two noise sources. It is noted that how cumulative impacts are assessed are strongly influenced by the status of the other developments (already ongoing or committed, i.e. approved or proposed) and how much data is available about them. Cumulative effects in respect of this EIA relate to those related to other known concurrent projects in the immediate vicinity of the Project Sites (see *Section 4.3.1*).

The impact assessment process itself is broadly similar to that presented herein, i.e. scoping to define the ongoing/ committed developments; level of information available; potential interactions; baseline data gathering which is usually captured in the EIA Study Area of the project; impact assessment to determine the magnitude and significance of impacts considering the vulnerability of the resources and receptors and their limits of acceptable change; and development of any management and monitoring measures to mitigation significant impacts.

4.7 Management and Monitoring

The final stage in the impact assessment process is the definition of basic management and monitoring measures needed to ascertain if impacts remain in conformance with applicable standards, and if mitigation measures are effectively addressing impacts or reducing effects to the extent predicted. An EMMP has been developed accordingly and is presented in *Section 12* of this report.

4.7.1 Adaptive Management

The EIA has adopted a practical approach to managing uncertainty, where implementation of mitigation and management measures are responsive to changing conditions and the results of monitoring throughout the Project. This is known as “Adaptive Management”. Adaptive management actions may include, in addition to physical mitigation measures: refinement of thresholds/ criteria, initiation of remedial action, continued monitoring, ceasing monitoring, etc.

4.8 Ecological/ Ecosystem Level Approach

Based on consultations with Technical Agencies, an Ecological/ Ecosystem Level Approach was to be carried out for this Project. The objective was to inform the assessment of environmental impacts during the operation of the Project, in particular, impacts on resident and migratory birds' usage of, and movements around, the Kranji Reservoir and surrounding habitats and on the reservoir ecosystem. An approach was developed based off existing tools, but was contextualised to optimally document the Project's impacts on the Kranji Reservoir ecosystem and its environs.

In order to meet this requirement and inform the EIA, an internationally recognised system for understanding and assessing impacts on broader ecosystems was used, namely an Ecological Character Description (ECD). Originally developed for describing wetlands (as waterfowl habitats) listed under the Ramsar Convention on Wetlands of International Importance (the Ramsar Convention), the ECD approach allows the pooling of a wide range of data on both the abiotic (non-living) and biotic (living) elements of a waterbody, together with an understanding of human use, existing environmental stresses and ecosystem services; to conceptualise the waterbody's main ecosystem processes and components and the interactions between them.

While Singapore is not a signatory to the Ramsar Convention, nor does Kranji Reservoir qualify as a Ramsar Convention Wetland; Singapore is a Partner in the East Asian-Australasian Flyway, and a simplified version of an ECD for Sungei Buloh Wetlands Reserve (situated to the north of the Project site) was submitted under this Partnership by NParks in 2018.

A range of both desktop (secondary data), hydrological and biodiversity baseline studies (primary data) carried out for this EIA support the ECD process. As birds are an important element of the Kranji Reservoir ecosystem, to support the understanding of the ecosystem, the spatial distribution of birds, and how they use the reservoir (e.g. foraging/ feeding, roosting, nesting) has also been mapped based on field observations and spatially presented (the approach for which has been agreed with NParks).

The ECD provides a holistic understanding of how the Project's operation, in particular the deployment of FPV within the Kranji Reservoir, could drive changes in the functioning of the reservoir ecosystem, and how these changes could then influence the food resource provided by the reservoir. A main concept within the ECD is an understanding of natural variability within the system, and establishing the parameters of acceptable change.

The ECD informs the EIA process by bringing an understanding of how the main components of the ecosystem interlink, how changes in the ecosystem could affect those components, and what the limits of acceptable change within the ecosystem are. This allows a clear and transparent assessment of impacts associated with the Project.

These approaches have been shared and discussed with Government and Technical agencies, as well as Nature Groups.

The framework for preparing the ECD (DEHWA, 2008) is outlined in *Figure 4-8*. A technical report on the ECD approach and outcomes is available in *Appendix 7.3*.

Figure 4-8: Example ECD development framework (developed by Hydrobiology)

5. STAKEHOLDER ENGAGEMENT

5.1 Overview

Stakeholder engagement is an integral part of the EIA process. It enables the sharing of information and knowledge and supports a collaborative approach to problem-solving and decision-making.

Stakeholders are defined as "persons or groups who are directly or indirectly affected by a project, as well as those who may have interests in a project and/ or the ability to influence its outcome, either positively or negatively" (IFC, 2007). The primary objectives of stakeholder engagement are to:

- Ensure that adequate information is provided in a timely manner to those interested in or affected by the Project;
- Ensure that identified stakeholders are provided with sufficient opportunity to voice their opinions and concerns; and
- Ensure that stakeholder feedback is received and considered in Project decisions.

For this Project, a systematic process was undertaken to first develop an understanding of the issues, identify selected stakeholders, and allow these stakeholders to participate in the process of developing the EIA.

5.2 Overview of Approach

5.2.1 Local Context

It was identified at an early stage by the Project Proponent that Nature Group engagement was of importance throughout this EIA process, along with engaging with relevant academics and technical experts in relevant field of studies, as appropriate. The Project Proponent is aligned with the Government expectations for stakeholder engagement for this Project which required Nature Group consultation during (a) scoping of the EIA, (b) preparation of the EIA, and (c) public disclosure of the final EIA report. As indicated in *Table* 5-2, ERM has also engaged representatives of the Nature Groups in discussion on the proposed ecological assessment approaches, particularly for the ECD, given this is a unique approach not undertaken in the context of an EIA before in Singapore.

The Project's stakeholder engagement was developed with the understanding that while the Project must obtain the requisite formal approvals by the relevant Government agencies to proceed in accordance with the relevant Singapore laws and regulations, effective stakeholder engagement is an important aspect of the Project's compliance with industry best practice and stakeholder expectations. Engagement with stakeholders from the onset of the Project was important to identifying concerns and potential environmental risks associated with the Project, and to enable the development of effective mitigation and management plans.

The approach to engagement with stakeholders was tailored to each specific group based upon the output of the stakeholder mapping and ranged from provision of information (i.e. telling people about the Project) to engagement (i.e. asking people their opinions in relation to the Project) and participation (i.e. inviting groups such as Government agencies to review early study data and evaluate proposed decisions).

5.2.2 Other Guidelines Adopted

The approach to stakeholder engagement in this study has been informed by international best practice. ERM has followed its internal IA Standard which is generally consistent with international standards, such as the World Bank and International Finance Corporation (IFC). The Project's stakeholder engagement was designed to support the EIA process, for example, through the recording of all stakeholder engagement outcomes and the consideration of stakeholder concerns in the screening and scoping phases of the EIA, and engaging stakeholders in the subsequent development of effective baseline surveys, mitigation and management plans, reporting and disclosure processes. Other guiding principles which helped shape the Project stakeholder engagement include the following:

- For management of environmental risks associated with the Project, effective stakeholder engagement is required through disclosure of project-related information, disclosure and feedback with relevant agencies and communities on matters that directly affect them, at appropriate milestones throughout the Project; and
- Stakeholder engagement and disclosure is required to define an appropriate system of independent verification for the sustainable management of natural resources, e.g. to support the aim of water and biodiversity conservation.

5.3 Stakeholder Engagement Planning

To establish a local context and understanding of stakeholders in Singapore for the Project, a desktop review was undertaken of potentially interested parties related to the Project and its site and surroundings. Subsequent to this, ERM facilitated an internal stakeholder mapping workshop with the Project Proponent to identify priority Project stakeholders and their potential concerns/ interests. This process involved four main steps:

- Identification of the potential Project stakeholders;
- Identification of the stakeholders potential issues and interests;
- Mapping and prioritisation of stakeholders and their issues based on their level of interest and influence; and
- Setting out of next steps, including engagement actions and planning.

Following the workshop, ERM engaged with relevant Government agencies and Nature Group representatives to align on the priority Project stakeholders.

5.3.1 Identified Stakeholders

Project stakeholders identified were grouped into the following categories:

- Government Representatives, Technical Agencies & Other Government Agencies;
- Local Nature Groups (NGs), Non-Government Organisations (NGOs), Independent Interest Groups, and Independent Academics/ Professionals;
- Recreation Groups;
- Adjacent Landowners; and
- Media/ Social Media.

5.3.2 Identified Stakeholders Concerns

Potential issues and interests identified were mapped to the respective stakeholder categories, as presented in *Table 5-1* below. Based on this list, priority stakeholders with interests and concerns were identified and selected for engagement. These main interests and concerns were subsequently used to inform the development of stakeholder engagement materials.

Table 5-1: Stakeholder Categories and Issues Mapping

Stakeholder Category	Main Environmental Issues/ Interests
Government Representatives, Technical Agencies & Other Government Agencies	*General* ■ General community unrest, petitions and representations. ■ Potential impacts to Singapore's drinking water resources. ■ Achieving Singapore's renewables (including solar) commitments. ■ Conservation of biodiversity areas and networks. ■ Access to sensitive land uses e.g. military premises, reservoir. *Project's Construction & Operation* ■ Potential impact on existing and planned infrastructure. ■ Potential impact on long-term land use planning for Project's operational sites (e.g. Kranji Reservoir, integrated Project Substation site), and surrounding areas. ■ Potential impacts on the environment, including surface water quality and biodiversity.
Local Nature Groups (NGs), Non-Government Organisations (NGOs), Independent Interest Groups and Independent Academics/ Professionals	*General* ■ National biodiversity conservation. ■ Ecological sensitivity of Kranji area. ■ Legitimacy and credibility of Impact Assessment studies, and whether public can see the results. ■ Scope and baseline methodology and assessment criteria for EIA. ■ Regular project updates. *Project's Construction & Operation* ■ Any impact on flora and fauna of conservation concern (including birds) as well as supporting habitats within and surrounding the Project Sites (particularly Kranji Reservoir) due to: - Potential impacts from the construction activities on flora and fauna, e.g. surface water quality, airborne noise etc, associated with proximity of worksite areas (proposed temporary Staging/ Launching Areas and in-reservoir activities). - Potential long-term impacts of the FPV panels on the reservoir on fauna. - Unknown impacts to flora and fauna due to the lack of relevant scientific literature, or long term data from similar projects. ■ Adequacy of the environmental protection measures recommended/ implemented.
Recreational Groups	*General* ■ Access to public recreational spaces, e.g. parks. ■ Access to fishing grounds. ■ Health and safety. *Project's Construction & Operation* ■ Nuisance impacts e.g. airborne noise, air, vectors associated with proximity of worksite areas (particularly, in-reservoir activities and integrated Project Substation). ■ Visual amenity. ■ Potential impact on fishing stocks (quality and quantity).

Stakeholder Category	Main Environmental Issues/ Interests
Adjacent Land Owners (e.g. NSRCC, industrial estate tenants)	*General* ■ Safety of FPV panels, cables and building infrastructure. ■ Social impact from transient workforce. *Project's Construction & Operation* ■ Nuisance impacts e.g. airborne noise, air, vectors associated with proximity of worksite areas (proposed temporary Staging/ Launching Area, in-reservoir activities, and integrated Project Substation).
Media/ Social Media	*General* ■ Project updates. ■ Potential project benefits or impacts. ■ Enabling the clean energy transition in Singapore. ■ EIA findings. *Project's Construction & Operation* ■ Potential impacts on the environment, including surface water quality and biodiversity.

5.4 Engagement Activities

ERM has carried out a series of stakeholder engagements with local NGOs, Nature Group representatives, independent academics/ professionals, as well as representatives from Technical and other Government Agencies since January 2020. The aim of these engagement sessions was to consult with stakeholder representatives by sharing Project information and soliciting feedback on the Project and EIA study to further inform the EIA. Examples of focus topics include: feedback on the biodiversity surveys and assessment approaches, interim baseline biodiversity observations and EIA findings.

Further, as Ecological Character Description (ECD) approaches have not been used previously in the Singapore EIA process, a smaller technical working group was formed with selected Nature Group representatives to seek specific technical feedback on the ECD approach utilised for this EIA (see *Section 7* and *Appendix 7.3* for further details) to support the conceptualisation of the abiotic and biotic interactions within the Kranji Reservoir ecosystem.

The EIA report will be disclosed for public feedback over a 4 week period.

A summary of the stakeholder engagement activities undertaken leading up to the disclosure of this EIA report are summarised in *Table 5-2*. Noting regular engagements with Technical and other Government Agencies has been carried out throughout the EIA process since January 2020 (and are not included in *Table 5-2*).

Table 5-2: Summary of Stakeholder Engagement Activities to Date

No.	Description	Disclosure Method	Actions Undertaken Following Stakeholder Engagement
1	Presentation of the Project, EIA approach and phases including scope of baseline surveys, methodologies, and schedules.	Invited Stakeholder Forum	■ Clarifications provided and relevant stakeholder comments taken on board, e.g. on extension (additional locations/ durations) of baseline surveys.
2	Presentation of the updated survey methodology (based on Stakeholder Engagement No. 1, and Nature Group's comments), interim biodiversity baseline observations, introduction to Ecological Character Description approach and updated schedule of the EIA.	Invited Stakeholder Forum	■ Responses to concerns consolidated from 7 January 2021 engagement. ■ Clarifications provided and relevant stakeholder comments considered for EIA.

No.	Description	Disclosure Method	Actions Undertaken Following Stakeholder Engagement
3	Presentation of biodiversity baseline findings and discussion on ECD assessment.	Small Technical Working Group	▪ Clarifications provided and relevant stakeholder comments considered for EIA.
4	Presentation on EIA Report findings.	Invited Stakeholder Forum	▪ Clarifications provided and relevant stakeholder comments considered for EIA. ▪ Inclusion of additional setback distance of FPV layout from western shoreline.
5	Further discussion on EIA outcomes prior to disclosure.	Invited Stakeholder Forum	▪ Clarifications provided and relevant stakeholder considered for EIA. ▪ Confirmation of additional mitigation of 50m setback from western shoreline to FPV layout.

5.4.1 Main Concerns from Stakeholders

Main concerns from stakeholders highlighted during the abovementioned engagement activities are presented in *Table 5-3*, along with the corresponding references to the Sections within this EIA which address the respective concerns.

Table 5-3: External Stakeholder Concerns & Report References

No.	Stakeholder	Concerns	Report Reference
1	Government Representatives, Technical Agencies & Other Government Agencies	■ Coverage of baseline surveys, including biodiversity, surface water quality, reservoir bed sediments. ■ Potential impacts to and assessment of surface water quality via modelling of the Kranji Reservoir. ■ Potential impacts to reservoir operations and assets. ■ Potential impacts to biodiversity, including residential and migratory birds around Kranji Reservoir and adjacent areas. ■ Consideration of the ecological ecosystem (aquatic, terrestrial) of Kranji Reservoir. ■ Consideration of cumulative impacts during operation. ■ Mitigation, management and monitoring for the Project. ■ Engagement of relevant stakeholders throughout the EIA, and public disclosure of the EIA.	■ Section 2 (Project Description) ■ Section 5 (Stakeholder Engagement) ■ Section 6 (Surface Water Quality) ■ Section 7 (Biodiversity) ■ Section 12 (EMMP) ■ Appendix 6.1 (Water Quality Modelling Technical Annex) ■ Appendix 7.1 (Terrestrial Biodiversity Baseline) ■ Appendix 7.2 (Aquatic Environment Baseline) ■ Appendix 7.3 (Ecological Character Description, ECD)
2	Local Nature Groups (NGs), Non-Government Organisations (NGOs), Independent Interest Groups and Independent Academics/ Professionals	■ Setback distance between shoreline and nearest FPV panels. ■ Biodiversity baseline surveys and methodologies, including on camera traps, bats, birds, and coverage of other fauna species; as well as aquatic vegetation considerations and sampling extent. ■ Aquatic biodiversity baseline surveys and methodologies, such as side-scan sonar surveys. ■ Potential impacts of the FPV on Kranji Marshes and wildlife and birdlife, and need to understand feeding habits of birds, Black Crowned Night Herons, long-term interactions and species populations. ■ Potential impacts from leaching from reservoir bed sediments.	■ Section 1 (Introduction) ■ Section 2 (Project Description) ■ Section 6 (Surface Water Quality) ■ Section 7 (Biodiversity) ■ Appendix 6.1 (Water Quality Technical Report) ■ Appendix 7.1 (Terrestrial Biodiversity Baseline) ■ Appendix 7.2 (Aquatic Environment Baseline) ■ Appendix 7.3 (Ecological Character Description, ECD)

No.	Stakeholder	Concerns	Report Reference
		■ Concerns over crocodiles if found within the Kranji reservoir, and potential need for relocation. ■ Potential impact of displaced wildlife on neighbouring industrial, residential and recreational areas. ■ Water quality model inputs, simulations and results, e.g. potential impact of FPV operation on reservoir water temperature, including for future climate scenarios. ■ Unknown impacts to flora and fauna due to the lack of relevant scientific literature/ comparable Singapore and international projects and studies. ■ Biodiversity and water quality monitoring programmes. ■ Visual amenity/ aesthetics. ■ Interactions and interplay of limits of acceptable change (discussed in the Ecological Character Description), and longer term relationships, e.g. on vegetation coverage.	

5.5 Stakeholder Feedback Mechanism

The disclosure of this EIA report provides the opportunity to communicate the proposed Project activities, implementation schedules, associated risks, impacts, benefits and mitigation measures. The Project Proponent, Malkoha Pte Ltd, will be responsible to manage public feedback following the disclosure of the EIA report up until the appointment of the Developer/ Owner.

The appointed Developer/ Owner (which will own, design, construct, install, operate and maintain the System) will be responsible to assume the foregoing, commitments herein, and address and provide an appropriate forum, e.g. phone number/ email address, to receive and respond to project specific concerns, complaints, comments and feedback during the Project's implementation.

6. SURFACE WATER QUALITY

6.1 Overview

This Section of the EIA evaluates the potential surface water quality impacts associated with the construction and operation phases of the Project. Where required, the mitigation hierarchy of avoidance, minimisation, reduction or compensation has been applied to potentially significant impacts to reduce impact levels to as low as reasonably practicable. Monitoring recommendations for surface water quality during the construction and operation phases of the Project are also referenced, where applicable.

Relevant Government agencies have been consulted since the early phases of the Project (since January 2020) to understand surface water quality concerns, collaboratively develop the surface water quality modelling for the Project, draw on past experience from previous FPV projects in other reservoirs in Singapore in preparing the surface water quality impact assessment for this Project. The discussions and recommendations from relevant Government agencies have been taken into account in the following assessment.

Construction activities at the land-based proposed temporary Staging/ Launching Area and integrated Project Substation worksite may generate site runoff and wastewater and result in a change in surface water quality of receptors. In-reservoir construction works could result in disturbance to reservoir bed sediment and potential unplanned spillages. The potential impacts from these activities have been evaluated and assessed.

During the long-term operational phase, the presence of the FPV and related generation of wastewater and sediment disturbance from the O&M of the FPV facilities (including cleaning of PV panels) in the reservoir may change the hydrodynamics and surface water quality of the reservoir; which have also been evaluated and assessed.

This section summaries, and draws on, information from the following technical reports:

- Water Quality Modelling Technical Appendix (refer to *Appendix 6.1*) on the surface water quality model developed for the Project, and main surface water quality considerations and assumptions; and
- Aquatic Environment Baseline Report (refer to *Appendix 7.2*).

Biodiversity implications are covered under the Biodiversity section, *Section 7.*

6.2 Regulatory Framework

The legislation, standards and/ or guidelines applicable to governing surface water quality, particularly at construction sites, in Singapore relevant to this Project include those listed in *Table 6-1*. These legislation, standards and guidelines provide requirements and general guidance for the protection of storm water drainage systems; detail compulsory earth control measures (ECM) to prevent erosion, deposition and impact to the quality of nearby surface water bodies. The legislation also provides instructions for the management of wastewater and polluting materials which can be a source of contamination of surface water bodies in close proximity to construction sites.

- The NEA is responsible for the monitoring and regulation of surface water quality of Singapore. It regulates overall surface water quality in Singapore's inland water bodies and coastal areas. Discharge standards are specified according to the receiving watercourse. The discharge of wastewater into open drains, canals and rivers is regulated by the *Environmental Protection and Management Act (EPMA), 2021* and the *Environmental Protection and Management (EPM) (Trade Effluent) Regulations, 2011*, which are administered by the NEA's Pollution Control Department (PCD). The *EPM (Trade Effluent) Regulations, 2011*, define "trade effluent" as any liquid, including particles of matter and other substances in suspension in the liquid, which is the outflow from any trade, business or manufacture or of any works of engineering or building construction. The EPMA prohibits the discharge of any toxic or hazardous substances into any “inland waters”, which is defined as any natural or manmade river, stream, reservoir, lake or pond.

- The provision, operation and maintenance of Singapore’s sewerage systems are governed by the *Sewerage and Drainage Act (SDA), 2021*. This act and its subsidiary regulations, mainly the *Sewerage and Drainage (Surface Water Drainage) Regulations, 2007*, and S*ewerage and Drainage (Trade Effluent) (Amendment) Regulations, 2022* which govern the treatment and discharge of industrial wastewater into sewers, are administered by PUB. No wastewater, otherwise referred to as trade effluent, is to be discharged into the public sewerage system without the prior permission of the PUB. PUB manage and operate Singapore’s local water catchments, where water from drains, canals, rivers and ponds collect into Singapore’s 17 reservoirs for storage and are then treated by PUB to become drinking water.

Table 6-1: Summary of Legislative Requirements and Guidelines to Protect Surface Water Quality

Legislation/ Standard/ Guideline	Relevance to Surface Water Quality for this EIA
Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021 *Environmental Protection and Management (Trade Effluent) Regulations, 2011* *Environmental Protection and Management (Hazardous Substances) Regulations, 2008*	■ The Act provides for the control of air, water and noise pollution, for the safe management of hazardous waste and for the protection and management of the environment and resource conservation. Establishes NEA Allowable Limits for Trade Effluent Discharge to Watercourses or Controlled Watercourses. ■ Only trade effluent that are treated and compliant with the discharge standards for watercourses and controlled watercourses, and which do not contain prohibited materials such as pesticides, refuse, petroleum etc, will be discharged from the Project worksites. ■ Store concrete and cementitious materials according to the Material Safety Data Sheet (MSDS). ■ Carry out washout of cement and concrete mixing plant or ready-mix lorries and equipment in concrete washout areas to protect against spills and leaks. ■ Treat all trade effluent to relevant standards before it is discharged, and approval should be obtained from the Director-General of the NEA. ■ Install sampling test points, inspection chambers, flow-meters, and recording and other apparatuses for trade effluent discharged into any watercourse or land. ■ Analyse trade effluent discharged into any watercourse or land in accordance with the latest edition of “Standard Methods for the Examination of Water and Wastewater” published jointly by the American Public Health Association, the American Water Works Association and the Water Pollution Control Federation of the United States. ■ Workers will be adequately trained to handle toxic wastes stored on site, and to implement emergency action plans to deal with spills and leaks of toxic waste. ■ Ensure that workers have received adequate instruction and training to handle any accident or emergency involving any toxic industrial waste stored or transported within the construction site.
Environmental Public Health Act (EPHA), (Amendment), 2022	■ Ensure proper storage, handling and disposal of industrial waste. ■ Prevent excessive production of toxic industrial waste. ■ Ensure provision of adequate sanitary facilities. ■ Adequate temporary sanitary facilities will be provided for workers to ensure no public areas will be used for sanitary purposes.
Environmental Public Health (Toxic Industrial Waste) Regulations (Amendment), 2022	■ Toxic waste, such as contaminated soil from construction works must be disposed by a licensed toxic waste collector. ■ Ensure that toxic waste is stored in accordance with the approved code of practice. ■ Ensure that the toxic industrial waste is not mixed with non-toxic waste, unless it is an approved process of treatment, use or disposal. ■ Emergency response kits will be provided at all worksites.
Environmental Public Health (General Waste Collection) Regulations (Amendment), 2019	■ Only licensed general waste collectors will collect, transport and dispose of general waste to a licensed disposal facility. ■ Incinerable, non-incinerable and recyclable wastes will be disposed appropriately.
Fire Safety Act (Amendment), 2022	■ Petroleum or flammable materials will be stored in compliance with requirements under the relevant storage license. ■ All practical steps will be taken to prevent the occurrence of an accident through fire, explosion, leakage or ignition of any petroleum or flammable material or vapours. ■ Firefighting equipment and other emergency response equipment will be provided at all worksites. ■ Workers will be trained in the use of available firefighting and emergency response equipment. ■ A SCDF Plan will need to be submitted to and approved by SCDF during the final design stage.

Legislation/ Standard/ Guideline	Relevance to Surface Water Quality for this EIA
Public Utilities (Reservoir and Catchment Areas and Waterway) Regulations 2018	The Project should: ■ Observe for prohibited activities in the Kranji Reservoir and its Catchment Area Park and obtain approval for site clearance, land-based or water-based works as necessary. ■ Implement specific safety rules, including look-out rules, speed limits, collision avoidance, navigation course control, etc.
Sewerage and Drainage Act (Chapter 294) (Amendment) (SDA), 2021	■ Identify location of public sewerage and drainage infrastructure near any grading, boring, excavation or ground breaking works through desktop review of drainage plan and sewerage plan prior to the commencement of the works. Subsequent to this, carry out trial trenches to confirm the location of any such public sewerage system. ■ Restrict erection of structure or object, above or across any surface water drain. ■ Prohibit works that will affect any storm water drainage system, drain or drainage reserve, directly or indirectly, without obtaining in respect of those works, a clearance certificate or approval of PUB. ■ Monitor trade effluent discharged to the public sewer and submit a monitoring record that includes the following information to PUB: - the amount of water consumed or used for the purposes of any trade, manufacture, business or building construction carried out by the persons and in the course of which the trade effluent is wholly or partly produced or of which the trade effluent is the waste or refuse; - the physical, organic and chemical nature of the trade effluent; - the raw materials and chemicals used in the trade, manufacture, business or building construction and the direction of the flow of any liquid or the trade effluent from or produced by any machinery, plant or equipment used in the trade, manufacture, business or building construction; and - such other matters relating to the trade effluent and the discharge thereof as may be required by PUB. ■ Prohibit discharge of trade effluent with characteristics that exceed the statutory limits to sewerage system. ■ Ensure that all activities involving repair, servicing, engine overhaul works, etc are carried out on a concreted area which will be bunded or provided with scupper drains to channel all wastewater into the sewerage system. ■ Trade effluent discharged to the public sewer from the worksites will be monitored and recorded. ■ Earth stockpiles will be positioned outside of the drainage reserve, and all land adjacent to drains will be turfed during general landscaping and finishing works to minimise sediment loading of stormwater drains during rainfall events. ■ Used water will be recycled whenever practicable.
Sewerage and Drainage (Surface Water Drainage) Regulations, 2007	■ No person shall discharge or cause or permit the discharge into the storm water drainage system of Total Suspended Solids (TSS) in concentrations greater than 50 milligrams per litre of the discharge. ■ Earth control measures will be provided and maintained in accordance with the Code of Practice on Surface Water Drainage. ■ Runoff within, upstream of and adjacent to the work site will be effectively drained away without causing flooding within or in the vicinity of the work site. ■ All earth slopes adjacent to any drain will be closed turfed. ■ Adequate measures shall be taken to prevent any earth, sand, top-soil, cement, concrete, debris or any other material to fall or be washed into the storm water drainage system from any stockpile thereof.

Legislation/ Standard/ Guideline	Relevance to Surface Water Quality for this EIA
Sewerage and Drainage (Trade Effluent) (Amendment) Regulations, 2022	■ Any person who discharges trade effluent into any sewerage system shall, in connection with such discharge, install such sampling test points, inspection chambers, measuring devices, and recording and other apparatuses. ■ Any person who discharges trade effluent into any sewerage system shall install a pre-treatment plant if PUB so requires and shall: - use or operate the plant to treat trade effluent before discharging the trade effluent into the sewerage system; and - maintain the plant in an efficient condition at all times. ■ A person must not discharge or caused to be discharged into any public sewer any trade effluent: - which is not of a nature or type approved by PUB; - the temperature of which exceeds 45°Celsius at the point of its entry into the public sewer (NEA allowable limit for trade effluent discharge); - the pH value of which is less than 6 or more than 9 at the point of its entry into the public sewer; or - the caustic alkalinity of which is more than 2,000 milligrams of calcium carbonate per litre at the point of its entry into the public sewer. ■ A person must not discharge or caused to be discharged any trade effluent which contains any of the following substances: - any toxic industrial waste specified in the first column of the Schedule to the *Environmental Public Health (Toxic Industrial Waste) Regulations (Cap. 95, Rg 11)*; - calcium carbide; - petroleum spirit or other inflammable substance; - any organic compound specified in the First Schedule; - any substance that either by itself or in combination or by reaction with other waste or refuse may give rise to any gas, fume, odour or substance which is or is likely to be a hazard to human life, a public nuisance, injurious or otherwise objectionable, or which prevents or is likely to prevent entry into the public sewer by workmen maintaining or repairing it; - yeast, spent or unspent molasses, crude tar, tar oil, crude oil, carbon disulfide, hydro-sulfide and poly-sulfide; - any radioactive material; - any waste or refuse liable to form a viscous or solid coating or deposit on any part of the public sewer or sewerage system; - any excessively discolouring substance; - any pesticide, fungicide, herbicide, insecticide, rodenticide or fumigant; - blood waste; or - infectious waste. ■ Prohibit discharge of trade effluent with characteristics that exceed the statutory limits to public sewerage system.
Singapore Standard SS 593: 2013 Code of Practice for Pollution Control (COPPC), 2013	■ Submit an Earth Control Management Plan endorsed by a Qualified Erosion Control Professional (QECP) to the PUB, prior to commencement of work. ■ Implement adequate preventive measures including the provision of proper and stable barricades or screens, where deemed necessary by a QECP.

Legislation/ Standard/ Guideline	Relevance to Surface Water Quality for this EIA
PUB Code of Practice on Surface Water Drainage, 7th Edition December, 2018	■ Provide and maintain Earth Control Measures (ECMs) in accordance with the Code of Practice on Surface Water Drainage. ■ Submit an Earth Control Management Plan to the PUB, endorsed by a QECP prior to commencement of work. ■ Effectively drain away runoff within, upstream and adjacent to the work site without causing flooding within or in the vicinity of the site. ■ Material from any stockpile shall not be allowed to fall or be washed into the drain. Adequate preventive measures, including the provision of proper and stable barricades or screens where necessary, shall be provided. ■ Bare surfaces (including earth stockpiles) shall be covered by concrete-lining, concrete-paving, milled waste, erosion control blankets, close turfing or other suitable materials. Access roads within the site and at exit/ entrance as well as the surfaces around the site facilities shall be covered or paved. Work areas shall be covered with canvas sheets, tarpaulin sheeting or other suitable materials during rain or before work stops every day.
PUB Code of Practice on Sewerage and Sanitary Works, 2nd Edition, 2019	■ After obtaining Temporary Occupation Permit for the development, the operator shall apply to PUB for “Written Approval to Discharge Trade Effluent”. ■ PUB may require the installation of autosampler and/ or additional monitoring of the trade effluent e.g. Volatile Organic Compound (VOC) monitoring, when granting the Written Approval. ■ All effluents that are prohibited to be discharged into a public sewer shall be disposed of by only NEA licensed toxic industrial waste collector. ■ Animal wastes and sludge generated shall be stabilised, dewatered and disposed of as solid waste.
PUB Guidebook on Erosion and Sediment Control at Construction Sites – For Site Implementation, 2018	■ A Clearance Certificate will be obtained from the PUB, before the commencement of works. ■ Submission of an ECM proposal at the start of construction works. ■ Revision and resubmission of the ECM plans as required. ■ The ECM and Sediment Control measures listed to be effectively implemented.
NEA’s Code of Practice for Environmental Control Officers for Construction Sites, 2021	■ Provides recommended guidelines on practice measures to manage earth control measures, wastewater and sanitary facilities etc on construction sites.

6.3 Assessment Criteria

The assessment criteria for potential impacts to surface water quality are based on the prevailing legislation and understanding of the sensitivity of water receptors to effluents from the construction and operation activities.

It is understood from PUB that relevant guideline criteria for the Project are (with mitigation, if required):

- Temperature increase of not more than 0.3°C throughout the column; and
- Dissolved Oxygen (DO) not below 3 mg/L throughout the column.

As agreed with PUB, the threshold criteria for other construction and operational surface water quality parameters will be agreed in advance of works commencement with PUB, see *Section 12 (EMMP)*.

The magnitude of potential impacts on surface water quality have been assessed in accordance with the agreed criteria presented *Table 6-2.*

Table 6-2: Magnitude Criteria for Assessment of Impacts on Surface Water Quality

Magnitude	Definitions
Negligible	■ Discharges are expected to be well within the statutory limits set down in the *Environmental Protection and Management (Trade Effluent) Regulations 2011*; or well within the threshold criteria pre-agreed with PUB; and/ or ■ There is likely to be negligible or no impact on upstream or downstream flood flows, drainage patterns and/ or surface water levels caused by the Project.
Small	■ Discharges are expected to be within statutory limits from the *Environmental Protection and Management (Trade Effluent) Regulations 2011*; or within the threshold criteria pre-agreed with PUB; and/ or ■ There is likely to be some alteration to existing drainage regimes and characteristics, although the frequency and magnitude of flooding upstream or downstream of the Project is not expected to be materially affected.
Medium	■ Occasional breach(es) of statutory discharge limits (e.g. in order of once every few days) from the *Environmental Protection and Management (Trade Effluent) Regulations 2011* over short timeframes (e.g. in order of a month or less) expected; or occasional breach(es) of the threshold criteria pre-agreed with PUB; and/ or ■ The Project is likely to involve significant alterations to existing drainage regimes and patterns (e.g. floodplain embankments, cross drainage structures, canalisation etc.)
Large	■ Repeated breaches of statutory discharge limits (e.g. breaches expected in period of every 2 days or less) from the *Environmental Protection and Management (Trade Effluent) Regulations 2011* over extended periods (e.g. longer than one month) expected; or repeated breaches of the threshold criteria pre-agreed with PUB; and/ or ■ The Project is likely to involve significant alterations to existing drainage regimes and patterns (e.g. floodplain embankments, cross drainage structures, canalisation etc.).

The agreed sensitivity criteria adopted to assess the sensitivity of the surface water receptors are presented in *Table 6-3* (see *Section 6.5* for further discussion on sensitivity of Kranji Reservoir following consultation with PUB).

Table 6-3: Sensitivity Criteria for Surface Water Quality

Sensitivity	Definitions
Low	■ No protected[a] surface water receptors within the Study Area; and/ or ■ The water resource has little or no role in terms of providing services (e.g. drinking, recreational) for the local community.
Medium	■ Protected surface water receptors outside construction areas but within Study Area; and/ or ■ The water resource has local importance in terms of providing services (e.g. drinking[b], recreational) but there is ample capacity and/ or adequate opportunity for alternative sources of comparable quality.

Sensitivity	Definitions
High	■ Protected surface water receptors within Study Area, including construction areas; and/ or ■ The water resource is wholly relied upon locally[(b)], with no suitable technically or economically feasible alternatives.
Notes: *(a) Protected surface water receptors are defined as any water bodies demarcated as a 'Marine Nature Area' under the Parks & Waterbodies Special & Detailed Controls Plan (URA, 2019) or within areas demarcated as Nature Reserves.* *(b) A watercourse from which the PUB obtains potable water supply is defined as a 'Controlled Watercourse' under the Environmental Protection and Management Act. The surface water quality limits defined for Controlled Watercourses are more stringent (when compared with Watercourse), as per the Environmental Protection and Management (Trade Effluent) Regulations 2011 (see Table B.1, Appendix B).*	

6.4 Baseline Conditions

The following section briefly describes the methodology and findings for establishing baseline conditions of the Reservoir Study Area (i.e. Reservoir Project Site and broader Kranji Reservoir). Please refer to *Appendix 7.2* for details on methodology and presentation of the detailed baseline survey findings.

6.4.1 Methodology

6.4.1.1 Short-term Surface Water Quality Sampling

Monthly surface water quality sampling surveys were carried out to establish the existing surface water quality at five selected locations (as agreed with PUB) within the Kranji Reservoir for six months between December 2020 to May 2021, with an additional sampling event carried out in September 2021 to capture reservoir water conditions following a storm event (see *Table 6-4* and *Figure 6-1*).

Table 6-4: Surface Water Quality and Reservoir Bed Sediment Sampling Locations and Selection Rationale

Sampling Location	Water Depth (m)[(a)]	Coordinates (WGS84)		Rationale
		x	y	
WQ01/ SS01	2.0 – 3.3	103.74095	1.43116	To establish ambient conditions within the Reservoir Study Area.
WQ02/ SS02	2.1 – 4.7	103.73972	1.42146	To establish ambient conditions from drainage outfall at Pang Sua Diversion Canal on the eastern bank.
WQ03/ SS03	0.6 – 2.9	103.73124	1.41421	To establish ambient conditions from drainage outfall on the eastern bank.
WQ04/ SS04	1.2 – 2.2	103.7177	1.41087	To establish ambient conditions from Sungei Kangkar.
WQ05/ SS05	1.3 – 3.1	103.72826	1.40577	To establish ambient conditions from Peng Siang River and Sungei Tengah.
Notes: *(a) Water depth measurements obtained during the water quality sampling events.*				

Water samples have been tested for the following parameters:

Table 6-5: Surface Water Quality Sampling Parameters and Sampling Approach

Parameters	For in-situ parameters (0.5m below surface, mid-depth and 0.5m above reservoir bed)	For ex-situ parameters (mid-depth)	For ex-situ parameters (0.5m above reservoir bed)	For ex-situ parameters (0.5m below surface)
Temperature	√			
pH	√	√	√	
Conductivity	√	√	√	
Turbidity	√	√	√	
Secchi depth (single measurement for entire water column)	√			
Dissolved oxygen (DO)	√			
Total organic carbon (TOC)		√	√	
Dissolved organic carbon (DOC)		√	√	
Biochemical oxygen demand (BOD_5)		√		
Chemical oxygen demand (COD)		√		
Total suspended solids (TSS)		√		
Total dissolved solids (TDS)		√		
Ammonia (NH_3-N)		√	√	
Nitrate (NO_3-N)		√	√	
Total nitrogen (TN)		√	√	

Parameters	For in-situ parameters (0.5m below surface, mid-depth and 0.5m above reservoir bed)	For ex-situ parameters (mid-depth)	For ex-situ parameters (0.5m above reservoir bed)	For ex-situ parameters (0.5m below surface)
Dissolved phosphorous		√	√	
Total phosphorous (TP)		√	√	
Phosphate (PO_4-P)		√	√	
Sulfide		√	√	
Iron (Fe)		√	√	
Aluminium (Al)		√	√	
Chlorophyll-a		√		
2-Methylisoborneol (2-MIB)		√		
Geosmin		√		
Total Microcystins		√		
Cylindrospermopsin		√		
Antimony (Sb)		√		
Molybdenum (Mo)		√		
Phenolic compounds (as phenols)		√		
Microcystin-LR		√	√	
All remaining parameters under NEA controlled watercourse		√		
Phytoplankton – species and counts				√

Parameters	For in-situ parameters (0.5m below surface, mid-depth and 0.5m above reservoir bed)	For ex-situ parameters (mid-depth)	For ex-situ parameters (0.5m above reservoir bed)	For ex-situ parameters (0.5m below surface)
Zooplankton – species and counts				✓

6.4.1.2 Long-term Surface Water Quality Monitoring Data

Data has been provided by PUB to support the hydrodynamic and surface water quality modelling for this EIA. To obtain an adequate understanding of hydrodynamic and surface water quality conditions in Kranji Reservoir, historic surface water quality data of 2019 was obtained from PUB for the use of calibrating and validating the hydrodynamic and water quality model. Detailed findings are presented under *Section 5* of *Appendix 6.1* the Water Quality Modelling Technical Appendix.

6.4.1.3 Reservoir Bed Sediment Quality

Sediment sampling for heavy metals in the reservoir bed was conducted to establish the existing sediment heavy metal conditions. The same five locations were selected as those for Surface Water Quality Sampling described above (see *Table 6-4* and *Figure 6-1*). Sampling efforts were carried out once every two months over a period of six months (three sampling times). Up to 3 kg of sample per location was collected from the reservoir bed surface via grab sampler (maximum penetration approximately 20cm), and were sent to the laboratory for analysis.

Sediment samples were tested for the following parameters:

- Total Nitrogen;
- Total Phosphorus;
- Loosely-bound P;
- Fe/ Al bound P;
- Ca bound P;
- Organic bound P; and
- Heavy metals – Al; Sb; Arsenic (As); Barium (Ba); Boron (B); Cadmium (Cd); Chromium (Cr); Copper (Cu); Fe; Lead (Pb); Manganese (Mn); Mercury (Hg); Mo; Nickel (Ni); Selenium (Se); and Zinc (Zn).
- To support water quality modelling efforts, a one-time sediment sampling effort at the 5 locations was carried out to analyse the following parameters to account for pore water[1] and elutriate[2] (leachability) from sediments.

Additional parameters analysed included:

- Total Organic Carbon (TOC);

[1] Refers to the water contained in the interstices/pore space of aquatic sediments.

[2] Refers to the release/ leaching of contaminants to the water column.[3] The names of waterways/ rivers were retrieved from the PUB's 2014 Managing Stormwater for Our Future publication (accessed 2 May 2023 https://www.pub.gov.sg/drainage#:~:text=The%20%E2%80%9CManaging%20Stormwater%20for%20Our,for%2012%20waterways%20in%20Singapore.)

- % organic matter;
- Particle Size Distribution (PSD); and
- Particle Density.

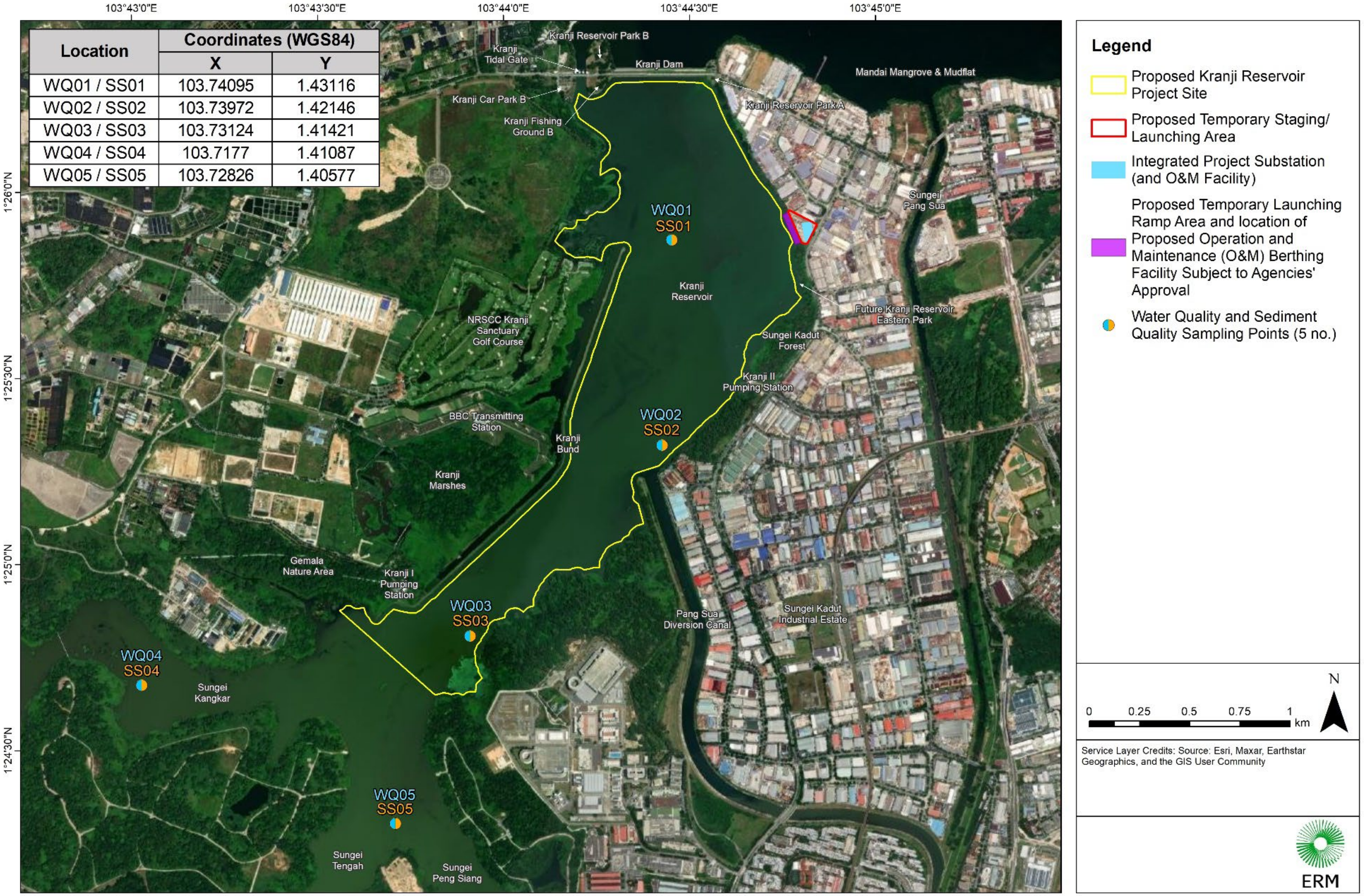
Pore water from sediments:

- TP;
- TN;
- NH_3-N;
- NO_3-N;
- PO_4-P;
- TOC;
- pH; and
- Heavy metals (Al, Sb, As, Ba, B, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Mo, Ni, Se, Zn).

Elutriate (leachability):

- pH;
- NO_3-N;
- NO_2- N (Nitrite);
- NH_3-N;
- PO_4-P;
- Total Nitrogen (TN);
- Total Phosphorus (TP); and
- Heavy metals (As, Cd, Pb).

All boat-based surveys were subject to health and safety considerations (including for COVID-19), actual site conditions and relevant Government clearances (e.g. PUB).



Location	Coordinates (WGS84)	
	X	Y
WQ01 / SS01	103.74095	1.43116
WQ02 / SS02	103.73972	1.42146
WQ03 / SS03	103.73124	1.41421
WQ04 / SS04	103.7177	1.41087
WQ05 / SS05	103.72826	1.40577

Figure 6-1: Surface Water Quality and Reservoir Bed Sediment Quality Sampling Locations

6.4.2 Findings

The following section presents the summary of main findings for the baseline survey conducted. Detailed graphical presentation for these survey findings is provided in *Appendix 7.2*.

6.4.2.1 In-situ Profiling

The main observations and summary of in-situ parameters is shown in *Table 6-6,* also refer to *Figure 3-7* of *Appendix 7.2* for detailed graphical presentation of in-situ profiling results across the sample locations.

Table 6-6: Summary Findings for In-Situ Surface Water Quality Parameters

Parameters	Results and Discussion
Temperature	■ Average water temperature recorded for each survey event ranged from 25.7°C to 31.7°C. ■ Higher water temperature was observed at WQ01 in the month of May 2021, where the temperature was recorded at 35.7 °C at water surface and 35.4°C at 0.5m above reservoir bed. This appeared to be a one-time occurrence and could be attributed to the time of sampling during the day. ■ Typically, higher water temperatures may suggest increased heat stress was exerted on aquatic life at this time. High water temperatures can also increase the solubility and toxicity of certain compounds like ammonia, meaning that toxic compounds may have become more readily available in the water column during this period.
pH	■ Typical pH range for freshwater systems is between 6 to 9. ■ pH readings over the monitoring months were well within this range, suggesting that the water was alkaline in nature. However, pH levels outside of this range were observed in a reservoir water sample collected after the September 2021 storm event, with pH values of up to 10.4 at WQ01.
Secchi Depth	■ Secchi depth typically provides estimates of water clarity, with larger values indicating greater water transparency. ■ Secchi depth from the surveys generally ranged from 0.3m – 1.0m but ranged from 0.1m – 0.5m during the reservoir sampling after a storm.
Turbidity	■ Higher turbidity values typically indicate a loss of water transparency. ■ Surveys indicate turbidity ranged from 4.5 NTU (Nephelometric Turbidity Units) to 47.4 NTU. ■ High turbidity levels of 256.4 NTU were recorded during the reservoir sampling after a storm at WQ04. The relatively elevated level indicates a substantial loss of water clarity and is expected to be a result of the close proximity of WQ04 to the undeveloped shoreline, which may have resulted in high suspended solids contributions from surface runoff or stormwater discharges.
Dissolved Oxygen (DO)	■ Dissolved oxygen (DO) is the amount of oxygen available in the water, with higher DO levels being an indicator of good surface water quality. ■ Surveyed mean concentrations of DO (by stations per survey event) ranged from 4 mg/L – 11mg/L. For surface measurements, the average DO across the sampling events was 7.6 mg/L and measurements ranged between 4.6 mg/L - 10.9 mg/L. For mid-depth measurements, the average DO was 6.9 mg/L and ranged between 4.05 mg/L - 11.07 mg/L. For measurements 0.5m above reservoir bed, the average DO across the sampling events was 6.0 mg/L and measurements ranged between 1.6 mg/L and 10.1 mg/L. ■ A decrease in bottom-depth DO levels to <3mg/L at the relatively deeper sampling site, WQ02, during the survey in May 2021 at 0.5 m above the reservoir bed, may suggest enhanced anoxia and an increase in organic decomposition on the reservoir bed at this time. ■ Note: there are currently five artificial aerators in the reservoir that increase and maintain oxygen saturation in the water.

Parameters	Results and Discussion
Conductivity	■ Conductivity values typically reflect the amount of dissolved salts in the water. Typical freshwater values range between 30 to 500 µS/cm. ■ Values at Kranji Reservoir ranged between 105 µS/cm to 225 µS/cm. ■ Lower conductivity levels were observed during the reservoir sampling event after a storm, which suggests flushing and dilution of the water salinity concentration occurred. ■ Conductivity readings were relatively consistent throughout the water column at each of the survey stations.

6.4.2.2 Ex-situ Profiling

Water samples were taken at 2 depths at each location, namely mid-depth and 0.5m above the reservoir bed, for laboratory analysis. Where detectable, parameter concentrations were generally below NEA's allowable limits for trade effluent discharge to controlled watercourses. Where non-detectable for heavy metal parameters, a lower detection limit was applied for these heavy metals and are indicated in their respective graphs in *Figure 3-8 and Figure 3-9* of *Appendix 7.2*. Where detectable and without target or intervention limits, these results serve as a benchmark for consideration for future monitoring purposes. A summary of the main findings of exceedances in water parameters analysed at mid-depth and 0.5 m above the reservoir bed are provided in *Table 6-7*. For other ex-situ surface water quality findings not included in the table, no non-compliances were recorded. *Figure 3-8* and *Figure 3-9* of *Appendix 7.2* present the lab results for water samples taken at mid-depth and 0.5m above reservoir bed respectively. Minor exceedances were recorded for the parameters of total suspended solids (TSS), arsenic (As) and iron (Fe).

Table 6-7: Summary Findings for Ex-Situ Surface Water Quality Parameters

Parameters	Results and Description
Total Suspended Solids (TSS)	■ Total suspended solids (TSS) is a measure of suspended solids present within the water column, which has an effect on water clarity. Higher TSS was observed at WQ04 at mid-depth throughout the sampling months. TSS level exceeded NEA's Trade Effluent limit of 30 mg/L at mid-depth level of WQ04 during the reservoir sampling after a storm in September 2021, which may reflect enhanced disturbance and suspension of bed sediments at shallow depths (<1.2m).
Arsenic, As	■ Arsenic is a toxin to aquatic life as well as in drinking water. Arsenic can be released into freshwater systems from natural deposits or from anthropogenic sources (e.g. industrial and agricultural pollution). Arsenic was generally less than NEA limits (0.01 mg/L) during the sampling months and reservoir samples only exceeded the limit level during a one-off occurrence (and not during / after a storm event) suggesting such an exceedance could be incidental only. Exceedance was recorded at 0.012mg/L at WQ01 at mid-depth in December 2020.
Iron, Fe	■ Iron is a natural element that can be released from natural deposits. High levels can be found in areas with organic material in shallow or surface water. Iron is generally non-toxic but could affect the colour and taste of drinking water. Iron levels exceed NEA's allowable limits level of 1 mg/L in reservoir samples at 0.5 m above reservoir bed at WQ05 in February and May 2021, as well as at 0.5 m above reservoir bed at WQ04 in September 2021 after a storm event. These occurrences of high iron values (up to 0.96 mg/L) likely reflect increased disturbance and suspension of reservoir bed sediments.

6.4.2.3 Sediment, Pore water and Elutriate

Sediment samples were taken at up to 20 cm deep into the reservoir bed at each sample location. *Figure 3-10* of *Appendix 7.2* presents the lab results for these sediment samples. As there are no local sediment quality regulations to classify the results, the 2009 Dutch Soil Quality Standard (Dutch

Standards) was adopted for comparison. Parameter concentrations were compared to both target and intervention limits of the Dutch Standards. Organic Matter as LOI (Loss on Ignition) and Total Organic Carbon (TOC) were agreed to be analysed once throughout the sediment sampling program, while pore water and elutriate as seen in *Figure 3-11* and *Figure 3-12* of *Appendix 6.1*, respectively, were also analysed for various parameters for the purpose of the surface water quality assessment.

Where detectable and without target or intervention limits, these results serve as a benchmark for consideration for future monitoring purposes. These include sediment parameters - TN, TP, Loosely-bound P, Fe/Al bound P, Ca bound P, Organic bound P, Organic Matter as LOI, TOC, Al, B, Fe and Mn.

Metal contamination of sediment could impact both the genetic structure and the functional potential of chronically exposed microbial communities. This poses an ecological risk as it may impact ecosystem and benthic communities' functions. Within sediments, benthic heterotrophic microbial communities support various ecosystem functions from organic matter recycling to pollutant degradation and biomass production. The main observations of exceedance of Dutch Standards and a summary for sediment parameters analysed are presented in *Table 6-8* below. The sediment quality data indicates some levels of heavy metal contamination were recorded in the reservoir, yet the pore water and elutriate tests suggest relatively low risk of these contaminants being released into the water column when disturbed. This information has been taken into account in the assessment of potential release of sediment-bound contaminants from piling/ anchoring works during the construction phase. Refer to *Appendix E* of *Appendix 6.1* for analysis of the potential impact from release of sediment-bound contaminants from sediment disturbance from the in-reservoir construction of the Project.

Table 6-8: Summary Findings for Ex-Situ Sediment Parameters with Exceedance of Dutch Soil Quality Standards

Parameters	Results and Description
Antimony, Sb	■ Non-detectable in location SS01 and SS02 in January 2021 and across all sites in March 2021. ■ Detected in May 2021 and above target limit at both SS02 and SS03.
Arsenic, As	■ Nine (9) out of a total 15 of samples (at SS01, SS02 and SS03) taken at 5 locations and 3 sampling dates have arsenic levels exceeding the target limit. Two (2) of the samples (at SS01 and SS03) also exceeded the corresponding intervention limits as well. ■ Arsenic in sediment may originate from mineral naturally, or anthropologically as industrial and/ or agricultural pollution.
Copper, Cu	■ Majority of samples (i.e. 11 out of a total of 15, covering all sites) taken at 5 locations and 3 sampling dates have copper levels exceeding the target limit.
Zinc, Zn	■ Majority of samples (i.e. 14 out of a total of 15) taken at 5 locations and 3 sampling dates have zinc levels exceeding the target limit. ■ Zinc may be transported and delivered via surface runoff and atmospheric deposition from nearby industrial zones.

6.5 Sensitive Receptors

The in-reservoir activities of the Project are located in the Kranji Reservoir, which is the main water sensitive receptor which could be affected by the construction and operation phases of this Project. Indirectly, the water extraction from Kranji Reservoir to the PUB water treatment plant for drinking water purposes could also be affected by the in-reservoir construction and operation phase of the FPV system.

All drains to the east of the Kranji Reservoir (which is generally industrial in nature), where the proposed temporary Staging/ Launching Area and integrated Project Substation site is situated, flow into Sungei

Pang Sua, therefore all treated runoff from ECM device(s) from land-based works would eventually enter Sungei Pang Sua and then into the Johor Strait but not into the Kranji Reservoir[3].

The summary of sensitivity and locations of the water sensitive receptors (developed based on the sensitivity criteria in *Table 6-3* and engagements with PUB) are listed in *Table 6-9* and shown in *Figure 6-2*, respectively.

[3] The names of waterways/ rivers were retrieved from the PUB's 2014 Managing Stormwater for Our Future publication (accessed 2 May 2023 https://www.pub.gov.sg/drainage#:~:text=The%20%E2%80%9CManaging%20Stormwater%20for%20Our,for%2012%20waterways%20in%20Singapore.)

Table 6-9: Surface Water Sensitive Receptors and Level of Sensitivity

<table>
<tr><th rowspan="2">Sensitive Receptor</th><th colspan="3">Level of Sensitivity (refer to Table 6-3 above for sensitivity criteria)</th></tr>
<tr><th>High</th><th>Medium</th><th>Low</th></tr>
<tr><td>Kranji Reservoir and its tributaries upstream

And

PUB Drinking Water Intakes in Kranji Reservoir, including intakes for Kranji I and Kranji II Pumping Station, as well as the Choa Chu Kang Water Works</td><td colspan="2">The Kranji Reservoir is the site of the FPV system, as well as O&M berthing facilities for this Project. The reservoir collects water flow from a number of rivers, namely, Sungei Peng Siang, Sungei Kangkar, Sungei Tengah and Pang Sua Diversion Canal. It is relied upon locally as a source of water supply of the country, i.e. controlled watercourse. The Kranji Reservoir is one of a number of reservoirs in Singapore used for the supply of potable water (via water treatment plants). This qualifies the Kranji Reservoir as “Medium” sensitivity (“the water resource has local importance in terms of providing services but there is ample capacity and/ or adequate opportunity for alternative sources of comparable quality”) according to Table 6-3.
Additionally, per discussions with PUB, major changes in surface water quality in Kranji Reservoir could result in disruption to raw water abstraction from the reservoir for potable water production. This qualifies the Kranji Reservoir as “High” sensitivity (“the water resource is wholly relied upon locally, with no suitable technically or economically feasible alternatives”) according to Table 6-3.
A “High” sensitivity rating is applied to Kranji Reservoir and the PUB Drinking Water Intakes for this impact assessment.</td><td>None</td></tr>
<tr><td>Sungei Pang Sua and other minor canals/drains discharging to it</td><td>None</td><td colspan="2">Sungei Pang Sua is located at around 470 m east of the proposed temporary Staging/ Launching Area and integrated Project Substation site. The river flows north towards the Johor Straits and passes through the Sungei Kadut Industrial Estate. All drains to the east of the Kranji Reservoir (which is generally industrial in nature) flow into Sungei Pang Sua.
The Sungei Pang Sua does not serve as a source of drinking water. Given its large size, it may serve recreational purposes and general amenity. There are alternatives to Sungei Pang Sua’s uses elsewhere. This qualifies the Sungei Pang Sua as “Medium” sensitivity (“the water resource has local importance in terms of providing services but there is ample capacity and/ or adequate opportunity for alternative sources of comparable quality”) according to Table 6-3.
Other minor canals/ drains also do not serve as a source of drinking water nor other notable recreational purpose. As such, this qualifies those minor canals and drains as “Low” sensitivity (“The water resource has little or no role in terms of providing services (e.g. drinking, recreational) for the local community.”) according to Table 6-3.</td></tr>
<tr><td>Johor Straits</td><td>None</td><td>Johor Straits is located north of the Kranji Reservoir as well as the Sungei Pang Sua. It receives excess water from Kranji Reservoir through tidal gates, as well as flow from Sungei Pang Sua. There are a number of notable intertidal areas of ecological interest along the Johor Straits section near the Project, namely, the Sungei Buloh Wetland Reserve (Sungei Buloh Besar River estuary is about 1.5 km by sea from the Kranji tidal gate) and Mandai Mangrove & Mudflat (Mandai River estuary is about 1.1 km by sea from the Sungei Pang Sua estuary). The Johor Straits does not serve as a source of drinking water. There are a number of angling locations along the Johor Straits but there are alternatives elsewhere. The same applies to the general amenity value provided by the Johor Straits. This qualifies the Johor Straits as “Medium” sensitivity (“the water resource has local importance in terms of providing services but there is ample capacity and/ or adequate opportunity for alternative sources of comparable quality”) according to Table 6-3.</td><td>None</td></tr>
</table>

6.5.1 Kranji Reservoir

Kranji Reservoir is located on the north-western coast of Singapore and forms a large portion of the Sungei Kadut Planning Area, as earmarked by URA (1997). The reservoir was formed by the construction of a 630 m long dam across the former Kranji River in 1972. After the damming of the Kranji River, water from 4 rivers upstream (Sungei Peng Siang, Sungei Kangkar, Sungei Tengah and Pang Sua Diversion Canal) flooded the original river valley and mangrove swamp on both sides and formed the reservoir. The reservoir is connected to the Johor Straits at the tidal gate at the north of the reservoir.

Today, the reservoir serves as one of Singapore's water supply reservoirs. The Kranji Reservoir Park is open for public use, and there are two fishing sites within the north of the reservoir for recreational fishing.

Surface water quality baseline conditions for the Kranji Reservoir are described in *Section 6.4* above. The reservoir shows the characteristics of eutrophic conditions, characterised by high nutrient content, high growth of aquatic vegetation, etc. According to information provided by PUB, regular removal of aquatic vegetation is conducted for reservoir operational purposes (e.g. for navigational purposes) and to limit biomass accumulation in the reservoir. The results of sediment sampling and testing also indicate heavy metal presence in sediments within the reservoir, which may originate from the historical land uses within the reservoir's footprint as well as the upstream areas of the reservoir.

Figure 6-2: Water Sensitive Receptors Identified

6.6 Impact Assessment – Construction and Operation

6.6.1 Construction Phase

6.6.1.1 Potential Sources of Impact

Land-based construction activities may generate site runoff and wastewater and result in a change in surface water quality of receptors during the construction phase. In-reservoir construction works could result in disturbance to reservoir bed sediment and potential spillages. Specific activities within these areas which may result in impacts to surface water quality include the following:

Proposed Temporary Staging/ Launching Area & Integrated Project Substation – Construction Works on Land

- Geotechnical/ site investigation at the proposed temporary Staging/ Launching Area and integrated Project Substation site;
- Preparation of the proposed temporary Staging/ Launching Area, including ramp into reservoir;
- Assembly of the FPV system; and
- Construction of the integrated Project Substation and land-based connector cable.

FPV – Construction Works on/ in Water

- Geotechnical/ site investigation in reservoir;
- Deployment of anchors/ ballasted foundations/ piles and mooring lines;
- Launching, towing and installation of FPV and ancillary equipment at designed locations;
- Installation of connector cables (between FPV islands and to shore);
- Trimming of aquatic vegetation; and
- Construction of O&M berthing facility (location subject to approval from agencies).

Unplanned Events (on water or land)

- Fire and Explosion; and
- Failure of Erosion Control Measures (ECM)/ Environmental Spill.

The impacts that may arise due to the above activities/ events that are considered in *Section 6.6.1.3* include:

- Site runoff and wastewater from geotechnical/ site investigation on land (at the proposed temporary Staging/ Launching Area and the integrated Project Substation site);
- Site runoff, wastewater and sediment disturbance from preparation of the proposed temporary Staging/ Launching Area;
- Site run-off and wastewater from land-based assembly of the FPV system;
- Sediment disturbance from geotechnical/ site investigation in reservoir;
- Sediment disturbance from deployment of anchors/ ballasted foundations/ piles and mooring lines;
- Sediment disturbance from launching, towing and installation of FPV and ancillary equipment at designed locations;
- Sediment disturbance from installation of connector cables (between FPV islands and to shore);

- Degradation/ change of surface water quality from trimming of aquatic vegetation;
- Site runoff and wastewater from construction of integrated Project Substation and land-based connector cable in the proposed temporary Staging/ Launching Area (adjacent to reservoir);
- Sediment disturbance from construction of O&M berthing facility (location subject to approval from agencies);
- Degradation/ change of surface water quality from unplanned events of fire and explosion; and
- Degradation/ change of surface water quality from unplanned event of failure of erosion control measures (ECM)/ environmental spill.

6.6.1.2 Embedded Controls

Embedded controls are measures (physical or procedural) that are planned to be put in place as part of the Project design, construction and operation from the outset. These actions are to manage the Project's compliance with relevant legislation, regulations and guidelines in relation to development and surface water quality. The below are further to the construction embedded controls outlined for Biodiversity (*Section 7*), Air Quality (*Section 8*), Airborne Noise and Vibration (*Section 9*), Soil and Groundwater (*Section 10*) and Vectors (*Section 11*).

Embedded controls beyond those identified in *Section 6.2* include good practice to be implemented such as:

Construction Earth Control Measures (ECM) Plan for Land-based Works

The Developer/ Owner will be required to meet the requirements of the *Environmental Protection and Management Act (EPMA)*. At a minimum, the controls on water resources management during the construction phase will include those listed in the *PUB Guidebook on Erosion and Sediment Control at Construction Sites – For Site Implementation, 2018*.

In summary, an ECM plan designed and endorsed by a Qualified Erosion Control Professional (QECP) with approval from PUB, will be prepared prior to the commencement of any construction works. The ECM plan will specify earth control measures and sediment control measures required for the construction worksite layout and will be designed such that it meets the requirements of relevant Government and Technical Agencies such as PUB. The ECM is to be designed to cater to 1 in 5-year storm events. A perimeter drain will be provided to ensure that the surface runoff within the worksites will be channelled towards centralised tanks for further treatment, before discharging to the road side drains. Closed-circuit television (CCTV) cameras including Silt Imagery Detection System (SIDS) will be located at the ECM discharge points into the existing drain. As stated in the previous section, the land-based elements of the Project (including the proposed temporary Staging/ Launching Area and integrated Project Substation) are located within the catchment of Sungei Pang Sua (i.e. the nearby drainage channel runs into Sungei Pang Sua and then into Johor Strait), therefore, any discharge from ECM discharge points would lead into drains flowing to the Sungei Pang Sua. The QECP will carry out monthly monitoring to verify the ECM implementation and its effectiveness. The construction site will also have an Environmental Control Officer (ECO) on site to ensure the implementation, maintenance and inspection of the ECM plan during the construction period.

Other ECM-related embedded controls include:

- A Clearance Certificate will be obtained from the PUB, before the commencement of works;
- Submission of an ECM proposal at the start of construction works;
- The ECM and Sediment Control measures listed to be effectively implemented;
- The sizing of an ECM system with adequate capacity to cater for exceptional rainfall events such as a once in five year storm, in accordance with PUB requirements for each worksite;

- The sizing of an ECM with adequate capacity to cater for exceptional rainfall events, which will double up as a holding pit for firewater till collection by a third-party Contractor for off-site disposal;
- A perimeter drain will be provided to ensure that the surface runoff within the worksites will be channelled towards centralised tanks for further treatment, before discharging to the roadside drains;
- Closed-circuit television (CCTV) cameras including Silt Imagery Detection System (SIDS) will be located at the ECM discharge points into the existing drain;
- The construction site will also have an Environmental Control Officer (ECO) on site to ensure the implementation, maintenance and inspection of the ECM plan during the construction period;
- Install sampling test points, inspection chambers, flow-meters, and recording and other apparatuses into the collection and treatment infrastructure at the ECM discharge point;
- Take all adequate measures to prevent any earth, sand, top-soil, cement, concrete, bentonite slurry, debris or any other material to fall or be washed into the stormwater drainage system from any stockpile;
- Whilst stored on site, stockpiles will be covered by erosion control blankets or canvas or similar protective covering to minimise erosion by rainfall;
- Silt from cut-off drains, silt traps and holding sumps should be removed regularly, with silt in holding sumps should be treated and emptied within 10 hours after a rainfall event;
- Settling pond, where required, should be lined with impervious lining or equivalent, and designed with sufficient capacity to ensure no overflow into surrounding;
- Hazardous liquid and wastewater contaminated with chemical should be stored for proper treatment and disposal offsite by approved contractor;
- Regular inspections of ECM system and discharge pipeline to ensure necessary repairs are promptly undertaken throughout the construction phase;
- Ensure that adequate preventive measures are in place including the provision of proper and stable barricades or screens where necessary;
- Effectively drain away runoff within, upstream and adjacent to the work site without causing flooding within or in the vicinity of the site;
- Provision of adequate training to operators;
- Revision and resubmission of the ECM plans as required;
- The Developer/ Owner is to submit an Earth Control Management Plan endorsed by a Qualified Erosion Control Professional (QECP) to the PUB, prior to commencement of work;
- Regular inspections of ECM system and discharge pipeline to ensure necessary repairs are promptly undertaken throughout the construction phase. Inspections should be done regularly and during/ after any rain event. The QECP shall carry out regular audit/ review for every stage of the earthworks and construction works, and revision of the ECM shall be done in accordance with the QECP advice. All inspection reports shall be kept on site and made available to the Board upon request; and
- Establish a response plan, e.g. contaminating material will be removed manually (in the case of viscous or solid material). Following this, regular visual inspections and monitoring of the relevant chemical parameters will be undertaken for the affected water body until conditions return to normal.

Construction Materials, Construction Waste and Wastewater Management (including Accidental Spillage and Leakage Management) for both Land-based and In-reservoir Works

All hazardous materials will be stored and handled following relevant regulatory requirements.

Notably, all chemicals will be stored in designated storage containers within bunded areas, with drip trays provided to contain spillage. The chemical storage areas will also be roofed to avoid rainwater collection within the bunded areas. In the event of a release greater than the drip tray capacity, fluids contained within the bunded areas will be either removed by a licensed third party collector; or treated on site to the required standard before being released to a nearby public drain.

Other embedded control measures that will be in-place include:

- Standard operation procedure for proper handling, storage, transfer and disposal of waste should be developed and implemented;
- Hazardous liquid and wastewater contaminated with chemical should be stored for proper treatment and disposal offsite by approved contractor;
- Proper storage/ bins should be provided for waste disposal. Such storage should be regularly cleaned up for offsite disposal at appropriate facilities by trained workers or contractor;
- Provide secondary containment facilities for storage tanks/ drums containing oils and chemicals. The containment should be sized to contain the entire contents of the largest storage tank;
- Sufficient chemical toilets (or equivalent) will be provided on site in accordance with the EPHA to serve the assembly workers for the FPV and no direct discharge of sanitary sewage would be allowed;
- Provide appropriate equipment to prevent any leakage or discharge from containers such as portable jerry cans for ease of refuelling or handling of smaller amounts of chemicals during construction;
- Install and operate pollution monitoring equipment to prevent and detect any leakage or discharge;
- In the event of leakage or spillage of any oil or chemicals, arrange for proper disposal of spilled product and any contaminated equipment or materials used in the response effort as TIW;
- The connection point for a filling pipe of a bulk storage tank shall be provided with measures to contain spillage;
- Ensure that all activities involving repair, servicing, engine overhaul works, etc are carried out on a concreted area which will be bunded or provided with scupper drains to channel all wastewater into the sewerage system;
- Carry out washout of cement or ready-mix lorries and equipment in concrete washout areas to protect against spills and leaks;
- In the event of an accidental release, leakage or spillage of oil or chemical, immediately notify the NEA and PUB;
- Prepare and keep up to date a Spill Prevention and Emergency Response Plan detailing how spillage, leakage or accidents involving hazardous materials will be dealt with and ensure that workers on site have received adequate training and instruction to enable them to implement the emergency action plan in the event of an emergency;
- Ensure that emergency spill response equipment are available at appropriate worksite locations to contain and/or absorb hazardous chemicals, fuel or oil in the event of a spillage;

- In the event of spillage or overflow of effluents into downstream surface waterbodies, the Spill Prevention and Emergency Response Plan will be triggered and as much of the contaminating material will be removed manually (in the case of viscous or solid material). Ensure spill control materials and protective equipment are readily accessible at the worksites and adequate training is provided to on site personnel on emergency response procedures to spill control and clean-up. Following the clean-up event, regular visual inspections and monitoring of the relevant chemical parameters will be undertaken for the affected water body until conditions return to normal; Groundwater, if any, should be discharged into the sewer with PUB's approval or disposed offsite;
- Trade effluent (not to be collected by ECM) should be discharged into the sewer or surface drainage systems, upon compliance with relevant discharge limits; and
- Any trade effluent treatment plant installed shall be designed with spillage containment facilities to channel any spillage back to the treatment plant.

Other Construction Embedded Controls for both Land-based and In-reservoir Works

Other embedded measures include:

- Refuelling of work boats should be conducted at specified locations equipped with spillage control equipment (e.g. floating booms) and clean up kits to ensure any spillage can be contained and clean up swiftly;
- Vessels are required to adhere to a speed limit in the reservoir. Speed limit of 5 knots will be implemented, particularly in shallow areas or close to the shore to minimise disturbance to the reservoir bed and erosion of the bank;
- Limited work boats/ barges are to be used in the reservoir. This in addition to the speed limit and low traffic on the reservoir would reduce the chances of accidental collision;
- Work boats/ rigs will be properly sized for the task involved and be equipped with suitable navigation safety features according to location and appropriate regulations and guidelines;
- Regular traffic routes should be established for routine works. Offset from shoreline as well as corridors between FPV islands allow safe navigation access, this will minimize the risk of getting into shallow water unintentionally and also minimizes the risk of collision or grounding;
- Work vessels should be well-maintained. Refuelling should be conducted at designated area equipped with spill containing equipment as well as clean up kit;
- Workers will be adequately trained to handle chemical/ hazardous wastes stored on site, and to implement emergency action plans to deal with spills and leaks of toxic waste; and
- Provision of emergency spill clean-up kits at locations where fuel and chemicals will be stored and used.

For the proposed temporary Staging/ Launching Area:

- Launching ramp would be installed at the waterfront of the proposed temporary Staging/ Launching Area. The ramp would isolate disturbance from the launching activities and protect the soil/ sediment underneath and at the shoreline from wake from frequent vessel activities;
- Silt fencing at or near the water edge to prevent on-shore sediments from washing into the reservoir;
- Straw wattles (or equivalent) on slopes for erosion and sediment control at the launching slope; and
- Geotextile and gravel in flat areas to prevent erosion and tracking of loose materials at the proposed temporary Staging/ Launching Area.

For firefighting:

- A Spill Prevention and Emergency Response Plan detailing how fires/ explosions will be managed will be prepared and agreed with SCDF, including response arrangements, and how spillage, leakage or accidents involving firefighting water and materials resulting from fire/ explosion management will be dealt with;
- All temporary electrical installations, equipment and tools should be checked and certified for use regularly by a full-time licensed electrical worker;
- The hoarding for the worksite will be composed of non-combustible material to deter the spread of fire beyond the worksite;
- Petroleum or flammable materials will be stored in compliance with requirements under the relevant storage license;
- All practical steps will be taken to prevent the occurrence of an accident through fire, explosion, leakage or ignition of any petroleum or flammable material or vapours;
- Workers onsite will be properly trained to operate vessels and machinery;
- Firefighting equipment and other emergency response equipment will be provided;
- Workers will be trained in the use of available firefighting and emergency response equipment;
- Considerations should be taken into account in design of FPV layout to reduce the potential for fire propagation between FPV islands;
- Design, installation and operation and maintenance of FPV system to be carried out to national and international standards and to manufacturers specifications;
- A Spill Prevention and Emergency Response Plan detailing how fires/ explosions will be managed will be prepared and agreed with SCDF, including response arrangements, and how spillage, leakage or accidents involving firefighting water and materials resulting from fire/ explosion management will be dealt with;
- The FPV arrays, including moorings and anchors, will not be placed over the top of any existing services, such as pipelines;
- Fire response time from SCDF will be an estimated 8 minutes from the time of call. The nearest fire station, Woodlands Fire Station, is located 8 minutes from the integrated Project Substation (and O&M Facility). Moreover, SCDF's quality service intent[4] states that response to fire emergencies will be within 8 minutes of the call 90% of the time. This allows fires to be quickly responded to and contained within the site; and
- Regular enforcement checks by SCDF will be conducted within industrial premises such as the integrated Project Substation (and O&M Facility) to ensure compliance with fire safety regulations[5].

For FPV floats:

- Floats to be made using a certified food-grade high-density polyethylene (HDPE) material that is recyclable, UV-resistant and corrosion-resistant.

For in-reservoir navigation/ works in general:

- Work boats/ barges will be properly sized for the task involved and be equipped with suitable navigation safety features according to location and appropriate regulations and guidelines;

[4] https://www.scdf.gov.sg/docs/default-source/scdf-library/scdf-service-quality-handbook95d2613e6ace4c13ac66f19bba3814ca.pdf

[5] SCDF (2021). Annual statistics for fire, emergency medical services and fire safety enforcement checks. Retrieved form https://www.scdf.gov.sg/docs/default-source/scdf-library/amb-fire-inspection-statistics/scdf-annual-statistics-2021.pdf

- Speed limit of 5 knots will be implemented, particularly in shallow areas or close to the shore to minimise disturbance to the reservoir bed and erosion of the bank;
- Regular traffic routes should be established for routine works. Offsets from shoreline as well as corridors between FPV islands allow safe navigation access, this will minimise the risk of getting into shallow water unintentionally and also minimises the risk of collision or grounding;
- Compliance with *Part IV Navigation Rules of the Public Utilities (Reservoirs, Catchment Areas and Waterway) Regulations 2006* and *the International Regulations for Preventing Collisions at Sea 1972* (COLREGs); and
- Work vessels should be well-maintained. Refuelling should be conducted at designated areas equipped with spill containing equipment as well as clean up kits.

For PUB reservoir operations:

- Establish and agreed Standard Operating Procedures (SOPs) for works activities during tidal gate operation (e.g. works stoppage prior to tidal gate opening) with PUB; and
- Existing aquatic vegetation management to continue, as appropriate.

For in-reservoir works:

- No dredging and excavation of reservoir sediment for anchoring approach or connector cable laying; and
- Connector cables should be laid on surface of the reservoir bed, not buried.

6.6.1.3 Impact Assessment and Mitigation Measures

A summary of the assessment of impacts to surface water quality and proposed mitigation measures during Project construction is provided in *Table 6-10*.

Table 6-10: Impact Assessment for Surface Water Quality (Construction Phase)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
C1	**Site runoff and wastewater from geotechnical/ site investigation on land (at the proposed temporary Staging/ Launching Area and the integrated Project Substation site)**	■ **Nature**: Degradation of surface water quality is considered **negative**. ■ **Type**: **Indirect** change in surface water quality is expected from site runoff and other wastewater from geotechnical/ site investigation on land. ■ **Duration**: Changes in surface water quality from site runoff and other wastewater from geotechnical/ site investigation on land are relatively **short-term** (12 to 16 weeks) for surface water quality. Such changes are temporary and surface water quality is expected to return to baseline after completion of the active works. ■ **Extent**: Impacts are **localised** within the work areas and the immediate surroundings. ■ **Scale**: Body of water and/ or drains within less than 100 m could be affected by increased suspended solids, oil and grease or other contaminants. ■ **Frequency**: Geotechnical/ site investigation on land will happen **daily/ intermittently** during the specified period of construction phase. Geotechnical/ site investigation at the proposed temporary Staging/ Launching Area and integrated Project Substation will likely be conducted based on typical in-situ methods such as the standard penetration test (SPT) per ASTM D1586, or the cone penetration test (CPT) per ASTM D3441. The approaches will comply with the relevant Singapore standards and will not result in notable deterioration of surface water quality from site runoff or discharge of wastewater. As an embedded control, an ECM Plan would be prepared to control potential risk of soil erosion from geotechnical/ site investigations on land. All discharge from the ECM system should be well within the statutory limits. Impact magnitude is expected to be ***Negligible*** for the receiving water of the Kranji Reservoir and Sungei Pang Sua, where impacts are expected to be well within existing baseline/ statutory limits, as geotechnical/ site investigation will only occur at small area(s) and be well controlled by embedded control measures.	Impact Magnitude: **Negligible** Receptor Sensitivity: **Low** (Sungei Pang Sua) **to High** (Kranji Reservoir/ tributaries/ PUB intakes) Impact Significance: **Negligible**	■ Detailed design and construction methodology of land-based geotechnical/ site investigation to optimise/ minimise extent and number of borehole locations, where feasible.	Impact Magnitude: **Negligible** Impact Significance: **Negligible**
C2	**Site runoff, wastewater, and sediment disturbance from preparation of the proposed temporary Staging/ Launching Area**	■ **Nature**: Degradation of surface water quality is considered **negative**. ■ **Type**: **Indirect** change in surface water quality is expected from site runoff and other wastewater from preparation of the proposed temporary Staging/ Launching Area including ramp into the Kranji Reservoir. ■ **Duration**: Changes in surface water quality from site runoff and other wastewater from preparation of the proposed temporary Staging/ Launching Area are relatively **short-term** (8 to 12 weeks) for surface water quality. Such changes are temporary and surface water quality is expected to return to baseline after completion of the active works. ■ **Extent**: Impacts are **localised** within the work area and the immediate surroundings. ■ **Scale**: Body of water and/ or drains within less than 100 m could be affected by increased suspended solids, oil and grease or other contaminants. ■ **Frequency**: Preparation of the proposed temporary Staging/ Launching Area will happen **daily/ intermittently** during the specified period of construction phase. The proposed temporary Staging/ Launching Area was previously an industrial yard (now vacated grassland). Minor grading and levelling works may be needed. Clearing of vegetation would be needed only along the 150 m shoreline section to allow installation of launching ramp and for works near the shoreline. As an embedded control, an ECM Plan will be prepared to control potential risk of soil erosion from works at the launching area. All discharge from the ECM system should be well within the statutory limits and thus the associated impact magnitude is considered <u>*Negligible*</u>. The launching ramp typically consists of wooden planks fixed on top of metal frame installed at the shoreline. Minor piling works may be required for the installation of metal frame and localised disturbance to the reservoir bed sediment underneath the ramp would be expected. Level of localised disturbance	Impact Magnitude: **Negligible to Small** Receptor Sensitivity: **Low** (Sungei Pang Sua) **to High** (Kranji Reservoir/ tributaries/ PUB intakes) Impact Significance: **Negligible to Moderate**	■ Detailed design and construction methodology of land-based site preparations (including launching ramp) to optimise/ minimise extent of sediment disturbance, where feasible.	Impact Magnitude: **Negligible** Impact Significance: **Negligible**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		from such installation works is expected to be within ambient levels and thus the associated impact magnitude is considered *Small*. Impact magnitude is expected to be ***Negligible*** to ***Small*** for the receiving water of the Kranji Reservoir and Sungei Pang Sua, where impacts are expected to be within existing baseline/ statutory limits, as the required work will be well controlled by embedded control measures and only minor sediment disturbance is expected from launching ramp installation.			
C3	**Site runoff and wastewater from land-based assembly of the FPV system**	■ **Nature**: Degradation of surface water quality is considered **negative**. ■ **Type**: The assembly process would be conducted on land and no wastewater will be generated from the assembly process. Water quality impacts from site runoff during this process would be **indirect**. Wastewater from workforce would also be **indirect**. ■ **Duration**: The work period for assembly of the FPV system is around 52 to 70 weeks, which is considered relatively **long-term** for surface water quality. Such changes are temporary and surface water quality is expected to return to baseline after completion of the active works. ■ **Extent**: Impacts are **localised** within the work area and the immediate surroundings. ■ **Scale**: Body of water and/ or drains within less than 100 m could be affected by increased suspended solids, oil and grease or other contaminants. ■ **Frequency**: The assembly of the FPV system will happen **daily** during the specified period of construction phase. Assembly of the FPV system typically follows the manufacturer's installation manual. It includes connecting the rows of floats to form a floating platform, mounting PV panels on the floating platform, connecting cables, inverters, connection lines, etc. No wastewater will be generated from the assembly process. Sufficient chemical toilets (or equivalent) will be provided on site in accordance with the EPHA to serve the assembly workers for the FPV and no direct discharge of sanitary sewage form the site (including to the Kranji Reservoir) would be allowed. All discharge from the site drainage should be well within the statutory limits. Impact magnitude is expected to be ***Negligible*** for the receiving water of Kranji Reservoir and Sungei Pang Sua, where impacts are expected to be well within existing baseline/ statutory limits, given the lack of discharge sources and embedded controls.	Impact Magnitude: **Negligible** Receptor Sensitivity: **Low** (Sungei Pang Sua) **to High** (Kranji Reservoir/ tributaries/ PUB intakes) Impact Significance: **Negligible**	No mitigation measures are required as embedded controls are considered to be adequate to manage impact significance to be **Negligible.**	N/A (To refer to Pre-Mitigation Impact Significance Column)
C4	**Sediment disturbance from geotechnical/ site investigation in reservoir**	■ **Nature**: Degradation of surface water quality is considered **negative**. ■ **Type**: In-reservoir geotechnical/ site investigation could result in disturbance to reservoir bed sediments, resulting in **direct** change in surface water quality. ■ **Duration**: Changes in surface water quality from disturbance to reservoir bed sediment from in-reservoir geotechnical/ site investigation are relatively **short-term** (12 to 16 weeks) for surface water quality. Such changes are temporary and elevated turbidity will subside relatively quickly and return to baseline after completion of the active works. Release of pore water will result in temporary elevation of ambient levels of nutrients and contaminants, which will be diluted in the surrounding water, the change is considered temporary. ■ **Extent**: Impacts are **localised** around the active site of geotechnical/ site investigation. Note that geotechnical/ site investigations will be conducted in phases across the reservoir. This means affected area would be localised at any one time. ■ **Scale**: Elevated levels of suspended solids as well as other changes in surface water quality would likely be limited to less than 100 m from the work front and return towards baseline beyond this (in view of its potential sediment disturbance being far less than the potential piling/ anchoring work, whose impact was estimated to return to baseline levels at a distance of around 100 m from sediment disturbance source, according to the evaluation in *Appendix E* of *Appendix 6.1*). ■ **Frequency**: Geotechnical/ site investigation will happen **daily/ intermittently** during the specified period of construction phase.	Impact Magnitude: **Small** Receptor Sensitivity: **High** (Kranji Reservoir/ tributaries/ PUB intakes) Impact Significance: **Moderate**	■ Detailed design and construction methodology (e.g. phasing) of reservoir-based geotechnical/ site investigation to optimise/ minimise extent and number of borehole locations and minimise sediment disturbance, where feasible. Monitoring and adaptive management measures (see *Section 4.7.1* for further details on adaptive management approaches) including: ■ Agree construction phase surface water quality threshold criteria with PUB prior to works commencement, including action and limit levels. ■ Establish construction phase surface water quality monitoring programme in agreement with PUB prior to works commencement, to inform the Developer/ Owner on any potential deterioration of surface water quality from the works. Online water quality systems, pre-agreed with PUB, should be deployed in the reservoir pre- and during construction (and throughout operation) prior to works being carried out in the reservoir. - Surface water quality monitoring parameters to include: Temperature (°C), pH, EC (µS/cm) (conductivity), Turbidity (NTU), Secchi Depth, Dissolved oxygen (DO), Metals and metalloids (including Aluminium, Arsenic, Copper, Iron, Lead, Manganese), Major ions (including chloride), grease and oil, PAR, Chlorophyll-a (fluorescence-based spectrophotometer) and nutrients (TP, TN, TOC, DOC, nitrate (as N), phosphate and ammonia (as N)), 2-MIB, Geosmin, Microcystin-LR, and Total Suspended Solids (TSS).	Impact Magnitude: **Negligible** Impact Significance: **Negligible**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		These geotechnical/ site investigations will be performed from over-water equipment or structures such as floating platforms or spud barges. The anchoring of these floating platforms or spud barges would likely involve concrete anchors sunk to the reservoir bed, which may result in temporary localised elevation of sediment. The methods for subsurface investigations vary based on the expected geology to be encountered but it is likely that over-water investigations will be performed using a shell and auger percussion rig with a winch, small diesel engine or generator, and tripod (similar to those used for Tengeh FPV construction). The retrieval of sediment samples will also result in temporary and localised elevation of sediment in the water column. Level of localised disturbance from such site investigation works is expected to be within ambient levels. Impact magnitude is expected to be ***Small*** for the receiving water of the Kranji Reservoir, where impacts are expected to be within existing baseline/ statutory limits, given the small scale of work, embedded controls, minor disturbance to sediment and relatively low tendency for release of sediment-bound contaminants as indicated in the baseline survey results.		- Pre-construction sediment quality monitoring parameters to include: nutrients, contaminants/ metals and hydrocarbons. ■ In case surface water quality monitoring results indicate notable change in surface water quality in reservoir as a result of project works, agree with PUB on adoption of further mitigation measures, such as silt curtains around the two reservoir water intakes and/ or geotechnical/ site investigation worksites, propose alternate construction methodologies, or to cease works temporarily.	
C5	**Sediment disturbance from deployment of anchors/ ballasted foundations/ piles and mooring lines**	■ **Nature**: Degradation of surface water quality is considered **negative**. ■ **Type**: Deployment of anchors/ ballasted foundations/ piles and mooring lines will disturb reservoir bed sediment, resulting in elevated turbidity. Compression of reservoir bed sediment could squeeze out pore water, which contains nutrients and contaminants. Both of these are considered **direct** impacts. Indirect impacts may occur to the Johor Straits when tidal gates are opened. ■ **Duration**: Depending on the final design of anchoring to be adopted, the installation of piles/ anchors/ ballasted foundations could take up to 52 to 70 weeks, which is considered relatively **long-term** for surface water quality. Such changes are temporary and elevated turbidity will subside relatively quickly and return to baseline after completion of the active works. Release of pore water will result in temporary elevation of ambient levels of nutrients and contaminants, which will be diluted in the surrounding water, thus the change is considered temporary. ■ **Extent**: Impacts are **localised** around the active site(s) of deployment. Note that deployment of anchors/ ballasted foundation, piles and mooring lines will be conducted in phases across the reservoir. This means affected area would be localised at any one time. Sediment plume from construction works around the tidal gate when it is opened could spread into the Johor Straits and has wider extent of impact. ■ **Scale**: Elevated levels of suspended solids as well as other changes in surface water quality would likely be limited to less than 100 m from the work front and return towards baseline beyond this (see the evaluation in *Appendix E* of *Appendix 6.1*). ■ **Frequency**: Deployment of anchors/ ballasted foundations/ piles and mooring lines will happen **daily/ intermittently** during the specified period of construction phase. It is anticipated that no dredging and excavation of reservoir sediment will be required for anchoring. The deployment of anchors/ ballasted foundations/ piles for FPV and PCUs and the O&M berthing facility is expected to result in temporary and localised disturbance of reservoir bed sediment. The disturbance to sediment could result in release of pore water and sediment-bound contaminants. Further details on the anchoring and mooring options under consideration are provided in *Appendix 2.1*, including work rates and workstation assumptions. Detailed analysis on the potential change in surface water quality associated with the piling/ anchoring is provided under *Appendix E* of the Water Quality Modelling Technical Appendix (*Appendix 6.1*). The potential conservative scenario in term of disturbance to reservoir bed sediment and associated change in surface water quality was identified between the anchoring options and the potential level of change in surface water quality was estimated. The main conservative assumptions adopted in *Appendix E* of *Appendix 6.1* include (1) conservative estimation (i.e. overestimation) of pile diameter (actual: up to 600 mm; assessed: up to 900 mm) and anchor block dimension (actual: 1 m × 2 m; assessed: 2 m × 2 m) as	Impact Magnitude: **Medium** Receptor Sensitivity: **Medium** (Johor Strait) **to High** (Kranji Reservoir/ tributaries/ PUB intakes) Impact Significance: **Major**	■ Detailed design and construction methodology of reservoir-based piles/ anchors/ ballasted foundations to optimise/ minimise extent and number and minimise sediment disturbance, where feasible. ■ Conduct lowering of anchors/ piles/ weights in controlled manner to reservoir bed to minimise sediment disturbance and the use of divers to assist with the underwater works (if necessary). Monitoring and adaptive management measures including: ■ Agree construction phase surface water quality threshold criteria with PUB prior to works commencement, including action and limit levels. ■ Establish construction phase surface water quality monitoring programme in agreement with PUB prior to works commencement, to inform the Developer/ Owner on any potential deterioration of surface water quality from the works (see item C4 above). Online water quality systems, pre-agreed with PUB, should be deployed in the reservoir pre-construction prior to works being carried out in the reservoir. ■ At the beginning of anchoring operations, work fronts should preferably be chosen at locations sufficiently far away from the water intakes to minimise potential impact from sediment disturbance. Surface water quality monitoring should be regularly reviewed (e.g. when work front moves) to inform work rate adjustments, for example, according to the distance of the work fronts to the water intakes for treatment plant (such as, where work front is closer to water intake, monitoring may indicate the Developer/ Owner should consider a reduced work rate). Work rate should start low and be allowed to ramp up for successive days showing no notable deterioration of surface water quality contributed by project works. ■ Any notable deterioration of surface water quality observed should be investigated. Investigation should determine whether or not the observed deterioration can be attributed to the construction work. If affirmative, work procedures should be reviewed and further mitigation identified, e.g. work rate could be reduced or silt curtains used. The Developer/ Owner should liaise with PUB closely on active work front locations, agreed work rates, monitoring results and frequency, and investigation findings and seek agreement on management action(s) to be conducted. Where observations are not attributable to the Project, the Developer/ Owner will liaise with relevant Government Agencies responsible for managing the identified effect for their action. ■ In case surface water quality monitoring results indicate notable change in surface water quality in reservoir as a result of project works, agree with PUB on adoption of further mitigation measures, such as silt curtains around the two reservoir water intakes and/ or piling/ anchoring	Impact Magnitude: **Small** Impact Significance: **Moderate**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		well as conservative selection of sediment source for assessment (solid pile assessed, which results in more sediment loss than cylindrical pile or anchor block options). It is estimated that the elevation of suspended solids would likely be at the level of 5.3 mg/L at 100 m from the active works area and would be even lower at further distances. For release of sediment-bound nitrogen and phosphorus, it is estimated that the released total nitrogen and total phosphorus from the piling works would be below 0.25% and 0.03% of the catchment load respectively. Similar analysis conducted for sediment-bound contaminants including arsenic, cadmium and lead also indicated the potential release of these contaminants would be negligible (*Table E-8* of *Appendix E* of *Appendix 6.1* refers) and is not considered to be a major cause of concern in terms of surface water quality. Impact magnitude on the Kranji Reservoir is expected to be *Medium*. Release of suspended sediments, nutrients and contaminants to the Johor Straits may occur during tidal gate opening. Given the tidal gate is only opened during rain events in the catchment area (i.e. upstream of the reservoir) or to manage reservoir water levels (i.e. when there is notable inflows), impacts (if any) will only be limited to such time periods. It should be highlighted that with the combined effect of limited extent of impact within the reservoirs, embedded controls, as well as sedimentation/ dilution/ assimilation within the reservoir itself, any change in surface water quality as a result of works under this Project would be limited to the immediate proximity from the tidal gate. Also, since Standard Operating Procedures will be agreed and applied (e.g. works stoppage prior to tidal gate opening); sufficient mixing and dilution will have occurred with sediments, nutrients and contaminants being relatively small compared to the existing baseline of the reservoir outflows from the tidal gate. Impact magnitude on the Johor Straits is expected to be *Negligible*. Given the distance from the Project to the international boundary (over 1.1km from the tidal gate), it is considered that no cross-border impacts are anticipated from this Project. The installation of mooring lines is not expected to result in notable disturbance to reservoir bed sediment or other changes in surface water quality. Overall, conservatively, impact magnitude is expected to be ***Medium*** for the receiving water of the Kranji Reservoir, where impacts are expected to occasionally exceed existing baseline/ statutory limits over short timeframes at the works areas with embedded controls.		worksites, propose alternate construction methodologies, or to cease works temporarily.	
C6	**Sediment disturbance from launching, towing and installation of FPV and ancillary equipment at designed locations**	■ **Nature**: Degradation of surface water quality is considered **negative**. ■ **Type**: Installation of FPV and ancillary equipment involves launching of assembled equipment from the proposed temporary Staging/ Launching Area, towing them to designated locations and then securing them in place. These works may disturb reservoir bed sediment **directly or indirectly**. ■ **Duration**: Launching of FPV from the proposed Staging/ Launching Area into the reservoir and towing FPV into designated locations, connecting FPV to piles/ anchors/ ballasted foundations via mooring lines, and installation of water-based ancillary equipment (e.g. PCUs/ inverters) etc., could take 52 to 70 weeks, which is considered to be relatively **long-term** for surface water quality. Such changes are temporary and elevated turbidity will subside relatively quickly and return to baseline after completion of the active works. ■ **Extent**: Impacts are **localised** around the active site of the launching area and mooring locations as well as the active travel routes for work boats. ■ **Scale**: Elevated levels of suspended solids as well as other changes in surface water quality would likely be limited to less than 100 m from the work front and return towards baseline beyond this (in view of its potential sediment disturbance being far less than the potential piling/ anchoring work, whose impact was estimated to return to baseline levels at a distance of around 100 m from sediment disturbance source, according to the evaluation in *Appendix E* of *Appendix 6.1*). ■ **Frequency**: Installation will happen **daily/ intermittently** during the specified period of construction phase.	Impact Magnitude: **Negligible to Small** Receptor Sensitivity: **High** (Kranji Reservoir/ tributaries/ PUB intakes) Impact Significance: **Negligible to Moderate**	■ Detailed design and construction methodology of launching/ towing and installation of FPVs and ancillary equipment to minimise sediment disturbance, where feasible. ■ Design of vessel operation procedures to account for the relatively shallow water off the launching ramp and shorelines to avoid the work boats/ barges from getting into the shallow depths and running their engines at full throttle. Account for heavy loads activity procedures/ navigation routes. Ensure boat operators are familiar with water depths across the reservoir. ■ Vessels required for transportation of crew and/ or materials/ equipment should account for the additional load when considering navigation routes to ensure sufficient reservoir bed clearance. Monitoring and adaptive management measures including: ■ Agree construction phase surface water quality threshold criteria with PUB prior to works commencement, including action and limit levels. ■ Establish construction phase surface water quality monitoring programme in agreement with PUB prior to works commencement, to inform the Developer/ Owner on any potential deterioration of surface water quality from the works (see item C4 above). ■ In case surface water quality monitoring results indicate notable change in surface water quality in reservoir as a result of project works, agree with PUB on adoption of further mitigation measures, such as silt curtains around the two reservoir water intakes, propose alternate construction methodologies, or to cease works temporarily.	Impact Magnitude: **Negligible** Impact Significance: **Negligible**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		The launching of assembled FPV and ancillary equipment from launching ramp or via land-based crane lifting will not result in notable disturbance to reservoir bed sediment. However, work boats moving within shallow areas or close to banks at high speed, or heavily laden barges, could disturb reservoir bed sediment or erode soil from the banks. Disturbed sediment and eroded soil would result in localised increases in turbidity. Such increased turbidity will settle relatively quickly after the disturbance subsides and any potential release of sediment-bound contaminants would be limited. The more exposed reservoir bank at the proposed temporary Staging/ Launching Area would be covered by the installed launching ramp, and thus be shielded from wake from work boats, thus limiting the potential erosion. The resulting elevation in surface water quality is likely to be within ambient levels and thus considered to be of *Small* impact magnitude. After launching, the FPV and ancillary equipment will be towed and the equipment will be secured at designed locations by connecting the mooring lines between the floating elements with the installed piles/ anchors/ ballasted foundations. Any potential disturbed sediment is expected to be minimal and will settle relatively quickly around the work area. The resulting elevation in surface water quality is likely to be well within ambient levels and thus considered to be of *Negligible* impact magnitude. Overall, impact magnitude is expected to be ***Negligible*** to ***Small*** for the receiving water of the Kranji Reservoir, where impacts are expected to be within existing baseline/ statutory limits, considering the minimal disturbance to reservoir bed sediment and banks with embedded controls.			
C7	**Sediment disturbance from installation of connector cables (between FPV islands and to shore)**	■ **Nature**: Degradation of surface water quality is considered **negative**. ■ **Type**: Laying of cable on reservoir bed could result in disturbance of reservoir bed sediment, resulting in a **direct** change in surface water quality. ■ **Duration**: Installation of connector cables could take 24 to 32 weeks, which is considered to be relatively **short-term** for surface water quality. Such changes are temporary and elevated turbidity will subside relatively quickly and return to baseline after completion of the active works. Release of pore water will result in temporary elevation of ambient levels of nutrients and contaminants, which will be diluted and disperse in the surrounding water, the change is considered temporary. ■ **Extent**: Impacts are expected to be **localised** along the connector cables between FPV islands and the landing location at the shore at the proposed temporary Staging/ Launching Area and integrated Project Substation site. ■ **Scale**: Elevated levels of suspended solids as well as other changes in surface water quality would likely be limited to less than 100 m from the work front and return towards baseline beyond this (in view of its potential sediment disturbance being far less than the potential piling/ anchoring work, whose impact was estimated to return to baseline levels at a distance of around 100 m from sediment disturbance source, according to the evaluation in *Appendix E* of *Appendix 6.1*). ■ **Frequency**: Connector cable installation will happen **daily/ intermittently** during the specified period of construction phase. Connector cables laid on the surface of the reservoir bed would result in minor sediment disturbance. The corresponding elevation of suspended solids is expected to be within ambient level. Impact magnitude is expected to be ***Small***, where impacts are expected to be within existing baseline/ statutory limits, given the small scale of work and minor disturbance to sediment with embedded controls.	Impact Magnitude: **Small** Receptor Sensitivity: **High** (Kranji Reservoir/ tributaries/ PUB intakes) Impact Significance: **Moderate**	■ Detailed design and construction methodology of reservoir-based connector cables to optimise/ minimise length and minimise sediment disturbance, where feasible. ■ Conduct lowering of cables in controlled manner to reservoir bed to minimise sediment disturbance and the use of divers to assist with the underwater works (if necessary). Monitoring and adaptive management measures including: ■ Agree construction phase surface water quality threshold criteria with PUB prior to works commencement, including action and limit levels. ■ Establish construction phase surface water quality monitoring programme in agreement with PUB prior to works commencement, to inform the Developer/ Owner on any potential deterioration of surface water quality from the works (see item C4 above). ■ In case surface water quality monitoring results indicate notable change in surface water quality in reservoir as a result of project works, agree with PUB on adoption of further mitigation measures, such as silt curtains around the two reservoir water intakes, propose alternate construction methodologies, or to cease works temporarily.	Impact Magnitude: **Negligible** Impact Significance: **Negligible**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
C8	**Degradation/ change of surface water quality from trimming of aquatic vegetation**	■ **Nature**: Degradation of surface water quality is considered **negative**. ■ **Type**: Trimming of aquatic vegetationin the top 1m of the water column[6], will not result in significant disturbance to reservoir bed sediment. For the trimming of aquatic vegetation, conservatively, if the cut waste vegetation is not collected and allowed to decompose in the water column, this will result in **indirect** changes in surface water quality. ■ **Duration**: Trimming of aquatic vegetation would be carried out in phases before works activities in different areas of the reservoir commence (due to rapid regeneration of the aquatic vegetation) throughout the in-reservoir construction period (approximately 104 weeks), which is considered to be relatively **long-term** for surface water quality. If any trimmings of aquatic vegetation are left in-reservoir they would likely settle into the sediment and decay slowly. The effect of decomposition of these cut vegetation would diminish over time but could linger beyond the construction period. A detailed literature review on rate of decomposition of aquatic plant material is provided in *Appendix D* of *Appendix 6.1*. On average, about 40%, 20% and 16% of total phosphorus, total nitrogen and total carbon could be released in the first 30 days respectively. For the effect of reduced photosynthesis from reduced vegetation resulting from trimming and FPV shading, the effect on dissolved oxygen (DO) levels as well as the change in pH buffering capacity will be permanent throughout the Project operational phase (see also *Table 6-13*). ■ **Extent**: Conservatively, vegetation trimming works could cover the entirety of the Reservoir Project Site within the Kranji Reservoir, to be carried out in phases. Impacts would be **localised** within the work areas of the current work phase and the immediate surroundings judging by the lack of notable change in surface water quality from existing ongoing regular (daily) aquatic vegetation removal works by PUB. ■ **Scale**: Conservatively, the effect of the release of nutrients and depletion of dissolved oxygen associated with the decomposition of trimmed vegetation left in-reservoir would likely be limited to less than 100 m from the work front given the small vegetation amounts and the lack of notable change in surface water quality from existing regular aquatic vegetation removal works. ■ **Frequency**: Trimming of aquatic vegetation will happen **intermittently** during the specified period of construction phase. Detailed estimation on the nutrient content in the aquatic vegetation in the Kranji Reservoir is provided in *Appendix D* of *Appendix 6.1*. It is estimated that in the very unlikely conservative scenario of having all the aquatic vegetation within the Reservoir Project Site (i.e. all vegetation in the water column) cut off at the same time (unlikely), and start decomposing and releasing nutrients immediately (unlikely), the addition of total phosphorus, total nitrogen and total carbon in the 1st month will be approximately 11%, 9%, and 5% of the existing fluxes into the reservoir (catchment loadings, mineralisation, and atmospheric deposition). A realistic (yet still highly conservative) scenario is assessed here, of the aquatic vegetation in the top 1m of the water column being trimmed all at once (unlikely) and starting to decompose and releasing nutrients immediately (unlikely). In this case, the addition of total phosphorus, total nitrogen and total carbon in the 1st month will be approximately 3%, 3%, and 2% of the existing fluxes into the reservoir (catchment loadings, mineralisation, and atmospheric deposition) respectively. Note: that the assessed scenario is very conservative to account for uncertainties on vegetation decomposition rates, vegetation volumes etc, and thus is expected to over-estimate the potential flux. Given the actual trimming works is expected to be conducted in phases and be localised over a period of time, the potential flux would therefore be even lower. As the associated change in surface water quality is expected to be small and be within ambient levels, the impact magnitude is considered to be ***Small***.	Impact Magnitude: **Small to Medium** Receptor Sensitivity: **High** (Kranji Reservoir/ tributaries/ PUB intakes) Impact Significance: **Moderate to Major**	■ Detailed design and construction methodology of reservoir-based works to manage aquatic vegetation management/ trimming, as appropriate in consultation with PUB. ■ Detailed design and construction methodology and schedule to review the analysis conducted under *Appendix D* and *E* of *Appendix 6.1* to update estimation of potential surface water quality impact. Should changes (if any) be considered to be greater, or more impactful, than those assumed in this assessment, the impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein. ■ Establish an Aquatic Vegetation/ Invasive Species Management Plan (includes removal of aquatic vegetation). This plan should be prepared and submitted to PUB for agreement prior to commencement of the removal works for construction. ■ All aquatic vegetation trimmings, where required, to be collected and removed from the water column immediately for disposal offsite by a licenced contractor, thus further limiting surface water quality impacts from decomposition (far below the conservative estimation provided in *Appendix D* of *Appendix 6.1*). Monitoring and adaptive management measures including: ■ Agree construction phase surface water quality threshold criteria with PUB prior to works commencement, including action and limit levels. ■ Establish construction phase surface water quality monitoring programme in agreement with PUB prior to works commencement, to inform the Developer/ Owner on any potential deterioration of surface water quality from the works (see item C4 above). ■ Any notable deterioration of surface water quality observed should be investigated. Investigation should determine whether or not the observed deterioration can be attributed to the construction work. If affirmative, work procedures should be reviewed and further mitigation identified or to cease works temporarily. The Developer/ Owner should liaise with PUB closely on aquatic vegetation management/ trimming, monitoring results and investigation findings and seek agreement on management action(s) to be conducted. Where observations are not attributable to the Project, the Developer/ Owner will liaise with relevant Government Agencies responsible for managing the identified effect for their action.	Impact Magnitude: **Negligible to Small** Impact Significance: **Negligible to Moderate**

[6] Trimming of aquatic vegetation in the top 1m of the water column was determined to be sufficient for construction activities related to deployment of the in-reservoir Project components (e.g. vessel movements). This trimming depth has been determined to be achievable based on discussion with PUB and inputs from PUB's existing aquatic vegetation management contractors.

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		Aquatic plants regulate the pH in the water column by taking up pH affecting constituents such as dissolved carbon dioxide, ammonia as well as cations (such as calcium). The trimming of aquatic vegetation would reduce photosynthesis and stop the uptake of carbon dioxide, nutrients and ions, which would result in a reduction of DO levels and change the pH buffering capacity. Since, conservatively, the aquatic vegetation will not be allowed to re-establish after clearance, the potential change identified would remain through the period of project construction and operation. In view of the lasting change in surface water quality, the impact is considered of *Medium* magnitude. It should be noted that while existing ongoing removal of aquatic vegetation is regularly conducted (daily) in Kranji Reservoir by PUB without notable adverse surface water quality impacts being recorded, the Project would remove a larger area of aquatic vegetation over a shorter time period. Overall, impact magnitude is expected to be ***Small*** to ***Medium*** for the receiving water of the Kranji Reservoir, where conservatively impacts are expected to be potential lasting change which is not expected to exceed existing baseline/ statutory limits with embedded controls.			
C9	**Site runoff and wastewater from construction of integrated Project Substation and land-based connector cable in the proposed temporary Staging/ Launching Area (adjacent to reservoir)**	■ **Nature**: Degradation of surface water quality is considered **negative**. ■ **Type**: **Indirect** change in surface water quality is expected from site runoff and other wastewater from installation of the integrated Project Substation. ■ **Duration**: Changes in surface water quality from site runoff and other wastewater from installation of the integrated Project Substation are relatively **long-term** (44 to 64 weeks) for surface water quality. Such changes are temporary and surface water quality is expected to return to baseline after completion of the active works. ■ **Extent**: Impacts are **localised** within the work area and the immediate surroundings. ■ **Scale**: Body of water and/ or drains within less than 100 m could be affected by increased suspended solids, oil and grease or other contaminants. ■ **Frequency**: Construction of integrated Project Substation will happen **daily** during the specified period of construction phase. Construction of the integrated Project Substation involves foundation works, excavation works for basement, installation of underground conduits/ trenches for utilities, installation of steel structures, major electrical equipment, prefabricated building structures, ancillary buildings and O&M systems, as well as pulling and termination of cables. Note that the connector cables from the FPVs would be landing at the shoreline of the same site and thus require a short section of cable burial from the shore to the integrated Project Substation. Potential surface water quality issues include site runoff as well as control of wastewater from the construction. As an embedded control, an ECM Plan would be prepared to control potential risk of soil erosion from works for the integrated Project Substation and land-based connector cable. All discharge from the ECM system should be well within the statutory limits. Impact magnitude is expected to be ***Negligible*** for the receiving water of the Kranji Reservoir and Sungei Pang Sua, where impacts are expected to be well within existing baseline/ statutory limits, given construction of the integrated Project Substation and cable connection will be well controlled by embedded measures.	Impact Magnitude: **Negligible** Receptor Sensitivity: **Low** (Sungei Pang Sua) **to High** (Kranji Reservoir/ tributaries/ PUB intakes) Impact Significance: **Negligible**	■ Detailed design and construction methodology of land-based buildings/ equipment to minimise runoff and wastewater, where feasible.	Impact Magnitude: **Negligible** Impact Significance: **Negligible**
C10	**Sediment disturbance from construction of O&M berthing facility** (location subject to approval from agencies)	■ **Nature**: Degradation of surface water quality is considered **negative**. ■ **Type**: In-reservoir construction of O&M berthing facility could result in **direct** changes of surface water quality. ■ **Duration**: Changes in surface water quality from disturbance to reservoir bed sediment from in-reservoir installation of O&M berthing facility are relatively **short-term** (4 to 6 weeks) for surface water quality. Such changes are temporary and elevated turbidity will subside relatively quickly and return to baseline after completion of the active works. Release of pore water will result in temporary elevation	Impact Magnitude: **Small** Receptor Sensitivity: **High** (Kranji Reservoir/ tributaries/ PUB intakes)	■ Detailed design and construction methodology of reservoir-based O&M berthing facility to minimise sediment disturbance, where feasible. Monitoring and adaptive management measures including: ■ Agree construction phase surface water quality threshold criteria with PUB prior to works commencement, including action and limit levels. ■ Establish construction phase surface water quality monitoring programme in agreement with PUB prior to works commencement, to	Impact Magnitude: **Negligible** Impact Significance: **Negligible**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		of ambient levels of nutrients and contaminants, which will be diluted in the surrounding water, the change is considered temporary. ■ **Extent**: Impacts are **localised** within the work area and the immediate surroundings. ■ **Scale**: Elevated levels of suspended solids as well as other changes in surface water quality would likely be limited to less than 100 m from the work front and return towards baseline beyond this (in view of its potential sediment disturbance being far less than the potential piling/ anchoring work, whose impact was estimated to return to baseline levels at a distance of around 100 m from sediment disturbance source, according to the evaluation in *Appendix E* of *Appendix 6.1*). ■ **Frequency**: Installation of O&M berthing facility will happen **daily/ intermittently** during the specified period of construction phase Installation of O&M work boat berthing facility will involve piling (<10 no.) near the shoreline. The level of impact to reservoir bed sediment is expected to be similar or less than that of the initial works at the proposed temporary Staging/ Launching Area for ramp installation (see item C2 above). Level of localised disturbance from such installation works is expected to be within ambient levels. Impact magnitude is expected to be ***Small*** for the receiving water of the Kranji Reservoir, where impacts are expected to be within existing baseline/ statutory limits, given only minor sediment disturbance is expected from O&M berthing facility installation with embedded controls.	Impact Significance: **Moderate**	inform the Developer/ Owner on any potential deterioration of surface water quality from the works (see item C4 above). ■ In case surface water quality monitoring results indicate notable change in surface water quality in reservoir as a result of project works, agree with PUB on adoption of further mitigation measures, such as silt curtain around the two reservoir water intakes and/ or piling/ anchoring worksites, propose alternate construction methodologies, or to cease works temporarily.	
U1	**Degradation/ change of surface water quality from unplanned events of fire and explosion**	■ **Nature**: Degradation of surface water quality is considered **negative**. ■ **Type**: In case of fire and explosion, combustible materials/ fuels/ debris/ firefighting water or chemical(s) may enter bodies of water **directly** (if fire/ explosion occurs on work boat(s)) or **indirectly** (if fire/ explosion occurs at FPV or on land and then contaminating materials are washed into surrounding waters). This assessment item covers the effect of fire and explosion, as well as the effect of firefighting water/ reagent. If spillage of other hazardous materials (fuel leakage) is involved, its impact is assessed under item U2 below. ■ **Duration**: Impacts are **short-term** and temporary, and surface water quality is expected to return to baseline after the event. ■ **Extent**: Impacts are **localised** at area around the fire/explosion, with potential to spread across reservoir if uncontrolled. ■ **Scale**: Scale of impact depends on location and nature of fire and explosion. Effect of land-based fire and explosion would likely be limited to the immediate vicinity. Effect of fire and explosion in the reservoir could affect waters within a few hundred meters. ■ **Frequency**: **Infrequent**, due to the unlikely event of fire and explosion with embedded controls. ■ **Likelihood**: **Unlikely**. Spacing between islands of FPV, setbacks from reservoir edges etc, will control/ slow down the spread of fire and the associated impact, and enable firefighting access. Design and construction of the FPV and integrated Project Substation will align with the Fire Safety Act and the SCDF's requirements as well as relevant Singapore and international standards (*Appendix 2.2, Embedded Controls*). A Spill Prevention and Emergency Response Plan detailing how fires/ explosions will be managed will be prepared and agreed with SCDF, including how spillage, leakage or accidents involving firefighting water and materials resulting from fire/ explosion management will be dealt with (see U2 below). Workers on site will be properly trained to operate vessels and machinery. The implementation of Emergency Response Plan would allow minimising the surface water quality impacts from any fire or explosion incident. Impact magnitude is expected to be ***Negligible*** for the receiving water of the Kranji Reservoir and Sungei Pang Sua from land-based events, and ***Small*** for the receiving water of the Kranji Reservoir for reservoir-	Impact Magnitude: **Negligible to Small** Receptor Sensitivity: **Low** (Sungei Pang Sua) **to High** (Kranji Reservoir/ tributaries/ PUB intakes) Pre-Likelihood Significance: **Negligible** (land-based) **to Moderate** (in-reservoir)	<u>Likelihood Evaluation</u> Given the low vessel traffic and generally low travel speed, fire and explosion of work boats as a result of collision is unlikely. Other land-based machinery and vehicles should be well-maintained and should not have any elevated risk of fire and explosion. <u>Mitigation</u> The following measures would also be implemented to further mitigate the consequence of the unplanned event of fire and explosion: ■ Contractor to conduct thorough quality checks and inspections of materials prior to installation to ensure there are no manufacturing defects. ■ Proper material handling practices and inspections of installed materials should be done to ensure there are no defects during construction. ■ Developer/ Owner to conduct a review of past FPV design failure modes and incorporate main findings into the newer designs. ■ Where possible, drains/ body of water where fire and explosion occurs should be cut off from the Kranji Reservoir. Firefighting water will be contained within the ECM system and holding pond, where appropriate. Such water will be collected and be disposed by a licensed waste collector as soon as possible to ensure normal ECM/ holding pond operation can continue. ■ Only non-toxic firefighting reagent (if needed) will be used for firefighting. This will minimise human health and ecological risk in case using of such reagent is needed and such reagent ends up in reservoir water. Developer/ Owner to agree with PUB on the proposed firefighting reagent to be used on site prior to usage. ■ Train workers in implementation of Spill Prevention and Emergency Response Plan. ■ Joint exercises/ drills for spillage and fire will be conducted by the Developer/ Owner with SCDF each year to ensure preparedness on spillage containment and clean up, as well as fire preventing and fighting among workers. ■ In case of a fire and explosion in reservoir, a perimeter floating boom should be set up (where possible and safe) to allow containment of any floating debris from the event.	Pre-Likelihood Significance: **Negligible** (land-based) **to Moderate** (in-reservoir) Likelihood of Occurrence: **Unlikely** Post-Likelihood Impact Significance: **Negligible** (land-based) **to Minor** (in-reservoir)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		based events, where impacts are expected to be within existing baseline/ statutory limits, given the short-term nature and embedded controls.		Monitoring and adaptive management measures including: ■ Establish construction phase surface water quality/ sediment quality monitoring programme in agreement with PUB prior to works commencement, to inform the Developer/ Owner on any potential deterioration of surface water quality from unplanned events. In addition to those parameters in C4 above: - Sediment quality monitoring parameters to include: Nutrients, contaminants/ metals and hydrocarbons.	
U2	**Degradation/ change of surface water quality from unplanned event of failure of erosion control measures (ECM)/ environmental spill**	■ **Nature**: Degradation of surface water quality is considered **negative**. ■ **Type**: Spillage can affect surface water quality of the receiving bodies of water **directly**, e.g. if spillage occurs during works within reservoir, such as fuel spillage from work boat. ECM failure/ spillage can **indirectly** affect surface water quality, e.g. ECM failure/ spillage on land may be washed into reservoir, or via groundwater. ■ **Duration**: Impacts are **short-term** and temporary, and surface water quality is expected to return to baseline after the event. ■ **Extent**: Spillage within the reservoir could **spread across the reservoir** if uncontrolled. ■ **Scale**: Scale of impact depends on location and nature of ECM failure/ environmental spill. Effect of land-based spill would likely be limited to the immediate vicinity. An ECM failure would likely be limited to the land-based Project Site and immediately adjacent launching area of the reservoir. An in-reservoir fuel spill/ leak at designated refuelling location would be limited within the containment (e.g. floating booms). A spillage in the middle of the reservoir could affect waters up to a few hundred meters. ■ **Frequency**: **Infrequent**, due to the unlikely event of ECM failure/ environmental spillage with embedded controls. ■ **Likelihood**: **Unlikely**. Sizing of the ECM will be for 1 in 5 years rainfall. Given outfall(s) for ECM would be located within the catchment of Sungei Pang Sua, a failure of ECM (e.g. failure of outlet discharge pump resulting in overflow of sedimentation basin or rupture due to accident or leakage or wear and tear of ECM discharge pipeline) would likely affect the Sungei Pang Sua instead of Kranji Reservoir, which has lower receptor sensitivity and does not serve as drinking water supply. Storage and use of chemicals and fuels are subjected to stringent control as stated under *Section 6.6.1.2,* therefore the risk for spillage on land is very low and is likely to be highly localised after taking into account the embedded control measures. For spillages in-reservoir, given the provision of spill clean-up kits at locations where fuel and chemicals would be stored or used, any spill is unlikely to spread beyond the initial location. In case of spill, for example, from vessel collision that is away from the berthing/ refuelling area and immediate containment is not possible, the typical amount of fuel spilled is expected to be limited because of the limited size of fuel tank (due to small vessel sizes) as well as the low possibility of fuel tank being completely compromised from collision at low navigation speed (<5 knots). Also, evaporation is the dominant process contributing to the removal of spilled diesel from the water surface and can account for 60-80% loss if no spill response is mounted. As oil weathers (i.e. through evaporation of its lightest and most toxic fractions), its inherent toxicity also reduces. Overall, with the implementation of the Spill Prevention and Emergency Response Plan, small spill volumes as well as the tendency to evaporate means the overall impact would be limited and temporary. A Spill Prevention and Emergency Response Plan detailing how spillage, leakage or accidents involving hazardous materials will be dealt with will be prepared. The implementation of Spill Prevention and	Impact Magnitude: **Negligible to Small** Receptor Sensitivity: **Low** (Sungei Pang Sua) **to High** (Kranji Reservoir/ tributaries/ PUB intakes) Pre-Likelihood Significance: **Negligible** (land-based) **to Moderate** (in-reservoir)	<u>Likelihood Evaluation</u> With the implementation of embedded control measures related to ECM management, accidental spillage/ leakage, notable change in surface water quality as a result of land-based spillage is unlikely. For spillage within the reservoir, one plausible scenario of spill is a result of accidental collision. A vessel to vessel collision is unlikely given limited traffic within the reservoir. Vessel to shore collision, vessel to FPV collision and vessel grounding are also unlikely given the use of navigation aids (embedded control measures) as well as the very low occurrence of severe weather conditions which hinder navigation (such as typhoons). Also, given only vessels of small size would and could be used in the reservoir and the slow speed these vessels will travel, the scale of potential spillage will be limited as well. <u>Mitigation</u> The following measures would also be implemented to further mitigate the consequence of the unplanned event of environmental spill: ■ Preparation and implementation of vessel standard operating procedures. ■ Chemicals and/ or hydrocarbons will be handled and stored in compliance with the Material Safety Data Sheet (MSDS). ■ All chemical and/ or hydrocarbon wastes will be segregated into clearly marked containers prior to onshore disposal by a licensed waste management contractor, as per the relevant MSDSs. Secondary containment should also be provided for these chemicals. ■ Daily inspection of boat and machinery to avoid fuel leakage. ■ Practise due diligence in proper storage and handling of machinery to prevent leaching of oil or harmful materials. ■ Regular maintenance of vehicles and equipment, proper training to operators to avoid fuel leakage or spillage into reservoir. ■ Where possible, drains/ body of water where fire and explosion occurs should be cut off from the Kranji Reservoir. Firefighting water will be contained within the ECM system and holding pond, where appropriate. Such water will be collected and be disposed by a licensed waste collector as soon as possible to ensure normal ECM/ holding pond operation can continue. ■ Work boats will be refuelled at specified locations following standard procedures. Refuelling location(s) should be equipped with spill control kits and measures, e.g. floating booms at the perimeter, clean up kits ready to use, etc. This means any spillage from refuelling would be contained and cleaned up properly. ■ Provision of navigation aides and establishment of regular traffic routes would further reduce the risk of collision. ■ Train workers in implementation of the Spill Prevention and Emergency Response Plan. ■ Joint exercises/ drills for spillage and fire will be conducted by the Developer/ Owner with SCDF each year to ensure preparedness on	Pre-Likelihood Significance: **Negligible** (land-based) **to Moderate** (in-reservoir) Likelihood of Occurrence: **Unlikely** Post-Likelihood Impact Significance: **Negligible** (land-based) **to Minor** (in-reservoir)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		Emergency Response Plan would allow minimising the surface water quality impact from any accidental spillage or release. Impact magnitude is expected to be ***Negligible*** for the receiving water of the Kranji Reservoir and Sungei Pang Sua from land based events, and ***Negligible*** to ***Small*** for the receiving water of the Kranji Reservoir for reservoir based events, where impacts are expected to be within existing baseline/ statutory limits, given the short-term nature and embedded controls.		spillage containment and clean up, as well as fire preventing and fighting among workers. Monitoring and adaptive management measures including: ■ Establish construction phase surface water quality/ sediment quality monitoring programme in agreement with PUB prior to works commencement, to inform the Developer/ Owner on any potential deterioration of surface water quality from unplanned events. In addition to those parameters in C4 above: - Sediment quality monitoring parameters to include: Nutrients, contaminants/ metals and hydrocarbons.	

6.6.1.4 Summary of Construction Impacts

Adoption of the abovementioned mitigation measures are expected to reduce the construction residual impact magnitudes of the described impacts on surface water quality. Potential construction residual impact significance for surface water quality are anticipated to be reduced to ***Negligible*** to ***Moderate***.

Significant (above minor) residual construction impacts to surface water quality are anticipated to remain for:

- Moderate (residual) = sediment disturbance from deployment of anchors/ ballasted foundations/ piles and mooring lines (C5); and
- Moderate (residual) = degradation/ change of surface water quality from trimming of aquatic vegetation (C8).

A programme of monitoring and adaptive management is proposed to verify and minimise impacts on surface water quality during construction, see *Section 6.6.3* and *Section 12* (EMMP) for further details.

Unplanned events for fire/ explosion, ECM failure and environmental spills during construction on surface water quality are considered unlikely to occur with embedded controls. The residual impact significance (considering their likelihood and mitigation measures) are anticipated to be ***Negligible*** (land-based) to ***Minor*** (in-reservoir) for unplanned events.

Should any of the design and/ or construction assumptions assessed in this Section change (i.e. be considered to be greater, or more impactful, than those assumed in this assessment) as a result of the Developer/ Owner’s detailed design and construction methodology, the above impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein.

A summary of the impact assessment for the construction phase is presented in *Table 6-11* and construction unplanned events in *Table 6-12.*

Table 6-11: Impact Summary of Surface Water Quality during Construction

Impacts	■ Site runoff and wastewater from geotechnical/ site investigation on land (at the proposed temporary Staging/ Launching Area and the integrated Project Substation site) (C1) ■ Site runoff, wastewater and sediment disturbance from preparation of the proposed temporary Staging/ Launching Area (C2) ■ Site runoff and wastewater from land-based assembly of the FPV system (C3) ■ Sediment disturbance from geotechnical/ site investigation in reservoir (C4) ■ Sediment disturbance from deployment of anchors/ ballasted foundations/ piles and mooring lines (C5) ■ Sediment disturbance from launching, towing and installation of FPV and ancillary equipment at designed locations (C6) ■ Sediment disturbance from installation of connector cables (between FPV islands and to shore) (C7) ■ Degradation/ change of surface water quality from trimming of aquatic vegetation (C8) ■ Site runoff and wastewater from construction of integrated Project Substation and land-based connector cable in the proposed temporary Staging/ Launching Area (adjacent to reservoir) (C9) ■ Sediment disturbance from construction of O&M berthing facility (location subject to approval from agencies) (C10)				
Impact Nature	**Negative**	Positive	Neutral		
	Degradation of surface water quality is considered negative.				
Impact Type	**Direct**	**Indirect**	Induced		
	Direct and indirect impacts to receiving waters (Kranji Reservoir and Sungei Pang Sua) will arise from Project construction activities.				
Impact Duration	**Temporary**	**Short-term**	**Long-term**	Permanent	
	These impacts will be present at different stages and durations throughout the construction phase, which is estimated to take approximately 3 years (total in-reservoir construction period is approximately 104 weeks).				
Impact Extent	**Local**	Regional	Global		
	In general, impacts are localised within the work areas, and the immediate surroundings and Kranji Reservoir.				
Impact Scale	Overall, analysis estimates that waters up to a hundred meters away from the work front could be affected.				
Impact Frequency	Typically, impacts may occur daily or intermittently based on the specific period for each construction activity.				
Impact Magnitude	Positive	**Negligible**	**Small**	**Medium**	Large
	Conservatively, without mitigation, impact magnitudes for impacts during construction ranges from **Negligible** to **Medium**. An impact magnitude of Medium is where impacts are expected to be occasionally exceed existing baseline/ statutory limits over short timeframes at the works areas with embedded controls.				

<table>
<tr><td>Receptor Sensitivity</td><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td></td><td colspan="3">■ Kranji Reservoir and its tributaries upstream and PUB Drinking Water Intake in Kranji Reservoir (Medium to High, high rating used herein)
■ Sungei Pang Sua and other minor canals/ drains discharging to it (Low to Medium)
■ Johor Straits (Medium)</td></tr>
<tr><td>Key Embedded Controls (beyond legislation, regulations, standards and guidelines)</td><td colspan="3">■ Develop and implement Earth Control Measures (ECM) Plan by Qualified Erosion Control Professional (QECP)
■ No dredging and excavation of reservoir sediment for anchoring options or connector cable laying
■ Conservative surface water quality analysis of sediment suspension and nutrient release from anchoring options, and trimmed aquatic vegetation decomposition
■ In-reservoir construction will be phased, only limited areas will be affected by works activities concurrently
■ Sufficient chemical toilets (or equivalent) will be provided on site and no direct discharge of sanitary sewage into surface drainage would be allowed</td></tr>
<tr><td>Significance (without mitigation)</td><td colspan="3">Negligible | Minor | Moderate | Major</td></tr>
<tr><td></td><td colspan="3">The significance ranges from Negligible to Major without mitigation. Significant (above minor) impacts are:
■ Major (without mitigation):
- Sediment disturbance from deployment of anchors/ ballasted foundations/ piles and mooring lines (C5)
- Degradation/ change of surface water quality from trimming of aquatic vegetation (C8)
■ Moderate (without mitigation):
- Site runoff, wastewater and sediment disturbance from preparation of the proposed temporary Staging/ Launching Area (C2)
- Sediment disturbance from geotechnical/ site investigation in reservoir (C4)
- Sediment disturbance from launching, towing and installation of FPV and ancillary equipment at designed locations (C6)
- Sediment disturbance from installation of connector cables (between FPV islands and to shore) (C7)
- Sediment disturbance from construction of O&M berthing facility (location subject to approval from agencies) (C10)</td></tr>
<tr><td>Key Mitigation and Monitoring Measures</td><td colspan="3">■ Detailed design and construction methodology to optimise/ minimise extent of Project footprint and sediment disturbance, including anchoring options and work front phasing, where feasible.
■ Vessel operating procedures should avoid having work boat/ barges etc getting into shallow water, e.g. near the launching ramp, and using full throttle. Account for heavy loads activity procedures/ navigation routes. Ensure boat operators are familiar with water depths across the reservoir
■ Lowering of anchors, piles, weights and cables should be conducted in a controlled manner (using diver assistance, if required)
■ Aquatic vegetation trimmings to be collected and removed from water column immediately for disposal offsite by licenced company
■ Work boats will be refuelled at specified locations with spill control kits and measures, e.g. floating booms
■ Provision of navigation aides and establishment of regular traffic routes
■ Establish an Aquatic Vegetation/ Invasive Species Management Plan (including removal of aquatic vegetation). This plan should be prepared and submitted to PUB for agreement prior to commencement of the removal works for construction.
■ Silt fencing on land at or near the water edge to prevent on-shore sediments from washing into the reservoir
■ Monitoring and adaptive management measures:
- Agree construction phase surface water quality threshold criteria with PUB prior to works commencement, including action and limit levels;</td></tr>
</table>

<table>
<tr><td></td><td colspan="20">- Establish construction phase surface water quality monitoring programme (surface water quality, sediment quality) in agreement with PUB prior to works commencement, to inform the Developer/ Owner on any potential deterioration of surface water quality from the works. Online water quality systems, pre-agreed with PUB, should be deployed in the reservoir pre-construction prior to works being carried out in the reservoir, through operation (including decommissioning);
- Review the analysis conducted under Appendix D and E of Appendix 6.1 based on estimation of potential surface water quality impact. Should changes (if any) be considered to be greater, or more impactful, than those assumed in this assessment, the impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein;
- Initial anchoring work fronts away from water intakes. Monitoring to inform work rate adjustments. Start work rate low and ramp up where no deterioration of surface water quality from work activities; and
- If notable deterioration of surface water quality, investigate cause (if from Project, or otherwise). If from Project, review and identify further mitigation (such as silt curtains around the two reservoir water intakes, geotechnical investigation/ site investigation and/ or piling/ anchoring worksites, propose alternate construction methodologies, or to cease works temporarily) in close liaison with PUB.</td></tr>
<tr><td rowspan="2">Residual Impact Magnitude (with mitigation)</td><td colspan="4">Positive</td><td colspan="4">Negligible</td><td colspan="4">Small</td><td colspan="4">Medium</td><td colspan="4">Large</td></tr>
<tr><td colspan="20">The residual impact magnitude is expected to be reduced to Negligible to Small with mitigation. An impact magnitude of Small is defined where impacts are expected to be within existing baseline/ statutory limits.</td></tr>
<tr><td rowspan="2">Residual Impact Significance (with mitigation)</td><td colspan="5">Negligible</td><td colspan="5">Minor</td><td colspan="5">Moderate</td><td colspan="5">Major</td></tr>
<tr><td colspan="20">The residual impact significance with mitigation ranges from Negligible to Moderate. Significant (above minor) residual impacts are:
■ Moderate (residual, with mitigation):
- Sediment disturbance from deployment of ballasted foundations/ piles and mooring lines (C5)
- Degradation/ change of surface water quality from trimming of aquatic vegetation (C8)
A programme of monitoring and adaptive management is proposed to verify and minimise impacts on surface water quality during construction, see Section 6.6.3 and Section 12 (EMMP) for further details.</td></tr>
</table>

Table 6-12: Impact Summary of Surface Water Quality during Construction Unplanned Event

Impacts	■ Degradation/ change of surface water quality from unplanned events of fire and explosion (U1) ■ Degradation/ change of surface water quality from unplanned event of failure of erosion control measures (ECM)/ environmental spill (U2)				
Impact Nature	**Negative**	Positive	Neutral		
	Degradation of surface water quality is considered negative.				
Impact Type	**Direct**	**Indirect**	Induced		
	Direct and indirect impacts to receiving waters (Kranji Reservoir and Sungei Pang Sua) could arise from unplanned events.				
Impact Duration	**Temporary**	**Short-term**	Long-term	Permanent	
	These impacts will be present temporarily for a short period of time after the unplanned event.				
Impact Extent	**Local**	Regional	Global		
	Impacts are localised within the work areas and the immediate surroundings, with potential to spread across reservoir if uncontrolled.				
Impact Scale	Analysis estimates the effect could be up to a couple of hundreds of meters away from the event depending on the location and nature of event.				
Impact Frequency	Infrequent, with embedded controls.				
Impact Magnitude	Positive	**Negligible**	**Small**	Medium	Large
	With embedded controls impact magnitude for impacts during construction phase unplanned events is considered **Negligible** to **Small**. An impact magnitude of Small is defined where impacts are expected to be within existing baseline/ statutory limits.				
Receptor Sensitivity	**Low**	**Medium**	**High**		
	■ Kranji Reservoir and its tributaries upstream and PUB Drinking Water Intake in Kranji Reservoir (**Medium to High**, high rating used herein) ■ Sungei Pang Sua and other minor canals/ drains discharging to it (**Low to Medium**) ■ Johor Straits (**Medium**)				
Key Embedded Controls (beyond legislation, regulations, standards and guidelines)	In addition to key embedded controls identified in *Table 6-11*: ■ Spill Prevention and Emergency Response Plan detailing how fires/ explosions will be managed and spillage, leakage or accidents involving hazardous materials will be dealt with will be prepared ■ Secondary containment should be provided for chemicals ■ Train workers in use of equipment and machinery and vessels ■ Sizing of the ECM will be for 1 in 5 years rainfall				
Pre-likelihood Significance (without mitigation)	**Negligible**	**Minor**	**Moderate**	Major	
	The pre-likelihood significance ranges from **Negligible** (land-based) **to Moderate** (in-reservoir). Significant (above minor) impacts are: ■ Moderate (without mitigation):				

<table>
<tr><td></td><td colspan="4">- Degradation/change of surface water quality from unplanned events of fire and explosion (U1) – in-reservoir
- Degradation/change of surface water quality from unplanned event of failure of erosion control measures (ECM)/ environmental spill (U2) – in-reservoir</td></tr>
<tr><td>Key Mitigation and Monitoring Measures</td><td colspan="4">In addition to key mitigation and monitoring identified in Table 6-11:
■ Regular maintenance and daily inspection of vehicles, vessels and equipment
■ Only non-toxic firefighting reagent (if needed) will be used for firefighting. Developer/ Owner to agree with PUB on the proposed firefighting reagent to be used on site prior to usage.
■ Train workers in implementation of Spill Prevention and Emergency Response Plan.
■ Joint exercises/ drills for spillage and fire will be conducted by the Developer/ Owner with SCDF each year
■ In case of a fire and explosion or spill in reservoir, set up a perimeter floating boom for containment, where possible</td></tr>
<tr><td rowspan="2">Likelihood of Occurrence</td><td>Unlikely</td><td>Possible</td><td colspan="2">Likely</td></tr>
<tr><td colspan="4">Fire and explosions and ECM failure/ environmental spills are considered unlikely to happen during construction phase with embedded controls.</td></tr>
<tr><td rowspan="2">Post-likelihood Residual Significance (with mitigation)</td><td>Negligible</td><td>Minor</td><td>Moderate</td><td>Major</td></tr>
<tr><td colspan="4">The post-likelihood residual significance with mitigation ranges from Negligible (land-based) to Minor (in-reservoir). No significant (above minor) residual impacts are anticipated.</td></tr>
</table>

6.6.2 Operation Phase

6.6.2.1 Potential Sources of Impact

Specific Project activities which may result in operational impacts to surface water quality include but are not limited to the following:

FPV & Integrated Project Substation – Operation in reservoir/ on land

- Presence of FPV in reservoir;
- Operation and maintenance (O&M) of FPV Facilities (including cleaning of PV panels) in reservoir; and
- Presence of integrated Project Substation (with O&M facilities) on land.

Unplanned Events

- Fire and explosion; and
- Environmental Spill.

The impacts that may arise due to the above activities/ events that are considered in *Section 6.6.2.4* include:

- Change of hydrodynamics and surface water quality from the presence of FPV in reservoir;
- Wastewater and sediment disturbance from the O&M of FPV facilities (including cleaning of PV panels) in reservoir;
- Degradation/ change of surface water quality from unplanned event of fire and explosion; and
- Degradation/ change of surface water quality from unplanned event of environmental spill.

6.6.2.2 Embedded Controls

To control the surface water quality impacts from the operation phase, the following design and operational features are taken into account. The below are further to the operational embedded controls outlined for Biodiversity (*Section 7*), Air Quality (*Section 8*), Airborne Noise and Vibration (*Section 9*), Soil and Groundwater (*Section 10*) and Vectors (*Section 11*).

Embedded controls beyond those identified in *Section 6.2* include good practice to be implemented such as:

For FPV layout design:

- Inclusion of the intra-island block spacing (i.e. breaking up large FPV islands with 30-40m corridors), as required for safe and viable operations, and firefighting access. Noting that whilst this is an embedded control requirement from operational perspective and SCDF, this has not been accounted for in the Water Quality Model, therefore enabling a more conservative assessment of potential surface water quality impacts in this EIA; and
- A 25m setback distance from the Reservoir Project Site to the shoreline and inter-island spacing between FPV islands contains and limits the spread of fire from FPV island to FPV island, as well as to surrounding shorelines.

For maintenance:

- For cleaning of FPVs in reservoir, no detergent or soap would be allowed. Water (pressurised if needed) drawn from the reservoir directly would be used.

For work boats:

- Work boats will be properly sized for the task involved and be equipped with suitable navigation safety features according to location and appropriate regulations and guidelines;
- Speed limit of 5 knots will be implemented, particularly in shallow areas or close to the shore to minimise disturbance to the reservoir bed and erosion of the bank;
- Limited work boats/ barges are to be used in the reservoir. This in addition to the speed limit and low traffic on the reservoir would reduce the chances of accidental collision; and
- Regular traffic routes should be established for routine works. Offsets from shoreline as well as 30-40 m corridors between FPV islands allow safe navigation access, this will minimise the risk of getting into shallow water unintentionally and also minimises the risk of collision or grounding.

For handling of chemical/ hazardous waste:

- Workers will be adequately trained to handle chemical/ hazardous wastes stored on site, and to implement emergency action plans to deal with spills and leaks of toxic waste;
- Appropriately licensed waste collectors to be used;
- Emergency response kits will be provided at all Project Sites;
- Provision of emergency spill clean-up kits at locations where fuel and chemicals will be stored and used; and
- Prepare and keep up to date a Spill Prevention and Emergency Response Plan detailing how spillage, leakage or accidents involving hazardous materials will be dealt with and ensure that workers on site have received adequate training and instruction to enable them to implement the emergency action plan in the event of an emergency.

For firefighting:

- Petroleum or flammable materials will be stored in compliance with requirements under the relevant storage license;
- All practical steps will be taken to prevent the occurrence of an accident through fire, explosion, leakage or ignition of any petroleum or flammable material or vapours;
- Workers onsite will be properly trained to operate vessels and machinery;
- All temporary electrical installations, equipment and tools should be checked and certified for use regularly by a full-time licensed electrical worker;
- The hoarding for the worksite will be composed of non-combustible material to deter the spread of fire beyond the worksite;
- Firefighting equipment and other emergency response equipment will be provided;
- Workers will be trained in the use of available firefighting and emergency response equipment;
- Considerations should be taken into account in design of FPV layout to reduce the potential for fire propagation between FPV islands;
- Design, installation and operation and maintenance of FPV system to be carried out to national and international standards and to manufacturers specifications;
- A centralised monitoring system shall be implemented to observe the FPV system operations and immediately flag any faults/ issues as they occur;
- A Spill Prevention and Emergency Response Plan detailing how fires/ explosions will be managed will be prepared and agreed with SCDF, including response arrangements, and how spillage, leakage or accidents involving firefighting water and materials resulting from fire/ explosion management will be dealt with;

- Manual emergency shut-off system for the disconnection of the FPV modules shall be provided on land and at the inverter if it is on the water;
- All solar FPV strings within the array shall be differentiated and easily identifiable by responders;
- Fire response time from SCDF will be an estimated 8 minutes from the time of call. The nearest fire station, Woodlands Fire Station, is located 8 minutes from the integrated Project Substation (and O&M Facility). Moreover, SCDF's quality service intent[7] states that response to fire emergencies will be within 8 minutes of the call 90% of the time. This allows fires to be quickly responded to and contained within the site; and
- Regular enforcement checks by SCDF will be conducted within industrial premises such as the integrated Project Substation (and O&M Facility) to ensure compliance with fire safety regulations[8].

6.6.2.3 Operational Phase Water Quality Modelling: A Conservative Approach

In agreement with PUB, water quality modelling of Kranji Reservoir has been conducted to assess the potential change in surface water quality related to the coverage of FPV over the reservoir during the operational phase. A conservative water quality model and assessment was developed to: (i) understand and assess the implications of the FPV on Kranji Reservoir's water quality, and (ii) understand the maximum possible extent of FPV coverage that is acceptable in terms of surface water quality.

The conservative operational surface water quality modelling and assessment presented below and documented in *Appendix 6.1* (Water Quality Modelling Technical Appendix) covers a larger, maximum possible extent (thus more impactful) FPV coverage (of 122 ha) than that ultimately proposed by this EIA for approval (112 ha coverage, see *Figure 2-4*). The larger FPV coverage assessed in the conservative water quality model assumed: (i) no breaking up of the large FPV islands with 30-40m corridors (which will be incorporated into the final FPV layout design to accommodate operational and SCDF requirements for safe and viable operations, and firefighting access), and (ii) included a southern extension (which was originally considered, and later not taken forward due to biodiversity concerns where it was identified as a "no build" zone, see *Section 2.3, Project-specific Alternatives*).

This conservative water quality modelling approach (i.e. of a larger coverage of FPV) provides greater confidence in the surface water quality impact assessment and the understanding of the maximum possible extent of FPV layout that is acceptable in terms of surface water quality. For example, where the larger FPV coverage (122 ha) results in acceptable surface water quality impacts; an FPV coverage that is equal to, or smaller than (e.g. 112 ha) those modelled and assessed herein are anticipated to have similar, or more acceptable surface water quality impacts.

Also, it is noted in the "mitigation measures" outlined below that the Developer/ Owner should conduct updated hydrodynamic and water quality model runs (and hydraulic studies) based on the final design's FPV layout (of up to 112 ha FPV coverage). Should changes (if any) be considered to be greater, or more impactful, than those assumed in this assessment, the impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein.

See *Appendix 6.1* (Water Quality Modelling Technical Appendix) for details of the methodology, scenarios and findings of the modelling exercise (across both the base year of 2019, and future climate change scenario years of 2030, 2040 and 2050, with and without the presence of FPV on the Kranji Reservoir).

[7] https://www.scdf.gov.sg/docs/default-source/scdf-library/scdf-service-quality-handbook95d2613e6ace4c13ac66f19bba3814ca.pdf

[8] SCDF (2021). Annual statistics for fire, emergency medical services and fire safety enforcement checks. Retrieved form https://www.scdf.gov.sg/docs/default-source/scdf-library/amb-fire-inspection-statistics/scdf-annual-statistics-2021.pdf

Figure 6-3: Indicative Layout of Maximum Possible Extent of FPV Coverage considered in Conservative Operational Water Quality Model

6.6.2.4 Impact Assessment and Mitigation Measures

A summary of the assessment of impacts to surface water quality and proposed mitigation measures during the Project's operation is provided in *Table 6-13*.

Table 6-13: Impact Assessment for Surface Water Quality (Operation Phase)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
O1	**Change of hydrodynamics and surface water quality from the presence of FPV in reservoir**	■ **Nature**: Predicted change in surface water quality within model results are mixed, **positive** (improvement) for certain parameters and **negative** (deterioration) for other parameters. ■ **Type**: The presence of FPV will alter light penetration, wind drag, heat exchange and other physical parameters that **indirectly** affect the surface water quality in the reservoir. ■ **Duration**: Impacts are **permanent** throughout the Project operational phase. Its effect on surface water quality is reversible should the Project's FPV be removed. ■ **Extent**: Impacts are limited **locally** within the reservoir only. ■ **Scale**: The change in surface water quality is expected at locations covered by Project's FPV islands (including FPV, walkways and perimeter floats) and PCUs. ■ **Frequency**: Impact may happen **daily/ intermittently** during the operational phase. A detailed water quality modelling exercise was conducted to assess the potential change in surface water quality associated with the presence of FPV in the Kranji Reservoir. Methodology, scenarios and findings of the modelling exercise is provided in *Appendix 6.1*. Modelling results indicated: ■ The change in median temperature (average of whole reservoir) difference with presence of FPV (change in temperature = FPV minus Non-FPV) was not more than 0.3°C (PUB's guideline for this Project) in all assessment years, including base case in 2019 and climate change assessment years of 2030, 2040, 2050. Change in water temperature could affect a host of physiochemical (e.g. DO saturation) and biological processes (e.g. respiration, nitrification) in the reservoir. ■ Total nitrogen (TN), Total Organic Carbon (TOC) and Chlorophyll-a reduce (i.e. improve) when compared to the Non-FPV simulation results under all assessment years (year 2019 as well as 2030, 2040 and 2050), which resulted in reduced time of non-compliance by at least 30% for all three parameters. These indicate lower algal activities in the reservoir. ■ Total phosphorous (TP) concentration increases under the FPV scenarios for all assessment years. Note that TP level always exceeds, and is generally well above, the surface water quality guideline criteria of 0.06 mg/L in the baseline scenario (Non-FPV) as well as in the observed data, and thus the change in predicted TP levels is not expected to result in an increase in time of exceedance in surface water quality criterion for TP. ■ Decrease in DO level is predicted in the reservoir with FPV (assuming the 5 current aerators are retained within the reservoir) but the median DO levels were within water quality guideline values (not below 3 mg/L, PUB's guideline for this Project) for more than 97% of time (i.e. more than 354 days in a year)[9] under the FPV scenarios in all assessment years (year 2019 as well as 2030, 2040 and 2050). Extent of locations with DO non-compliance is predicted to be highly localised. Percentage time with reservoir average DO level below 3 mg/L under Non-FPV scenarios for all assessment years ranges from 0.0% to 1.1%, and under FPV scenarios range from 0.3% to 1.4%. The reduction in DO level could affect a host of chemical (e.g. reduction/ oxidation) and biological processes (e.g. respiration, denitrification) in the reservoir. Note that the modelling conducted was based on a conservative larger FPV layout (122 ha, see *Section 6.6.2.3*), and did not take into account the breaking up of the large FPV islands with 30-40m corridors (which will be incorporated into the final FPV layout design to accommodate operational and SCDF requirements for safe and viable operations, and firefighting access). A reduced FPV layout, and presence of such additional corridors within the large FPV islands will also improve gaseous/ heat exchange, increase light penetration, all or which partially counteracts the effect of the presence of the FPV. This means the conservative modelled changes in hydrodynamic and surface water quality is anticipated to be greater than	Impact Magnitude: **Medium** Receptor Sensitivity: **High** (Kranji Reservoir/ tributaries/ PUB intakes) Impact Significance: **Major**	■ Detailed design of FPV layout to optimise/minimise FPV island footprint, where feasible. ■ Establish an Aquatic Vegetation/ Invasive Species Management Plan (includes removal of aquatic vegetation). This plan should be prepared and submitted to PUB for agreement prior to commencement of the operations. ■ All aquatic vegetation trimmings, where required, to be collected and removed from the water column immediately for disposal offsite by a licenced contractor. Monitoring and adaptive management measures including: ■ Conduct updated model runs (e.g. hydrodynamic and water quality) and hydraulic studies based on the final FPV layout. Review water quality impact assessment based on the findings of the updated model runs. Should changes (if any) be considered to be greater, or more impactful, than those assumed in this assessment, the impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein. ■ Agree operational phase surface water quality threshold criteria with PUB, including action and limit levels. ■ Online water quality monitoring systems installed pre-construction should be maintained and remain within the reservoir during operation (including decommissioning). Establish operation phase surface water quality monitoring programme in agreement with PUB prior to operation, to inform the adaptive management of any potential deterioration of surface water quality attributable to the Project, and provide analysis of long term changes and trends. Operation phase surface water quality monitoring programme is to continue for the entire operation period (including decommissioning). - Surface water quality monitoring parameters to include: Temperature (°C), pH, EC (μS/cm) (conductivity), Turbidity (NTU), Secchi Depth, Dissolved oxygen (DO), Metals and metalloids (including Aluminium, Arsenic, Copper, Iron, Lead, Manganese), Major ions (including chloride), grease and oil, PAR, Chlorophyll-a (fluorescence-based spectrophotometer) and Nutrients (TP, TN, TOC, DOC, nitrate (as N), phosphate and ammonia (as N)), 2-MIB, Geosmin, Microcystin-LR, and Total Suspended Solids (TSS). ■ Any notable deterioration of surface water quality observed should be investigated. Investigation should determine whether or not the observed deterioration can be attributed to the operation of the Project. If affirmative, the cause of adverse surface water quality events should be reviewed and targeted adaptive mitigation implemented. The Developer/ Owner should liaise with PUB closely on monitoring results and investigation findings and seek agreement on management action(s), which may include provision of artificial aeration, potential layout changes, removal of the FPV etc where appropriately agreed between responsible agencies and the Developer/ Owner. Where observations are not attributable to the Project, the Developer/ Owner will liaise with relevant Government Agencies responsible for managing the identified effect for their action.	Impact Magnitude: **Small** Impact Significance: **Moderate**

[9] The use of median DO levels and the derivation of the 97% value are explained in *Appendix 6.1 Section 5.5.2* under 'Daily whole-reservoir averages' subsection.

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		that ultimately proposed by this EIA for approval (112 ha). Overall, based on the conservative modelling, the change in surface water quality due to the presence of FPV would result in increased occasion of exceedance for some of surface water quality parameters (while improvement in others), and thus is considered to be of *Medium* impact magnitude. The presence of FPV will reduce sunlight entering the water column, thus limiting the regrowth of aquatic vegetation, assessed in *Table 6-10* item C8 above (see also *Appendix D* of *Appendix 6.1*). Certain aquatic vegetation species that do not receive sufficient sunlight could die off partially or entirely, releasing some of their captured carbon, nitrogen and phosphorus through decomposition. As stated under the assessment under item C8, quantitative analysis of a very unlikely conservative scenario of having all the aquatic vegetation within the Reservoir Project Site (i.e. all vegetation in the water column) start decomposing at the same time and releasing nutrients immediately, the addition of total phosphorus, total nitrogen and total carbon in the 1st month will be approximately 11%, 9%, and 5% of the existing fluxes into the reservoir (catchment loadings, mineralisation, and atmospheric deposition) respectively. Therefore, the potential release of nutrients from dying of aquatic vegetation due to FPV shading is expected to have small impact on the reservoir surface water quality. Given this effect would be cumulative to the effect of presence of FPV assessed in the previous paragraph, the overall impact magnitude is considered to be *Medium*. The Floating Solar Handbook for Practitioners (World Bank Group, ESMAP and SERIS, 2019) refers to the potential for reduced evaporation from FPV projects depending on the system design such as the configuration of FPV panels. Various internationally published studies in tropical/ sub-tropical regions (Melvin and Xiang, 2015; Rosa-Clot et al., 2017; Gonzalez Sanchez et al., 2021; Mamatha & Kulkarni, 2021; Farrar et al., 2022) have estimated evaporation rates related to FPV projects via various means. Depending on the coverage and configuration of FPV panels, a number of these studies indicate evaporation rates below FPV panels could reduce by 40–80% compared to non-FPV areas (Farfan et al., 2018; Gonzalez Sanchez et al., 2021; Farrar et al., 2022). For this Project, the potential for reduced evaporation will be reviewed/ studied as the Project progresses where appropriate, subject to further discussions between PUB and the Developer/ Owner on requirements and monitoring approaches. Overall, the impact magnitude is expected to be ***Medium*** for the receiving water of the Kranji Reservoir, where impacts are expected to be over the long term, however only occasionally exceedances of existing baseline/ statutory or guideline limits over short timeframes are expected with embedded controls, with positive changes in nutrients and chlorophyll-a levels.			
O2	**Wastewater and sediment disturbance from the O&M of FPV facilities (including cleaning of PV panels) in reservoir**	■ **Nature**: Degradation of surface water quality is considered **negative**. ■ **Type**: O&M requires regular access to the FPV site. Boat access could result in minor disturbance of reservoir bed sediment at shallow areas, which is considered to be a **direct** impact. Wash water from cleaning of FPV with reservoir water would also result in **direct** impacts. ■ **Duration**: Though impacts are short-term and temporary, they will be **permanent** throughout the Project operational phase. ■ **Extent**: Impacts are **localised** at shallow areas (particularly around the O&M berthing facility). Impacts from wash water from cleaning of FPV would also be localised at the location where cleaning is necessary, where cleaning may be required throughout the FPV covered area. ■ **Scale**: Body of water within less than 100 m could be affected by increased suspended solids, oil and grease or other contaminants. ■ **Frequency**: Impact may happen **daily/ intermittently** during the operational phase. Work boats moving within shallow area or close to banks could disturb reservoir bed sediment or erode soil from the bank. Disturbed sediment and eroded soil would result in localised increase in turbidity. Such increased turbidity will settle quickly after the disturbance subsides. Embedded measures regarding vessel speed limits would minimise disturbance to the reservoir bed sediment or to the bank. The resulting	Impact Magnitude: **Negligible to Small** Receptor Sensitivity: **High** (Kranji Reservoir/ tributaries/ PUB intakes) Impact Significance: **Negligible to Moderate**	■ As item O1 above. ■ Design of the vessel operation procedures to account for the relatively shallow water to avoid the work boats etc from getting into the shallow depths and running their engines at full throttle. Account for heavy loads activity procedures/ navigation routes. Ensure boat operators are familiar with water depths across the reservoir.	Impact Magnitude: **Negligible** Impact Significance: **Negligible**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		elevation of suspended solids is expected to be within ambient levels/ statutory limits and thus the impact magnitude is considered to be *Small*. Other maintenance works include checking of main and secondary floats buoyancy, tightness of connections, physical appearance, as well as checking of harness, moorings, shackles and or concrete blocks for the anchoring, which will not result in change in surface water quality. Some targeted cleaning (water only) would be needed to clean up bird droppings as required. No detergent or soap would be allowed. Water (pressurised if needed) drawn from the reservoir directly would be used. Therefore, the impact magnitude is considered to be *Negligible*. Impact magnitude is expected to be ***Negligible*** to ***Small*** for the receiving water of the Kranji Reservoir, where impacts are expected to be within existing baseline/ statutory or guideline limits, given the localised impact.			
U3	**Degradation/ change of surface water quality from unplanned event of fire and explosion**	■ **Nature**: Degradation of surface water quality is considered **negative**. ■ **Type**: In case of fire and explosion, combustible materials/ fuels/ debris/ firefighting water or chemical(s) may enter bodies of water **directly** (if fire/ explosion occurs at FPV or on work boat(s)) or **indirectly** (if fire/ explosion occurs on land and then contaminating materials be washed into surrounding waters). This assessment item covers the effect of fire and explosion, as well as the effect of firefighting water/ reagent. If spillage of other hazardous materials (fuel leakage) is involved, its impact is assessed under item U4 below. ■ **Duration**: Impacts are **short-term** and temporary, and surface water quality is expected to return to baseline after the event. ■ **Extent**: Impacts are **localised** at area around the fire/ explosion. ■ **Scale**: Scale of impact depends on location and nature of fire and explosion. Effect of land-based fire and explosion would likely be limited to the immediate vicinity. Effect of fire and explosion in the reservoir could affect waters within a few hundred meters. ■ **Frequency**: Fire and explosion is **unlikely** to occur given the embedded controls. ■ **Likelihood**: **Unlikely**. Spacing between islands of FPV, setback from reservoir edges etc, will control/ slow down the spread of fire and the associated impact, and enable firefighting access. Design and operation of the FPV and integrated Project Substation will align with the Fire Safety Act and the SCDF's requirements as well as relevant Singapore and international standards. Electricity generation will be cut off remotely at the control room to facilitate firefighting. A Spill Prevention and Emergency Response Plan detailing how fires/ explosions will be managed will be prepared and agreed with SCDF, including how spillage, leakage or accidents involving firefighting water and materials resulting from fire/explosion management will be dealt with (see U4 below). Workers on site will be properly trained to operate vessels and machinery. The implementation of the Spill Prevention and Emergency Response Plan would allow minimising the surface water quality impacts from any fire or explosion incident. Impact magnitude is expected to be ***Negligible*** for the receiving water of the Kranji Reservoir and Sungei Pang Sua from land-based events, and ***Small*** for the receiving water of the Kranji Reservoir for reservoir based events, where impacts are expected to be within existing baseline/ statutory limits, given the short term nature and embedded controls.	Impact Magnitude: **Negligible to Small** Receptor Sensitivity: **Low** (Sungei Pang Sua) **to High** (Kranji Reservoir/ tributaries/ PUB intakes) Pre-Likelihood Significance: **Negligible** (land-based) **to Moderate** (in-reservoir)	Likelihood Evaluation Design and operation of the FPV and integrated Project Substation will align with relevant Singapore and international standards. Overall, fire risk for the FPV system is unlikely. No fuel will be required for FPV or other parts that will be installed in the reservoir and therefore risk for major fire at these parts is unlikely as well. Given the low vessel traffic and generally low travel speed, fire and explosion of work boats as a result of collision is unlikely. Mitigation The following measures would also be implemented to further mitigate the consequence of the unplanned event of fire and explosion: ■ Contractor to conduct thorough quality checks and inspections of materials prior to installation to ensure there are no manufacturing defects. ■ Proper material handling practices and inspections of installed materials should be done to ensure there are no defects during construction. ■ Developer/ Owner to conduct a review of past FPV design failure modes and incorporate main findings into the newer designs. ■ Where possible, drains/ body of water where fire and explosion occurs should be cut off from the Kranji Reservoir. Firefighting water will be contained within the drainage system. Such water will be collected and be disposed by a licensed waste collector as soon as possible to ensure the drains are empty for normal operation. ■ Only non-toxic firefighting reagent (if needed) will be used for firefighting with approval from agencies. This will minimise human health and ecological risk in case using of such reagent is needed and such reagent ends up in reservoir water. Developer/ Owner to agree with PUB on the proposed firefighting reagent to be used on site prior to usage. ■ Train workers in implementation of Emergency Fire Response Plan. ■ Do not use "PVStop" chemical spray as a fire retardant to render PV panels electrically safe. Instead, electricity generation will be cut off remotely at the Project's control room to facilitate firefighting. ■ Train workers in implementation of the Spill Prevention and Emergency Response Plan. ■ Joint exercises/ drills for spillage and fire will be conducted by the Developer/ Owner with SCDF each year to ensure preparedness on spillage containment and clean up, as well as fire preventing and fighting among site staff. ■ In case of a fire and explosion in reservoir, a perimeter floating boom would be set up (where possible and safe) to allow containment of any floating debris from the event.	Pre-Likelihood Significance: **Negligible** (land-based) **to Moderate** (in-reservoir) Likelihood of Occurrence: **Unlikely** Post-Likelihood Impact Significance: **Negligible** (land-based) **to Minor** (in-reservoir)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
				Monitoring and adaptive management measures including: ■ Establish operation phase surface water quality / sediment quality monitoring programme in agreement with PUB prior to operation, to inform the Developer/ Owner on any potential deterioration of surface water quality from unplanned events. In addition to those parameters in O1 above: - Sediment quality monitoring parameters to include: Nutrients, contaminants/ metals and hydrocarbons.	
U4	**Degradation/change of surface water quality from unplanned event of environmental spill**	■ **Nature**: Degradation of surface water quality is considered **negative**. ■ **Type**: Spillage can affect surface water quality of the receiving bodies of water **directly**, e.g. if spillage occurs during works within reservoir, such as fuel spillage from work boat) or **indirectly** via spillage on land being washed into reservoir. ■ **Duration**: Impacts are **short-term** and temporary, and surface water quality is expected to return to baseline after the event. ■ **Extent**: Spillage within the reservoir could **spread across the reservoir** if uncontrolled. ■ **Scale**: Scale of impact depends on location and nature of environmental spill. Effect of land-based spill would likely be limited to the immediate vicinity. An in-reservoir fuel spill/ leak at designated refuelling location would be limited. A spillage in the middle of the reservoirs could affect waters up to a few hundred meters. ■ **Frequency**: Environmental spillage on land is **unlikely** to occur given the embedded controls. Environmental spillage in the reservoir would likely be a result of vessel collision and refuelling, which are both very unlikely given the limited traffic, speed limit and embedded controls. ■ **Likelihood**: **Unlikely**. Storage and use of chemicals and fuels are subjected to stringent control as stated under *Section 6.2,* therefore the risk for spillage on land is very low and is likely to be highly localised after taking into account the embedded control measures. For spillages in-reservoir, given the provision of spill clean up kits at locations where fuel and chemicals would be stored or used, any spill is unlikely to spread beyond the initial location. In case of spill, for example, from vessel collision that is away from the berthing/refuelling area and immediate containment is not possible, the typical amount of fuel spilled is expected to be limited because of the limited size of fuel tank (due to small vessel sizes) as well as the low possibility of fuel tank being completely compromised from collision at low navigation speed. Also, evaporation is the dominant process contributing to the removal of spilled diesel from the water surface and can account for 60-80% loss if no spill response is mounted. As oil weathers (i.e. through evaporation of its lightest and most toxic fractions), its inherent toxicity also reduces. Overall, the implementation of the Spill Prevention and Emergency Response Plan, small spill volumes as well as the tendency to evaporate means the overall impact would be limited and temporary. A Spill Prevention and Emergency Response Plan detailing how spillage, leakage or accidents involving hazardous materials will be dealt with will be prepared. The implementation of a Spill Prevention and Emergency Response Plan would allow minimising the surface water quality impact from any accidental spillage or release. Impact magnitude is expected to be ***Negligible*** for the receiving water of the Kranji Reservoir and Sungei Pang Sua from land based events, and ***Negligible*** to ***Small*** for the receiving water of the Kranji Reservoir for reservoir based events, where impacts are expected to be within existing baseline/ statutory limits, given the short term nature and embedded controls.	Impact Magnitude: **Negligible to Small** Receptor Sensitivity: **Low** (Sungei Pang Sua) **to High** (Kranji Reservoir/ tributaries/ PUB intakes) Pre-Likelihood Significance: **Negligible** (land-based) **to Moderate** (in-reservoir)	<u>Likelihood Evaluation</u> With the implementation of embedded control measures related to accidental spillage/ leakage, notable change in surface water quality as a result of land-based spillage is unlikely. For spillage within the reservoir, one plausible scenario of spill is a result of accidental collision. A vessel to vessel collision is unlikely given limited traffic within the reservoir. Vessel to shore collision, vessel to FPV collision and vessel grounding are also unlikely given the use of navigation aids (embedded control measures) as well as the very low occurrence of severe weather conditions which hinder navigation (such as typhoons). Also, given only vessels of small size would and could be used in the reservoir and the slow speed these vessels will travel, the scale of potential spillage will be limited as well. <u>Mitigation</u> The following measures would also be implemented to further mitigate the consequence of the unplanned event of environmental spill: ■ Preparation and implementation of vessel standard operating procedures. ■ Chemicals and/ or hydrocarbons will be handled and stored in compliance with the Material Safety Data Sheet (MSDS). ■ All chemical and/ or hydrocarbon wastes will be segregated into clearly marked containers prior to onshore disposal by a licensed waste management contractor, as per the relevant MSDSs. Secondary containment should also be provided for these chemicals. ■ Daily inspection of boat and machinery to avoid fuel leakage. ■ Practise due diligence in proper storage and handling of machinery to prevent leaching of oil or harmful materials. ■ Regular maintenance of vehicles and equipment, proper training of operators to avoid fuel leakage or spillage into reservoir. ■ Work boats will be refuelled at specified locations following standard procedures. Refuelling location(s) should be equipped with spill control kits and measures, e.g. floating booms at the perimeter, clean up kits ready to use, etc. This means any spillage from refuelling would be contained and cleaned up properly. ■ Provision of navigation aids and establishment of regular traffic routes would further reduce the risk of collision. ■ Where possible, drains/ body of water where fire and explosion occurs should be cut off from the Kranji Reservoir. Firefighting water will be contained within the drainage system. Such water will be collected and be disposed by a licensed waste collector as soon as possible to ensure the drains are empty for normal operation. ■ Spill Prevention and Emergency Response Plans to have inclusions for addressing wildlife and biodiversity concerns from events. ■ Train workers in implementation of the Spill Prevention and Emergency Response Plan. ■ Joint exercises/ drills for spillage and fire will be conducted by the Developer/ Owner with SCDF each year to ensure preparedness on	Pre-Likelihood Significance: **Negligible** (land-based) **to Moderate** (in-reservoir) Likelihood of Occurrence: **Unlikely** Post-Likelihood Impact Significance: **Negligible** (land-based) **to Minor** (in-reservoir)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
				spillage containment and clean up, as well as fire prevention and fire fighting among site staff. Monitoring and adaptive management measures including: ■ Establish operation phase surface water quality / sediment quality monitoring programme in agreement with PUB prior to operation, to inform the Developer/ Owner of any potential deterioration of surface water quality from unplanned events. In addition to those parameters in O1 above: - Sediment quality monitoring parameters to include: Nutrients, contaminants/metals and hydrocarbons.	

6.6.2.5 Summary of Operational Impacts

Adoption of the abovementioned mitigation measures are expected to reduce the operational residual impact magnitudes of the described impacts on surface water quality. Potential operational residual impact significance for surface water quality are anticipated to be reduced to ***Negligible*** to ***Moderate***.

Significant (above minor) residual operational impacts to surface water quality are anticipated to remain for:

- Moderate (residual) = change of hydrodynamics and surface water quality from presence of FPV in reservoir (O1).

A programme of monitoring and adaptive management is proposed to verify and minimise impacts on surface water quality during operation, see *Section 6.6.3* and *Section 12* (EMMP) for further details.

It is noted that Water Quality modelling estimates there to be some potential positive improvement for certain surface water quality parameters (nutrients and chlorophyll-a levels) as a result of the Project being located in the Kranji Reservoir.

Unplanned events for fire/ explosion and environmental spills during operation on surface water quality are considered unlikely to occur with embedded controls. The residual impact significance (considering their likelihood and mitigation measures) are anticipated to be ***Negligible*** (land-based) to ***Minor*** (in-reservoir) for unplanned events.

Should any of the design and/ or operational assumptions assessed in this Section change (i.e. be considered to be greater, or more impactful, than those assumed in this assessment) as a result of the Developer/ Owner's detailed design and operations, the above impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein.

A summary of the impact assessment for the operation phase is presented in *Table 6-14* and operational unplanned events in *Table 6-15.*

Table 6-14: Impact Summary of Surface Water Quality during Operation

<table>
<tr><td rowspan="1">Impacts</td><td colspan="12">■ Change of hydrodynamics and surface water quality from the presence of FPV in reservoir (O1)
■ Wastewater and sediment disturbance from the O&M of FPV facilities (including cleaning of PV panels) in reservoir (O2)</td></tr>
<tr><td rowspan="2">Impact Nature</td><td colspan="4">Negative</td><td colspan="4">Positive</td><td colspan="4">Neutral</td></tr>
<tr><td colspan="12">Change in hydrodynamics, change in light penetration/ wind drag/ heat exchange, and disturbance to reservoir bed sediment in the Kranji Reservoir is overall considered negative. Noting some positive improvement for certain surface water quality parameters (nutrients and chlorophyll-a levels) from the presence of FPV.</td></tr>
<tr><td rowspan="2">Impact Type</td><td colspan="4">Direct</td><td colspan="4">Indirect</td><td colspan="4">Induced</td></tr>
<tr><td colspan="12">Direct and indirect impacts to Kranji Reservoir will arise from Project operations.</td></tr>
<tr><td rowspan="2">Impact Duration</td><td colspan="3">Temporary</td><td colspan="3">Short-term</td><td colspan="3">Long-term</td><td colspan="3">Permanent</td></tr>
<tr><td colspan="12">These impacts will be present throughout the operational phase (25 years) (noting its effect on surface water quality is reversible should the Project’s FPV be removed).</td></tr>
<tr><td rowspan="2">Impact Extent</td><td colspan="4">Local</td><td colspan="4">Regional</td><td colspan="4">Global</td></tr>
<tr><td colspan="12">Impacts are limited locally within the reservoir only.</td></tr>
<tr><td>Impact Scale</td><td colspan="12">Typically, impacts are estimated to affect FPV footprint and immediate surroundings.</td></tr>
<tr><td>Impact Frequency</td><td colspan="12">Impact may happen daily/ intermittently during the operational phase.</td></tr>
<tr><td rowspan="2">Impact Magnitude</td><td colspan="2">Positive</td><td colspan="3">Negligible</td><td colspan="2">Small</td><td colspan="3">Medium</td><td colspan="2">Large</td></tr>
<tr><td colspan="12">Without mitigation impact magnitude for impacts during operation ranges from Negligible to Medium. An impact magnitude of Medium is where impacts are expected to be occasionally exceed existing baseline/ statutory or guideline limits over short timeframes at the works areas with embedded controls.</td></tr>
<tr><td rowspan="2">Receptor Sensitivity</td><td colspan="4">Low</td><td colspan="4">Medium</td><td colspan="4">High</td></tr>
<tr><td colspan="12">■ Kranji Reservoir and its tributaries upstream and PUB Drinking Water Intake in Kranji Reservoir (Medium to High, high rating used herein)
■ Sungei Pang Sua and other minor canals/ drains discharging to it (Low to Medium)
■ Johor Straits (Medium)</td></tr>
<tr><td>Key Embedded Controls (beyond legislation, regulations,</td><td colspan="12">■ Conservative surface water quality modelling of FPV coverage (i.e. modelling of larger, thus more impactful, FPV footprint (122 ha) than that ultimately proposed by this EIA (112 ha)), as well as modelling of climate change scenarios up to 2050
■ Conservative surface water quality analysis of nutrient release from aquatic vegetation decomposition
■ Targeted cleaning of bird droppings on FPVs as required. No detergent or soap would be allowed. Water (pressurised if needed) drawn from the reservoir directly.</td></tr>
</table>

<table>
<tr><td>standards and guidelines)</td><td colspan="4"></td></tr>
<tr><td rowspan="2">Significance (without mitigation)</td><td>Negligible</td><td>Minor</td><td>Moderate</td><td>Major</td></tr>
<tr><td colspan="4">The significance ranges from Negligible to Major without mitigation. Significant (above minor) impacts are:
■ Moderate:
- Wastewater and sediment disturbance from the O&M of FPV facilities (including cleaning of PV panels) in reservoir (O2)
■ Major:
- Change of hydrodynamics and surface water quality from the presence of FPV in reservoir (O1)</td></tr>
<tr><td>Key Mitigation and Monitoring Measures</td><td colspan="4">■ Detailed design of FPV layout to optimise/ minimise FPV island footprint, where feasible
■ Vessel operating procedures should avoid having work boats etc getting into shallow water and using full throttle. Account for heavy loads activity procedures/ navigation routes. Ensure boat operators are familiar with water depths across the reservoir.
■ Aquatic vegetation trimmings (where required) to be collected and removed from water column immediately for disposal offsite by licenced company
■ Work boats will be refuelled at specified locations with spill control kits and measures, e.g. floating booms
■ Provision of navigation aides and establishment of regular traffic routes
■ Establish an Aquatic Vegetation/ Invasive Species Management Plan (includes removal of aquatic vegetation). This plan should be prepared and submitted to PUB for agreement prior to commencement of the operations.
■ Monitoring and adaptive management measures:
- Conduct updated model runs (e.g. hydrodynamic and water quality) and hydraulic studies based on the final FPV layout. Review water quality impact assessment based on the findings of the updated model runs. Should changes (if any) be considered to be greater, or more impactful, than those assumed in this assessment, the impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein.
- Agree operational phase surface water quality threshold criteria with PUB, including action and limit levels
- Online water quality monitoring systems installed pre-construction should be maintained and remain within the reservoir during pre-construction through operation (including decommissioning). Establish operation phase surface water quality monitoring programme (surface water quality, sediment quality) in agreement with PUB prior to works commencement, to inform the Developer/ Owner on any potential deterioration of surface water quality from the works
- If notable deterioration of surface water quality, investigate cause (if from Project, or otherwise). If from Project, review and identify further mitigation which may include potential layout changes, removal of the FPV etc where appropriately agreed between responsible agencies and the Developer/ Owner.</td></tr>
</table>

<table>
<tr><td rowspan="2">Residual Impact Magnitude (with mitigation)</td><td>Positive</td><td>Negligible</td><td>Small</td><td>Medium</td><td>Large</td></tr>
<tr><td colspan="5">The residual impact magnitude is expected to be reduced to Negligible to Small. An impact magnitude of Small is defined where impacts are expected to be within existing baseline/ statutory or guideline limits.</td></tr>
</table>

<table>
<tr><td rowspan="2">Residual Impact Significance (with mitigation)</td><td>Negligible</td><td>Minor</td><td>Moderate</td><td>Major</td></tr>
<tr><td colspan="4">The residual impact significance with mitigation ranges from Negligible to Moderate. Significant (above minor) residual impacts are:
■ Moderate (residual, with mitigation):</td></tr>
</table>

	- Change of hydrodynamics and surface water quality from the presence of FPV in reservoir (O1) A positive improvement for certain surface water quality parameters (nutrients and chlorophyll-a levels). A programme of monitoring and adaptive management is proposed to verify and minimise impacts on surface water quality during operation, see *Section 6.6.3* and *Section 12* (EMMP) for further details.

Table 6-15: Impact Summary of Surface Water Quality during Operation Unplanned Event

Impacts	■ Degradation/ change of surface water quality from unplanned event of fire and explosion (U3) ■ Degradation/ change of surface water quality from unplanned event of environmental spill (U4)				
Impact Nature	**Negative**	Positive	Neutral		
	Degradation of surface water quality is considered negative.				
Impact Type	**Direct**	**Indirect**	Induced		
	Direct and indirect impacts to receiving waters (Kranji Reservoir and Sungei Pang Sua) could arise from unplanned events.				
Impact Duration	**Temporary**	**Short-term**	Long-term	Permanent	
	These impacts will be present temporarily for a short period of time after the unplanned event.				
Impact Extent	**Local**	Regional	Global		
	Impacts are localised within the work areas and the immediate surroundings, with potential to spread across reservoir if uncontrolled.				
Impact Scale	Analysis estimates the effect could be up to a couple of hundreds of meters away from the event depending on the location and nature of event.				
Impact Frequency	Infrequent, with embedded controls.				
Impact Magnitude	Positive	**Negligible**	**Small**	Medium	Large
	With embedded controls impact magnitude for impacts during operation phase unplanned event is considered **Negligible** to **Small**. An impact magnitude of Small is defined where impacts are expected to be within existing baseline/ statutory limits.				
Receptor Sensitivity	**Low**	**Medium**	**High**		
	■ Kranji Reservoir and its tributaries upstream and PUB Drinking Water Intake in Kranji Reservoir (**Medium to High**, high rating used herein) ■ Sungei Pang Sua and other minor canals/ drains discharging to it (**Low to Medium**) ■ Johor Straits (**Medium**)				

<table>
<tr><td rowspan="1">Key Embedded Controls (beyond legislation, regulations, standards and guidelines)</td><td colspan="12">In addition to key embedded controls identified in Table 6-14:
■ Design and operation of the FPV and integrated Project Substation will align with the Fire Safety Act and the SCDF’s requirements as well as relevant Singapore and international standards
■ Electricity generation will be cut off remotely at the control room to facilitate firefighting
■ Spill Prevention and Emergency Response Plan detailing how fires/ explosions will be managed and spillage, leakage or accidents involving hazardous materials will be dealt with will be prepared
■ Train workers in use of equipment and machinery and vessels</td></tr>
<tr><td rowspan="2">Pre-likelihood Significance (without mitigation)</td><td colspan="3">Negligible</td><td colspan="3">Minor</td><td colspan="3">Moderate</td><td colspan="3">Major</td></tr>
<tr><td colspan="12">The pre-likelihood significance ranges from Negligible (land-based) to Moderate (in-reservoir). Significant (above minor) impacts are:
■ Moderate (without mitigation):
- Degradation/change of surface water quality from unplanned events of fire and explosion (U3) – in-reservoir
- Degradation/change of surface water quality from unplanned event of environmental spill (U4) – in-reservoir</td></tr>
<tr><td>Key Mitigation and Monitoring Measures</td><td colspan="12">In addition to key mitigation and monitoring identified in Table 6-14:
■ Developer/ Owner to conduct a review of past FPV design failure modes and incorporate main findings into the newer designs
■ Regular maintenance and daily inspection of vehicles, vessels and equipment
■ Only non-toxic firefighting reagent (if needed) will be used for firefighting. Developer/ Owner to agree with PUB on the proposed firefighting reagent to be used on site prior to usage
■ Train workers in implementation of Spill Prevention and Emergency Response Plan
■ Joint exercises/ drills for spillage and fire will be conducted by the Developer/ Owner with SCDF each year
■ In case of a fire and explosion or spill in reservoir, set up a perimeter floating boom for containment
■ Do not use “PVStop” chemical spray as a fire retardant to render PV panels electrically safe. Instead, electricity generation will be cut off remotely at the Project’s control room to facilitate firefighting.</td></tr>
<tr><td rowspan="2">Likelihood of Occurrence</td><td colspan="4">Unlikely</td><td colspan="4">Possible</td><td colspan="4">Likely</td></tr>
<tr><td colspan="12">Fire and explosions and environmental spills are considered unlikely to happen during operation phase with embedded controls.</td></tr>
<tr><td rowspan="2">Post-likelihood Residual Significance (with mitigation)</td><td colspan="3">Negligible</td><td colspan="3">Minor</td><td colspan="3">Moderate</td><td colspan="3">Major</td></tr>
<tr><td colspan="12">The post-likelihood residual significance with mitigation ranges from Negligible (land-based) to Minor (in-reservoir). No significant (above minor) residual impacts are anticipated.</td></tr>
</table>

6.6.3 *Surface Water Quality Monitoring*

As outlined in *Section 6.6.1.3 and 6.6.2.4* above, surface water quality monitoring is recommended to be carried out during the pre-construction, construction and operational (including decommissioning) phases of the Project. The surface water quality (and biodiversity) monitoring programmes have been aligned with the ecosystem level approach considered in the EIA to support monitoring of the interactions between biotic (living, e.g. flora/ fauna) and abiotic (non-living, e.g. water quality) components and processes within Kranji Reservoir.

The Environmental Management and Monitoring Plan (EMMP) (*Section 12*) establishes further details of the proposed monitoring programmes for this Project.

6.6.4 Potential Cumulative Impacts from Other Major Concurrent Developments

Consultation between URA and MND has been undertaken during the course of this study to identify other known concurrent projects in the immediate vicinity of the Project Sites for which works will occur at the same time as this Project, see *Section 4.3.1, Table 4-2*. The detailed schedules for such developments are not available at the time of writing. Cumulative impacts have therefore not been undertaken in this EIA due to the lack of available information. In the event that information on surrounding committed developments does become available, the Kranji FPV Project should be assessed under the cumulative impact assessments within the EIAs of these surrounding committed developments. Details of this Project, where appropriate, will be coordinated and provided to the EIA owners of surrounding developments to support their cumulative impact assessment.

7. BIODIVERSITY

7.1 Overview

This Section of the EIA evaluates the potential biodiversity impacts (i.e. to terrestrial and aquatic habitats, flora and fauna) associated with the construction and operation phases of the Project. Where required, the mitigation hierarchy of avoidance, minimisation, reduction or compensation has been applied to potentially significant impacts to reduce impact levels to as low as reasonably practicable. Monitoring recommendations for biodiversity during the construction and operation phases of the Project are also referenced, where applicable.

Relevant Government and Technical Agencies have been consulted since the early phases of the Project (since January 2020), and Nature Groups have been engaged since January 2021, to understand biodiversity concerns, and seek feedback in preparing the biodiversity impact assessment for this Project. The discussions and recommendations from Government and Technical Agencies and engaged stakeholders (including Nature Groups) have been taken into account in the following assessment.

Construction activities at the proposed temporary Staging/ Launching Area and integrated Project Substation worksite may generate a change in surface water quality of the Kranji Reservoir impacting aquatic biodiversity. Land-based and in-reservoir construction activities may also disturb both aquatic and terrestrial biodiversity, and biodiversity areas in the vicinity, such as Kranji Marshes, Gemala Nature Area, Sungei Buloh Wetland Reserve and Mundai Mangrove and Mudflats. The potential impacts from these activities have been evaluated and assessed.

During the long-term operational phase, the presence of the FPV may cause a change in aquatic biodiversity communities, and generate a change in terrestrial biodiversity, for example, changes in foraging opportunities for birds and other fauna. These have also been evaluated and assessed.

This section summaries, and draws on, information from the following technical reports:

- Terrestrial Biodiversity Baseline Study (refer to *Appendix 7.1*) encompassing a period of 20 months (October 2020 to May 2022) (*Table 7-5*) of desktop studies, field surveys and consultation;
- Aquatic Environment Baseline Report (refer to *Appendix 7.2*); and
- Ecological Character Description (ECD) (refer to *Appendix 7.3*) of Kranji Reservoir developed under this study to take an ecosystem-level approach to the assessment of longer-term operational biodiversity impacts.

Surface water quality implications are covered under the Surface Water Quality section, *Section 6.*

7.2 Regulatory Framework

The legislation, standards and/or guidelines applicable to governing biodiversity in Singapore relevant to this Project include those listed in *Table 7-1:*

Table 7-1: Summary of Legislative Requirements and Guidelines to Protect Biodiversity

Legislation/ Standard/ Guideline	Relevance to Biodiversity for this EIA
Parks and Trees Act (2021) and subsidiary legislation	■ The Act provides for the planting, maintenance and conservation of trees and plants within national parks, nature reserves, tree conservation areas, heritage road green buffers and other specified areas. ■ The Project should strictly control any: - Activities that will damage flora, the land or cause injury to fauna within the Nature Reserves; - Cutting or damaging trees with girth of more than 1 m within a Tree Conservation Area; and

Legislation/ Standard/ Guideline	Relevance to Biodiversity for this EIA
	- Cutting or damaging trees or plants within the heritage road green buffers. ■ The Project should also: - Provide temporary sanitary facilities and waste management areas to be provided to avoid fouling of surface water resources; and - Seek approval from NParks before carrying out restricted activities. ■ Trees with girths exceeding 1 m which are growing within any Tree Conservation Area or any vacant land, will not be cut down without approval from NParks.
Wildlife Act, 1965 (Revised edition 2020)	■ The Director-General may direct a person to implement any wildlife-related measures necessary to safeguard wildlife or health of ecosystem. ■ Workers to be trained to avoid undertaking prohibited activities such as: - The killing, taking or keeping of any wildlife; - Taking and destroying eggs of wild birds; and - Placing contraptions that are likely to cause injury to wildlife and humans.
Public Utilities (Reservoir and Catchment Areas and Waterway) Regulations 2018	The Project should: ■ Undertake measures to manage impacts to surface water quality; and ■ Ensure its activities will not lead to the damage of flora or fauna in reservoir catchment parks.
National Biodiversity Strategy and Action Plan (NBSAP) (NParks, 2009)	■ Fulfilment of commitments to United Nations Convention on Biological Diversity (UNCBD). ■ Sets out goals to conserve and enhance Singapore's biodiversity.
Nature Conservation Master Plan (NCMP) (NParks, 2015)	■ The NCMP aims to systematically consolidate, coordinate, strengthen and intensify the biodiversity conservation efforts outlined in the NBSAP. ■ Sets out biodiversity conservation plans for the following five years to achieve the Singapore's vision of a City in a Garden.
Singapore Red Data Book (2nd and 3rd edition[1])	■ List of species in Singapore which need improvement on their conservation status.
National Parks Board Guidelines on Greenery Provision and Tree Conservation for Developments (2018)	■ Set of guidelines to describe the statutory requirements on greenery provision, tree planting and conservation for development projects in Singapore, including protection of trees during construction.
Biodiversity Impact Assessment (BIA) Guidelines (NParks, 2020)	■ Provides reference for developers and industry professionals to understand the common requirements for the biodiversity component of an EIA.
United Nations Convention on Biological Diversity (UNCBD, 1993)	■ Promotes conservation of biodiversity.
International Union for Conservation of Nature (IUCN) Red List of Threatened Species	■ Provides global extinction risk status of animals, fungus, and plant species.

7.3 Assessment Criteria

The magnitude of potential impacts on habitats and species have been assessed in accordance with the agreed criteria presented in *Table 7-2*. The ERM impact assessment approach aligns with, and follows the same principles as, the NParks BIA Guidelines (NParks, 2020).

[1] Singapore Red Data Book status of species as of 28 July 2023. This may be subject to change.

Table 7-2: Magnitude Criteria for Assessment of Impacts on Biodiversity

Impact Magnitude	Definition for Habitats	Definition for Species
Negligible	Effect is within the normal range of natural variation.	Effect is within the normal range of natural variation for the population of the species.
Small	Affects only a small area of habitat, such that there is no loss of viability/ function of the habitat.	Effect does not cause a substantial change in the population of the species, or other species dependent on it.
Medium	Affects part of the habitat but does not threaten the long-term viability/ function of the habitat.	Effect causes a substantial change in abundance and/ or the reduction in distribution of a population over one or more generations but does not threaten the long-term viability/ function of that population, or any population dependent on it.
Large	Affects the entire habitat, or a significant proportion of it, and the long-term viability/ function of the habitat is threatened.	Affects entire population or a significant part of it, causing a substantial decline in abundance and/ or change in population; and recovery of the population (or another dependent on it) is not possible either at all, or within several generations due to natural recruitment i.e. reproduction or immigration from unaffected areas.

The agreed sensitivity criteria adopted to assess the sensitivity of habitat and species to impacts are presented in *Table 7-3,* see *Section 7.6* for further discussion on biodiversity sensitive receptors.

Table 7-3: Sensitivity Criteria for Biodiversity Receptors

Sensitivity	Definition for Habitats	Definition for Species [(a)]
Negligible	▪ Habitats with negligible interest for biodiversity.	▪ Species with no specific value or importance attached to them.
Low	▪ Habitats with no, or only a local, designation/ recognition; ▪ Habitats of significance for species listed as of Least Concern (LC) on IUCN Red List of Threatened Species; ▪ Habitats which are common and widespread within the region; or ▪ Habitats with low conservation interest based on expert opinion.	Species: ▪ on LC on the IUCN Red List; or ▪ not meeting criteria for medium or high value.
Medium	▪ Habitats within nationally designated or recognised areas; ▪ Habitats of significant importance to globally Vulnerable (VU) Near Threatened (NT), or Data Deficient (DD) species; ▪ Habitats of significant importance for nationally restricted range species; ▪ Habitats supporting nationally significant concentrations of migratory species and/ or congregatory species; and/ or	Species: ▪ on IUCN Red List as VU, NT or DD[(b)]; ▪ protected under national legislation; ▪ on latest Singapore Red Data Book (SRDB) as VU or DD; ▪ nationally restricted range species, nationally important numbers of migratory or congregatory species; ▪ not meeting criteria for high value; or species vital to the

Sensitivity	Definition for Habitats	Definition for Species [a]
	■ Low value habitats used by species of medium value.	survival of a medium value species.
High	■ Habitats within internationally designated or recognised areas; ■ Habitats of significant importance to globally Critically Endangered (CR) or Endangered (EN) species, habitats of significant importance to endemic and/ or globally restricted-range species; ■ Habitats supporting globally significant (>1%) concentrations of migratory species and/ or congregatory species (Birdlife International, 2020); ■ Highly threatened and/ or unique ecosystems; ■ Areas associated with key evolutionary species; and/or ■ Low or medium value habitats used by high value species.	Species: ■ on IUCN Red list as CR or EN [b]; ■ on latest SRDB as Nationally Extinct (NE), CR or EN; ■ having a globally restricted range (i.e. plants endemic to a site, or found globally at fewer than 10 sites, fauna having a distribution range (or globally breeding range for bird species) less than 50,000 km^2); ■ internationally important numbers of migratory, or congregatory species; ■ key evolutionary species; or ■ vital to the survival of a high value species.

Notes:

(a) Value Definitions follow the ERM Impact Assessment (IA) Standard, which takes into account Good Practices for Biodiversity Inclusive Impact Assessment and Management Planning (iadb.org),International Finance Corporation Performance Standards 6 (IFC PS6) and guidance such as the Business and Biodiversity Offsets Programme (BBOP) Standard and accompanying materials.

(b) Species that have value rankings of Medium and High are considered species of conservation concern.

7.4 Terminology

Throughout this section the following terms and their meaning are used:

- Biota - the animal and plant life of a particular region and/ or habitat.
- BIA Study Area - area captured by the biodiversity baseline studies (*Figure 7-1*). It comprises the Reservoir Project Site (defined below) and a wider area around this which covers the broader occurrence and distribution of biodiversity, rather than that within the Reservoir Project Site in isolation.
- Reservoir Project Site – 201 hectares (ha), of which approximately 112 ha will be covered by the FPV islands including areas for walkways, perimeter floats, inverters and other in-reservoir infrastructure. The FPV islands are expected to cover approximately 21.5% of the total Kranji Reservoir surface (522 ha).
- Pelagic zone – the open water part of the reservoir.
- Littoral zone – the nearshore part of the reservoir characterised by light penetration to the reservoir bed. Based on the Project's surveys, light penetration is within the first 3m of water depth, below which light levels were negligible.
- Photic zone – where light intensity is above 1% of the surface light; where light availability is high enough to allow photosynthesis. Based on the Project's surveys and desk study data, this is assumed to be around 3m depth.

Reference is made throughout this section to Species Conservation Status, with reference to international IUCN and Singapore Red Data Book, the following categories in *Table 7-4* are used:

Table 7-4: Definition of Each Global and/ or National Conservation Status following the IUCN Red List and Singapore Red Data Book

Global/ National Conservation Status	Definition
Data Deficient (DD)	Inadequate information to make a direct or indirect assessment of its risk of extinction.
Least Concern (LC)	Species does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened.
Near Threatened (NT)	Species does not qualify for Critically Endangered, Endangered or Vulnerable now, either globally or nationally, but is likely to qualify for a threatened category in the near future.
Vulnerable (VU)	Species facing a high risk of extinction in the wild/ in Singapore.
Endangered (EN)	Species facing a very high risk of extinction in the wild/ in Singapore.
Critically Endangered (CR)	Species facing an extremely high risk of extinction in the wild/ in Singapore.
Presumed Nationally Extinct (NE)*	There is no reasonable doubt that the last reproductively capable individual within Singapore has died or disappeared in the last 50 years (fauna) or 30 years (vascular plants).
*Notes: * it is presumed Nationally Extinct is a National Conservation Status (i.e. not in IUCN Red List).*	

Figure 7-1: BIA Study Area and Project Components

7.5 Baseline Conditions

The following section briefly describes the methodology and findings for establishing baseline conditions of the BIA Study Area. Please refer to *Appendix 7.1 and 7.2* for details on methodology and presentation of the baseline survey findings for terrestrial and aquatic biodiversity, respectively.

7.5.1 Methodology

Desktop and site-based studies were undertaken to describe the biotic environment within the BIA Study Area. Aquatic components were surveyed at the same time as physical and chemical water quality studies, which is appropriate given the latter strongly influences the biota. In addition to aquatic components, surveys were also carried out to characterise the use of the reservoir surface by terrestrial fauna, in particular foraging birds and bats. All adjacent terrestrial habitats, flora and fauna were also sampled (*Figure 7-2* and *Figure 7-3*). Site baseline surveys were carried out over a period of 20 months.

The coverage and methodologies of the terrestrial biodiversity and aquatic baseline surveys were discussed and agreed with relevant Government and Technical Agencies (e.g. NParks/ PUB) and other stakeholders (e.g. Nature Groups). Where appropriate the nature and extent of the surveys were updated following these engagements, particularly after feedback received from Nature Groups in January 2021. The methods applied were also chosen, in part, for their potential repeatability in future monitoring activities during construction and operation of the Project.

Table 7-5 below provides a summary of the biotic surveys undertaken. Full details of the methodologies and any limitations are provided in *Appendix 7.1 and 7.2*.

To support the biodiversity impact assessment to identify the key and supporting ecosystem components, processes and services at Kranji Reservoir, an Ecological Character Description (ECD) was conducted (see *Section 4.8* and *Appendix 7.3*), informed by the Project's baseline findings. The ECD ecosystem approach is a process adopted from the international Ramsar Convention. The ECD and the identification of Limits of Acceptable Change (LAC) specifically accounted for potential impacts by the Project.

Spatial sensitivity bird mapping was prepared to inform the impact assessment in terms of areas observed to be used by birds for foraging on the reservoir surface (*Appendix 7.5*). Spatial sensitivity mapping is a widely adopted tool to inform impact assessments, particularly in relation to spatial mapping of bird sensitivity to Project's effects.

Table 7-5: Summary of Biotic Baseline Surveys

Component	Methodology	Survey Period
Aquatic habitats and vegetation	■ Boat-based sonar transects.	■ May 2021, September 2021 and March 2022. ■ Habitat mapping survey area was extended to support understanding of aquatic vegetation further south of the Reservoir Project Site.
	■ Grab sampling and rake-dragging.	■ May 2021, September 2021 and February 2022.
	■ Satellite imagery used to generate Normalised Difference Vegetation Index (NDVI) to quantify floating vegetation on the reservoir surface across the site survey period.	■ Available data obtained for 12 months: March 2020, July 2020, August 2020, September 2020, March 2021, April 2021, July 2021, September 2021, October 2021, December 2021, January 2022, and February 2022.
Macroinvertebrates	■ Grab sampling (Ekman grab).	■ January, March and May 2021, and March 2022.

Component	Methodology	Survey Period
	■ Kick-net sampling and coloniser sampling.	■ May 2022.
Plankton	■ Tow netting.	■ December 2020 to March 2021, inclusive. ■ Then May 2021 and September 2021.
Fish	■ Hydroacoustic nocturnal survey.	■ June and July 2021.
	■ eDNA sampling.	■ March 2021.
Birds	■ Boat-based transects.	■ May 2021 to May 2022. ■ In total, six diurnal and/ or nocturnal surveys were conducted. For the transects carried out further than 25m away from the shore, only one nocturnal survey was conducted due to health and safety.
	■ Vantage point surveys (VPS). ■ Targeting foraging activity of 16 focal piscivorous (fish feeding) birds. The total number of foraging events recorded from each Vantage Point (VP) was mapped to a 50m x 50m cell and divided by the hours of observation at the VP to generate a map of foraging activity per hour. ■ Mapping bird flightpaths over site and to wider landscape including SBWR and other designated sites was also carried out.	■ October 2020 to October 2021 (VP1, VP2 and VP3). ■ March 2021 to March 2022 (VP4, VP5 and VP6). ■ VPS was extended to VP4 to 6 to support understanding of bird usage further north and south of the Reservoir Project Site. ■ Total 313 observation hours, ranging from 48.25 to 54 hours across the six vantage points. ■ During the migratory season (September to February), surveys were undertaken two times per month at each VPS location, and once a month during the non-migratory season of March to August. VPSs were conducted in four x 3-hour blocks per day.
	■ Transect surveys and point counts.	■ October 2020 to April 2021. ■ Monthly diurnal and nocturnal surveys.
	■ Targeted black-crowned night heron (*Nycticorax nycticorax*) roost verification.	■ February to April 2022. ■ Two rounds of dawn and dusk surveys.
Bats	■ Boat-based transects and point counts. ■ Targeting foraging activity on the Reservoir surface.	■ February 2021 to April 2022. There were 34 sampling points within the Reservoir Project Site and 10 sampling points to the south, outside this area. ■ Sampling points were extended to south to support understanding of bat foraging further south of the Reservoir Project Site. ■ The points were equally distributed across the Reservoir Project Site. Six replicates of boat-based 5-minute point counts were conducted for each point between 19:00 hrs to 22:00 hrs, after sunset.
	■ Unattended bat detectors. ■ Targeting bat activity in terrestrial habitats.	■ June 2021 to August 2021, and October 2021 – November 2021. ■ Three detectors were deployed along the Kranji bund on the western bank,

Component	Methodology	Survey Period
		one was deployed at Kranji Reservoir Park A and the remaining two were deployed on the edge of Sungei Kadut forest. Recorded from 30 minutes before sunset to 30 mins after sunrise. Each recorder was deployed for 30 nights at each location.
	■ Point count visual roost emergence surveys. ■ Targeting roosts of bamboo bats (*Tylonycteris spp.*).	■ May to June 2021 ■ Roost emergence surveys were conducted at all six bamboos observed within the Sungei Kadut forest. Each cluster was targeted by each survey (total 6 clusters, 1 survey at each). ■ Surveys were conducted between 18:30 hrs to 21:00 hrs, during which two to three personnel were stationed around the cluster to observe for emerging bats.
Terrestrial habitats and vegetation	■ Transects.	■ May 2021 and February 2022.
Terrestrial Fauna	■ Transects (Terrestrial).	■ October 2020 to October 2021. ■ Monthly diurnal and nocturnal terrestrial transect surveys were conducted over 12 months.
	■ Transects (Boat-based).	■ December 2020 to April 2021 ■ Monthly boat-based transect surveys for terrestrial fauna were conducted over 6 months.
	■ Camera traps.	■ March, April, June and July 2021. ■ 10 camera traps, one camera trap per 6.25 ha (i.e. 250m by 250m grids). 40 trap-nights each.

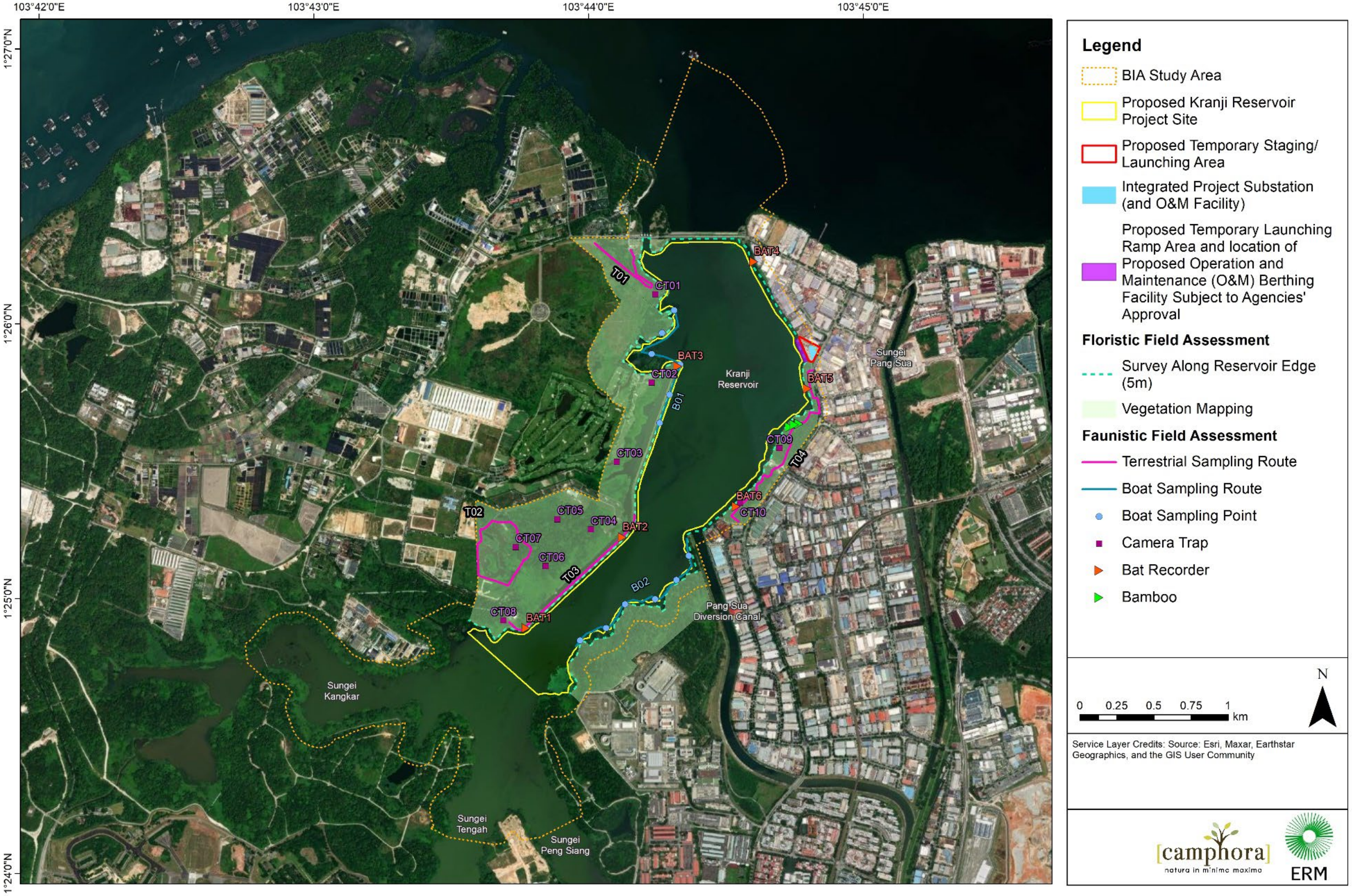


Figure 7-2: Aquatic and Terrestrial Sampling Locations (1)

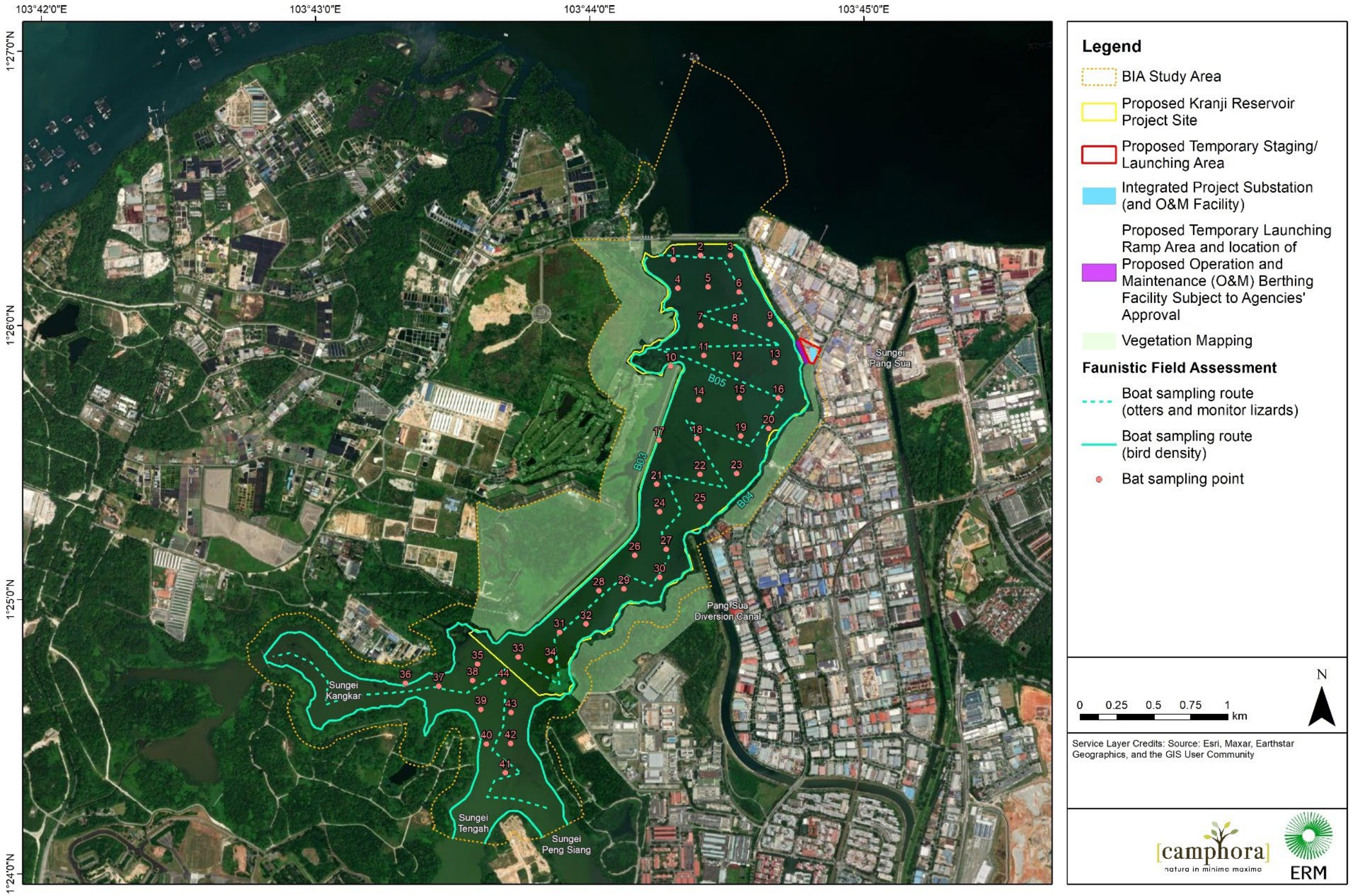


Figure 7-3: Aquatic and Terrestrial Sampling Locations (2)

7.5.2 Main Baseline Findings

7.5.2.1 Kranji Reservoir's Ecological Context

- Historically the Kranji River was surrounded by lowland dipterocarp forest with small patches of freshwater swamp and mangrove forest (Yee et al., 2010). Kranji Reservoir was engineered in 1972 through the damming of the Kranji River to create a freshwater storage reservoir. Mangroves surrounding the reservoir were backfilled with dredged spoil from channel widening works carried out at the time. Damming of the reservoir reduced sediment load and increased flushing of freshwater of the mangrove habitat at the former Kranji Sungei (Singapore Blue Plan, 2018). It also created freshwater wetland habitat at the western edge of the newly created Kranji Reservoir.
- The Kranji Reservoir is fed by the Sungei Tengeh, Sungei Kangkar and Sungei Peng Siang from the south and surface runoff / storm drains. The Pang Sua Diversion Canal was diverted to enter the eastern edge of the Reservoir in 2005 (*Figure 7-1*).
- Adjacent land uses include nature conservation and recreational areas to the north and west (Sungei Buloh Nature Park Network described in more detail below), Sungei Kadut Industrial Estate to the east, NSRCC Golf Course to the west, and Kranji military training areas to the south.
- Recent biological studies have reported Kranji Reservoir to be hyper-eutrophic with high productivity (Low et al. 2010; Ng et al. 2010; Gin et al. 2011; and Clews et. al 2014.). Ng et al (2010) further reported that much of Kranji Reservoir has moderate to low biodiversity, contained high levels of invasive species, and supported no areas of high native biodiversity. Such low species richness is generally known to be a function of eutrophic waterbodies (e.g. Dodson et al. 2000).
- Existing PUB operational and maintenance activities within/ around the reservoir include:
  - Five aerators that increase and maintain oxygen saturation in the water column;
  - Control of water levels within the reservoir via releases through the Kranji tidal gate into the Johor Straits to the north;
  - Removal/ cutting of floating and submerged vegetation, and disposal at appropriately licensed waste facilities; and
  - Maintenance of reservoir edge terrestrial habitats e.g. grass cutting.
- Cyanobacteria (blue-green algae species) blooms have occurred within Kranji Reservoir in the past (Harn Te and Gin (2011), and cyanobacteria is identified by PUB as the most abundant taxa.
- The Kranji Reservoir is used for recreational fishing with two publicly accessible fishing areas (Fishing Ground A and B) designated in the north at either end of Kranji Dam (*Figure 7-1*).

7.5.2.2 Sungei Buloh Nature Park Network

Kranji Reservoir is located adjacent to the Sungei Buloh Nature Park Network. These sites are managed collectively for the conservation of wetland biodiversity in northwest Singapore (EAA, 2018). A summary of the sites comprising the Sungei Buloh Nature Park Network is provided below in *Table 7-6.*

Table 7-6: Sites within the Sungei Buloh Nature Park Network

Site	Summary of Main Designating Features
Sungei Buloh Wetland Reserve (SBWR)	■ Internationally important site for migratory birds on the East Asian – Australasian Flyway and designated as a Nature Reserve, located

Site	Summary of Main Designating Features
	northwest of the reservoir and separated from it by Kranji Way road. Comprises mangroves, brackish and freshwater ponds, mudflats and marsh habitats. It contains the largest mangrove forest on mainland Singapore (~100 ha) and is fed by two rivers: Sungei Buloh Besar and Sungei Buloh Kechil, as well as tidal waters from the Johor Straits. ■ Supports c. 2,000 migratory wetland birds in a relatively small area (~130 ha), including species of global conservation concern: far eastern curlew (*Numenius madagascariensis*), Nordmann's greenshank (*Tringa guttifer*), great knot (*Calidris tenuirostris*), Chinese egret (*Egretta eulophotes*), masked finfoot (*Heliopais personatus*) (EAA, 2018). ■ Other notable migratory waterbirds include: Asian dowitcher (*Limnodromus semipalmatus*), bar-tailed godwit (*Limosa lapponica*), black-tailed godwit (*L. limosa*), Eurasian curlew (*Numenius arquata*), grey-tailed tattler (*Tringa brevipes*), red knot (*C. canutus*), red-necked stint (*C. ruficollis*), curlew sandpiper (*C. ferruginea*), northern pintail (*Anas acuta*), and ruff (*C. pugnax*) (EAA, 2018). ■ Other globally threatened bird species include the lesser adjutant (*Leptoptilos javanicus*), Christmas frigatebird (*Fregata andrewsi*), greater spotted eagle (*Clanga clanga*), straw-headed bulbul (*Pycnonotus zeylanicus*) and brown-chested jungle flycatcher (*Cyornis brunneatus*) (EAA, 2018). ■ Other globally near-threatened bird species include: oriental darter (*Anhinga melanogaster*), Himalayan vulture (*Gyps himalayensis*), grey-headed fish eagle (*Haliaeetus ichthyaetus*), cinnamon-headed green pigeon (*Treron fulvicollis*), jambu fruit dove (*Ptilinopus jambu*), chestnut-bellied malkoha (*Phaenicophaeus sumatranus*), long-tailed parakeet (*Psittacula longicauda*), mangrove pitta (*Pitta megarhyncha*), Japanese paradise flycater (*Terpsiphone atrocaudata*), streaked bulbul (*Ixos malaccensis*), and white-chested babbler (*Trichastoma rostratum*) (EAA, 2018). ■ Noteworthy animals that occur in the SBWR include estuarine crocodile (*Crocodylus porous*) and smooth-coated otter (*Lutrogale perspicillata*), both listed as CR species in Singapore. The Malayan water monitor (*Varanus salvator*) is one of the most commonly seen animals in the reserve. The king cobra (*Ophiophagus hannah*, Globally VU) and the leopard cat (*Prionailurus bengalensis*, Nationally CR) have been sighted via camera traps in the reserve (EAA, 2018).
Mandai Mangroves and Mudflats	■ ~73 ha Nature Park located northeast of the reservoir and ~3 km east of SBWR is designated to protect mangrove, mudflat and freshwater marsh habitats. The site supports 29 mangrove species, 16 of which are of conservation concern, as well as seagrasses and horseshoe crabs (NParks, 2022). ■ Supports a high diversity and abundance of benthic fauna which provide foraging resources to migratory shorebirds. Radiotracking has shown these birds roost at SBWR at high tide and utilise the habitats at Mandai during low tide (NParks, 2022).
Kranji Marshes	■ ~57 ha on the western shore of Kranji Reservoir containing freshwater marsh, woodland and grassland. These habitats support: >170 species of birds, 54 butterfly species and 33 dragonfly species. The Kranji Marshes contains a Core Conservation Area closed to public access (NParks, 2022).
Gemala Nature Area	■ This Nature Area has varied habitats such as wet grassland, freshwater marshes, as well as tall secondary woodland and abuts the reservoir. The Nature Area has biodiversity-rich wet grassland, with two plants of conservation concern *Leea angulata* (Nationally CR) and *Cayratia trifolia* (Nationally VU) being supported (MND, 2013).

With the above ecological context the following sub-sections present a summary of the findings of the baseline field studies carried out within the BIA Study Area (*see Appendix 7.1 and 7.2).*

7.5.2.3 Aquatic Habitats

- Depths range to a maximum of around 20 m, limited to one deep area. In general, deeper areas are located in the north and east, likely reflecting the hydraulic geometry of the Kranji River before its impoundment. On average most of the reservoir is relatively shallow (<10 m).
- Smooth sand/ mud was the most abundant substrate, with submerged vegetation covering 109 ha of the Reservoir Project Site (and shoreline setback areas) (*Table 7-7* and *Figure 7-4*).
- Most vegetation is associated with the shallow western side of the reservoir and includes water hyacinth *Eichhornia crassipes)*, lotus (*Nelumbo nucifera)* and hydrilla (*Hydrilla verticillata)*, the latter particularly in the northwest of the reservoir.
- High primary productivity (observed through the large area of submerged vegetation) is understood to be driven by nutrients which enter the reservoir from runoff and via release from benthic sediment. It also appears to be driving the abundance and dominance of primary producing taxa. In terms of nutrients, Nitrogen (N) and Phosphorus (P) are understood to be the main determinants of primary production in freshwater ecosystems.
- At Kranji Reservoir, temperature is unlikely to exert a major effect on reservoir components and processes, given the variation in daily and seasonal temperatures are relatively small due to the location of the Reservoir at a low latitude.
- During the surveyed inter-monsoon (March, April and May 2021) the abundance of *Aulacoseira* sp. decreased and a shift in the phytoplankton community occurred with *Pediastrum* sp. and *Staurastrum* sp. becoming more abundant. A cause of this change is likely to be the increased input of nutrients during the rainfall events, although *Pediastrum* sp. are also known to pulse during the northern spring (Reynolds 1980) and this may explain some of the variation. The decline in *Aulacoseira* sp. could also be a response to reduced mixing, as a result of weaker winds during the inter-monsoon period. *Aulacoseira* sp. are heavily silicified and therefore require greater mixing to remain suspended in the water column. Cyanophyta was the most abundant phyla in the phytoplankton samples collected by Kwik et al (2020) (and reported by PUB from their routine monitoring), but it was absent from the laboratory results of water samples collected during the baseline surveys. However, the Microcystin-LR and Total Microcystin (sum of congeners) detected in water samples collected is an indication of the presence of Microcystis in the Reservoir. Noting there are differences in phytoplankton assemblages between these various study findings, a combination of the two approaches is therefore more appropriate for providing a better understanding of the phytoplankton assemblages present during the baseline. To verify the findings of the EIA baseline surveys and support the ongoing review of potential impacts of the Project on the plankton community, further plankton monitoring is proposed pre-construction, during construction and post-construction, see *Section 12* (EMMP) for further details.

Table 7-7: Benthic Habitats/ Reservoir Bed Features/ Substrates in Reservoir Project Site

Feature	Area (ha) within Reservoir Project Site	Area (ha) within southern survey area	Comment
Smooth sand/ Mud (no vegetation)	~211	~102	The typical habitat/ feature on the reservoir bed. This appears as an untextured layer on the sonar viewer and is dominant in areas with deeper depths.
Submerged vegetation	~109	~61	Abundant in areas with shallower depths where light penetration is suitable to the growth of macrophytes.
Woody debris	~23	~0.5	This category consists of features that appear to be tree stumps, branches and twigs found as patches across the reservoir bottom.
Rocky outcrop	~4.5	-	Recorded at the south of Reservoir Project Site survey area.
Smooth sand/mud with small holes	~4	~0.05	-
Artificial structure	~3	~0.05	Possible metal fencing or metal barrier in reservoir.
Large hole/ pool	~1.5	~0.1	Large holes around 1 m deep, which may be due to historical usage.
Unscanned tracks	~14	~5	Area not surveyed due to inaccessibility (floating/ submerged vegetation prevented boat access to these areas).
Note: includes areas within 25 m shoreline setback area around the Reservoir Project Site (outside the 201 ha Reservoir Project Site), as well as contains some overlapping features.			

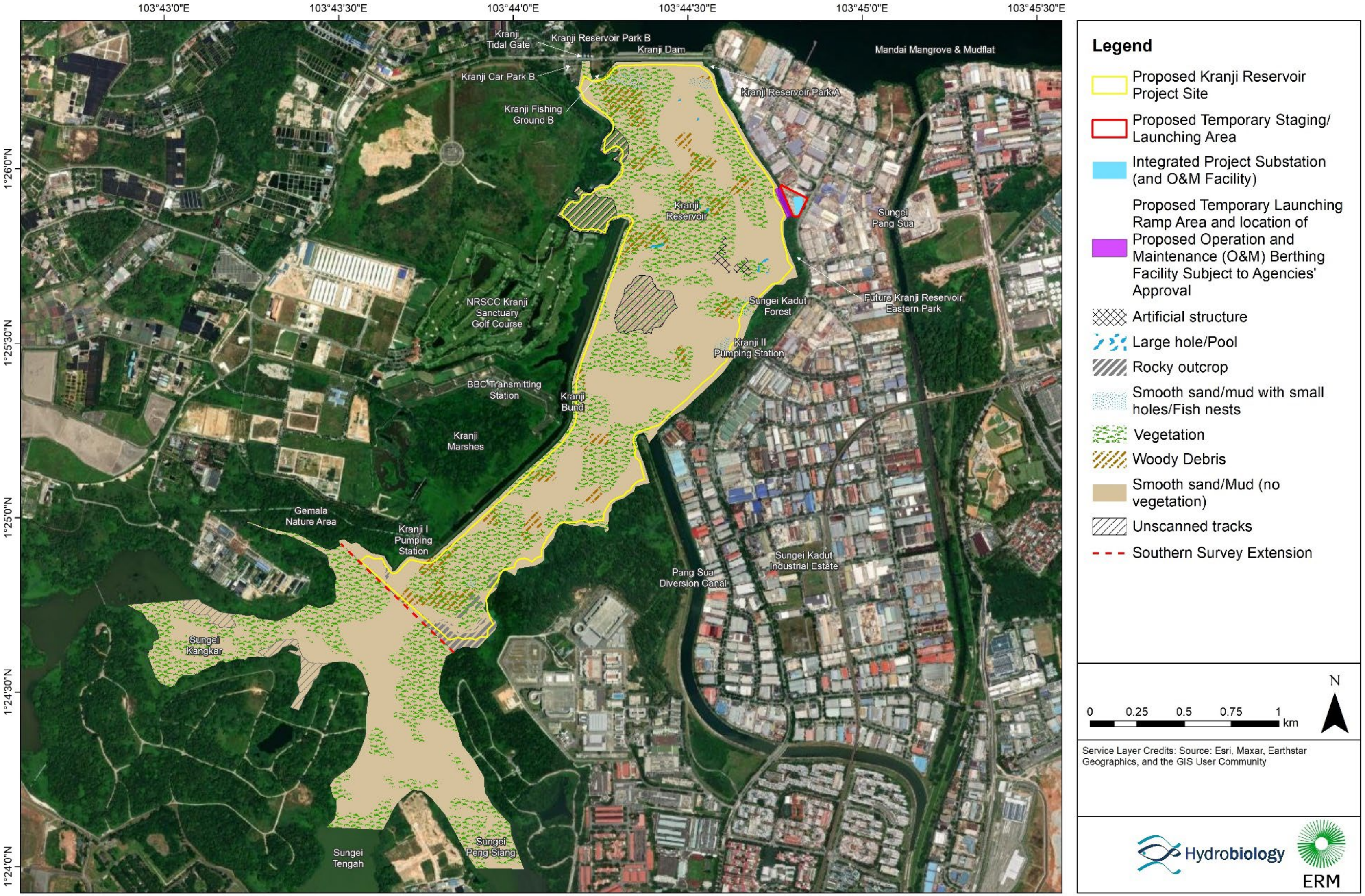


Figure 7-4: Benthic Habitats/ Reservoir Bed Features/ Substrates in Surveyed Area

7.5.2.4 Aquatic Vegetation

- Thirteen (13) aquatic flora species were recorded, none of which are of conservation concern.
- Plant biomass was greatest to the south of the reservoir, which correlates with the high levels of nutrients recorded here.
- The lowest plant biomass was recorded in the east of the reservoir.
- Analysis of satellite imagery (see results *in Appendix 7.4*) revealed that floating vegetation was particularly abundant during March and April 2021. Persistent pockets of floating vegetation, most likely alien and invasive weed species, were found in lentic (still freshwater) areas for the entire period the data were analysed. These areas were located to the east of the NSRCC Golf Club (potentially due to the discharge of nutrients entering the reservoir from the water behind the bund, which promote weed growth), in a small recess of the shoreline south of the PUB's Kranji I pumping station, and in a similar location on the opposite east bank by Sungei Kadut Forest.
- PUB has an aquatic vegetation management programme in Kranji Reservoir where floating macrophytes are regularly (daily) removed by PUB and disposed at a licensed facility.
- Fringing vegetation adjacent to the reservoir included *Ipomoea* sp., clusters of Nationally VU nipah palm (*Nypa frutiscens*) and other native species typically found on tidal rivers. In these areas of dense edge vegetation, the benthos comprised organic substrate e.g. detritus, periphyton and mud. Elsewhere, the fringing vegetation comprised of managed grassland with non-native trees. Bottom substrate in these areas was dominated by rocks and pebbles.

7.5.2.5 Phytoplankton

- Seven phytoplankton phyla with 13 species were identified.
- The abundance of phytoplankton species was high but the taxon variability amongst the species were considered low.
- Biodiversity (Shannon-Biodiversity Index) across the reservoir ranged from very low to medium. This indicates that while the abundance of phytoplankton species may be high, the taxon variability amongst the species were considered low.
- The relatively high abundance of *Aulacoseira* sp. during the survey indicates the reservoir is characterised by warm, well-mixed-nutrient-rich waters with relatively high P-availability, in pH conditions of 7.3 or higher (Tibby et al., 2020). It should be noted however that Kwik et al. (2020) and PUB's long-term routine sampling data indicates cyanobacteria species are most abundant in the phytoplankton assemblage.

7.5.2.6 Zooplankton

- Three zooplankton phyla with 14 species were identified.
- Abundant species included *Keratella* spp. and *Daphnia* spp. These two species are important food sources for fish and predatory invertebrates. *Keratella* spp. are commonly found in eutrophic waters. *Daphnia* spp. are sensitive to pollutants and are used as bio-indicators for water pollution.
- Biodiversity (Shannon-Biodiversity Index) across the reservoir was low-medium, except to the south of the Reservoir Project Site where a high diversity was recorded once in Feb 2021.
- Monthly variability in the abundance of zooplankton feeding guilds was observed, both in terms of overall abundance and relative abundance. These changes are expected to be driven by the inflows of pollutants to the reservoir (in particular phosphorus), e.g. following heavy rain events.

7.5.2.7 Macroinvertebrates

- Benthic macroinvertebrates were generally lower in abundance and species richness in the deeper areas compared to shallower zones in the littoral areas. Deeper areas of the reservoir had very low to low biodiversity (Shannon-Biodiversity Index), whilst shallower areas supported medium to high diversity.
- The areas with the highest taxonomic richness and species abundance in the pelagic zone was at the south beyond the Reservoir Project Site. This is likely to be in response to the mixing of the three rivers and the Reservoir as well as the high nutrients recorded here.
- In the littoral zone, highest taxonomic richness and species abundance was observed at the eastern edge next to Sungei Kadut Forest. This is due partly to the sampling methodology but likely reflects the better quality of benthic substrate (mud and detritus compared to rocks and pebbles) found here. The area is also more complex. It is assumed to receive input of organic matter from the adjacent Sungei Kadut Forest. This allows a different microbenthic community to prevail, dominated by filtering collectors such as shrimps and shredders. Overhanging vegetation also provides shade and shelter for predators.
- The communities were indicative of nutrient-enriched and/ or organically polluted waterbodies (Benthic Quality Index (BQI) and SingScore). The area to the south of the Reservoir Project Site appears to experience least ecological stress although its overall health was also considered “poor”.
- Of note was the reduction in diversity between March and May 2021 following heavy rainfall which washed away part of the benthic community. Recovery was rapid and biodiversity levels returned to previous levels by the next sampling event two months later.

7.5.2.8 Fish

- 68 fish species have been recorded from this study and previous research at Kranji Reservoir. Only eight (<12%) of these species are native.
- One fish species is of conservation concern: Asian arowana (*Scleropages formosus*, Nationally Not Assessed, globally EN). The population is decreasing due to the aquarium trade primarily but also due to habitat change and pollution. Its natural habitat is muddy swamps and flooded forests and it commonly occurs in reservoirs (Yue et al. 2004). It is believed the species was introduced to reservoirs in Singapore, and is not native (Tan et al 2020).
- The largest average number of taxa was detected at the east of the reservoir adjacent to Kranji Marshes (7-13 taxa), with the other locations providing between 2 and 5 taxa.
- Fish biomass was highest in the south of the Reservoir Project Site, see *Figure 7-5*. The biomass here was made up of large fish, present in low numbers. In the central and northern areas of the reservoir the biomass appeared to be made up of a large number of relatively small fish. There is reasonable certainty around these findings, although some limitations in the use of side-scan sonar in areas of floating vegetation did affect survey coverage.
- Smaller fishes were recorded utilising deeper waters within the reservoir (below 3m), notably along the east bank. Larger fish were recorded in the southern area of the reservoir where the confluence of the three rivers converge into the reservoir.

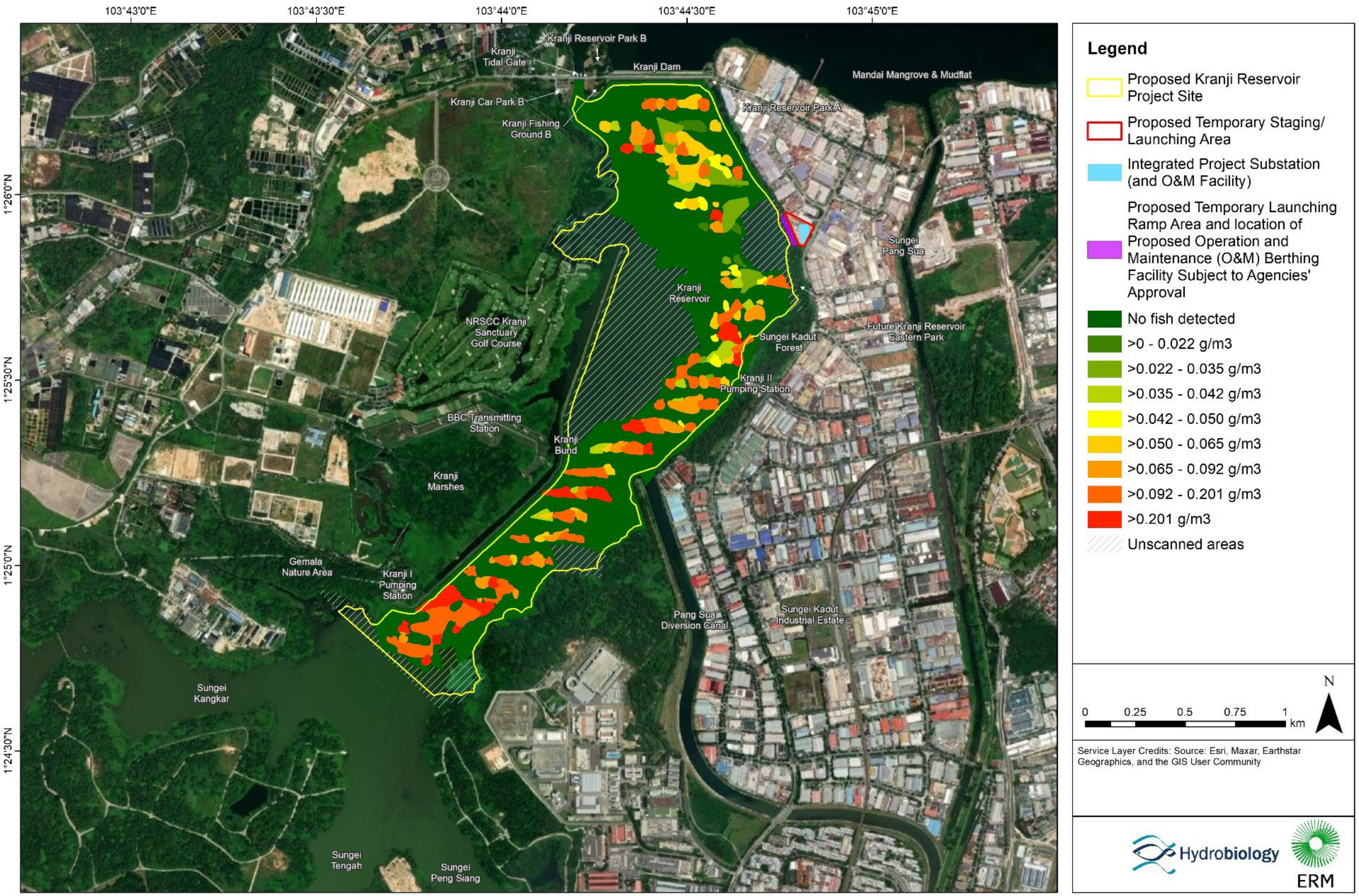


Figure 7-5: Fish biomass per volume (g/m^3) in Kranji Reservoir

7.5.2.9 Waterbirds

- The waterbird community, i.e. all wading or swimming bird species, at the reservoir is very different to that at SBWR, which is the only designated East Asian – Australasian Flyway site in Singapore. Only lesser adjutant (*Leptoptilos javanicus*) and wood sandpiper (*Tringa glareola*) were recorded during the Project's surveys over 12 months as non-breeding visitor and migratory wetland species, respectively, that also use SBWR, although neither was recorded in any great number at the reservoir (two individual lesser adjutants and one individual wood sandpiper). Other nationally rare and uncommon migratory birds of conservation concern recorded in the BIA Study Area were the nationally vulnerable black-capped kingfisher (*Halcyon pileate*) and the nationally endangered watercock (*Gallicrex cinerea*), providing some local value to migratory birds in north-western Singapore. However, both species were only observed once.
- Overall bird density (records of birds that were in contact with ground, vegetation or water surface) was evenly distributed along the reservoir edge (*Figure 7-6*), and was dominated by native resident species, in particular the white-breasted waterhen (*Amaurornis phoenicurus*), striated heron (*Butorides striata*) and the Nationally EN purple heron (*Ardea purpurea*). These waterbirds were frequently observed perching on, or foraging on, macrophytes.

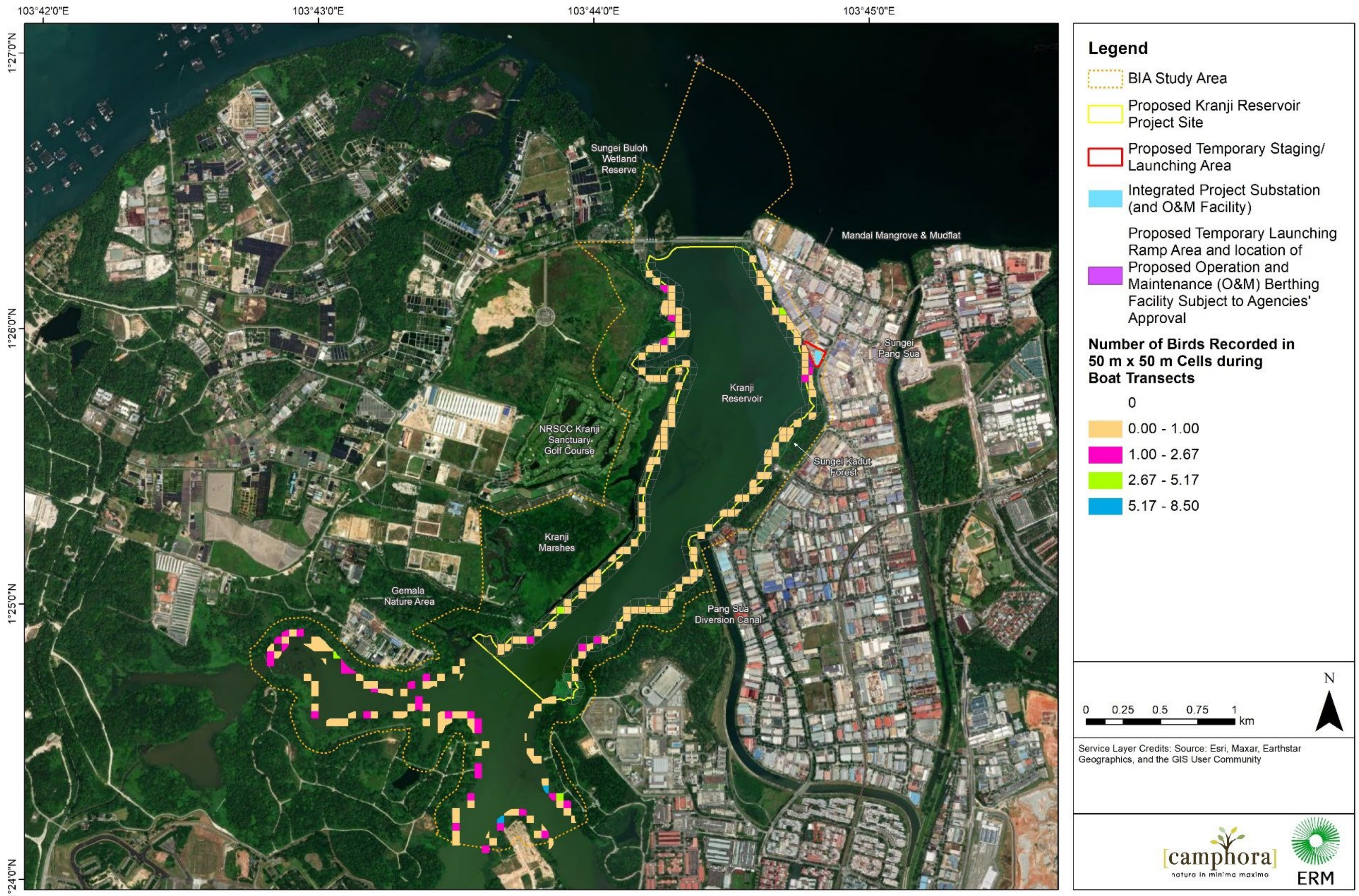


Figure 7-6: Recorded Bird Density along the Edge of Kranji Reservoir

7.5.2.10 Temporal and Spatial Usage of Birds on the Reservoir

- To understand areas of higher sensitivity and therefore of high importance for birds within the reservoir, spatial sensitivity bird mapping was conducted, overlaying observed foraging areas with the Reservoir Project Site (*see Appendix 7.5).*
- For the **purple heron** (*Ardea purpurea*), most foraging activities were observed in August, predominantly at the south western edge but also at the south eastern and north western shore of the Reservoir Project Site (*Figure 7-7*). The bird was recorded foraging 80 times within the survey periods indicated in *Table 7-5*. Foraging took place in both, shallow and deep areas of the reservoir.
- Communal roosts of the **black-crowned night heron** (Nationally EN) were recorded on the east and west banks of the northern part of the Reservoir Project Site *(Figure 7-8).* Up to 16 individuals were recorded roosting although most observations only noted two birds. This suggests the species uses alternative roost sites day-to-day. This species established in Singapore in 1975 at Kranji and other sites, and by 1983 the population had increased to 100 birds and breeding was confirmed. Typically, mangroves and freshwater wetlands provide regular nesting and roosting habitat during the daytime and freshwater wetlands are used for foraging at night. The species has been recorded breeding in October, December, July and August and also year-round (Wells, 1999).
- Other heron species were recorded foraging on the western bank of Kranji Reservoir (i.e. on the Kranji bund) and also to the south of the Reservoir Project Site (*Figure 7-9*). Foraging was recorded 507 times within the survey periods indicated in *Table 7-5*. Heron foraging was also recorded on the mudflat off SBWR and the single sighting of grey heron was recorded near Mandai Mangrove and Mudflats. All heron species observed using the reservoir roost at SWBR, except the black-crowned night heron (*Nycticorax nycticorax*).
- **Little tern** (*Sternula albifrons*) were recorded foraging most frequently on the reservoir (1,282 foraging events). Usually this species was recorded foraging as a single individual but on one occasion 15 individuals were noted. Foraging was concentrated at the western edge and southern part of reservoir, particularly to the area south of the Reservoir Project Site (*Figure 7-10*). Greater foraging activity was recorded during the little tern's breeding season (May – September, inclusive; *Figure 7-10*) as expected given the increased abundance of individuals during this period. Foraging was predominantly recorded in areas with low density in floating vegetation and in both, deep and shallow zones of the reservoir. No nesting sites were recorded during the surveys.

  The little tern population is decreasing in range and numbers in Singapore (Lim & Yong 2011). This resident breeding species has been recorded breeding on coastal landfills at Changi, Seletar and Tuas (Wells, 1999). Most colonies comprised only a few pairs but 100 were recorded at Seletar. It is unclear where this species overwinters. It is listed as Nationally EN. Little tern were observed utilising man-made structures such as railings at the PUB Kranji I Pumping Station, small-scale solar panels on PUB monitoring assets and buoys as perching spots.
- Other **tern species'** foraging mirrored that of the little tern south of the Reservoir Project Site but in lower numbers (*Figure 7-11*).
- Raptors foraging on the reservoir was very low and the one raptor of conservation concern, **grey-headed fish eagle** (Nationally VU), was observed foraging only once on the reservoir (*Figure 7-12*) during the 313 hours of vantage point surveys indicated in *Table 7-5*. Outside the VPS survey a bird was seen carrying fish on three other occasions. Most activity by this species was to the south of the Reservoir Project Site. An active nest was recorded on the eastern bank of the reservoir.

Habitat for grey-headed fish eagle includes reservoirs, lakes, and tidal lagoons in wooded country (Birdlife International, 2022). Original core habitat in the Thai-Malay Peninsular is likely to have been the lower, tidal reaches of large rivers backed by swamp forest. Around 40 pairs have been estimated across the Thai-Malay peninsula as a whole (Wells, 1999). In Singapore, the species is mostly recorded in the Central Catchment Nature Reserve (e.g. MacRitchie and Upper Seletar), flooded disused quarries (e.g. Bukit Gombak), and coastal reservoirs at Kranji, Sarimbun, Serangoon, and mangrove swamps at Sungei Buloh (Yong, 2011). Prey species for the grey-headed fish eagle include tilapias (*Oreochromis* sp.), peacock bass (*Cichla* sp.) and snakeheads (*Channa* sp.) (Yong et al., 2011) as well as water snakes (Birdlife International, 2022). Breeding can occur between January, February and March and July to October, inclusive. The main threats to this species include the loss of undisturbed wetlands, over-fishing, siltation, pollution and persecution. Yong et al. (2016) suggest that the Singaporean population may be increasing, due to the availability of prey, especially large fish introduced into Singaporean reservoirs e.g. *Channa micropeltes, Geophagus altifrons* and *Cichla orinocensi*s, etc. The species' ability to forage in water bodies near urban areas and tolerate heavily degraded habitats, such as secondary scrub, also contributed to its expansion in Singapore.

- Two pairs of **white-bellied sea eagle** were recorded nesting in SBWR north of Kranji Way. These two pairs at SBWR where not observed to utilise the Reservoir Project Site, nor southern survey area for foraging. Foraging by other individuals occurred 52 times (over 313 observation hours) (*Figure 7-13*) and mostly in the eastern area of the reservoir. Up to five individuals were recorded at any one time. The transmission towers to the west of the Kranji Reservoir are used as a perch.

  White-bellied sea eagle are Global LC and Nationally LC. Habitat for the species includes shorelines, large estuaries, large lagoons and reservoirs typically backed by mangroves and swamp forest which are used for nesting where tall emergent timber remains. In Singapore, ten nest sites were recorded between 1987 – 1992, with up to five pairs active in a given season (Wells, 1999). It is likely the population has increased since this time. Prey species for the white-bellied fish eagle include fish and sea-snakes. Breeding can occur between September – late April, inclusive, although young have been recorded in the nest December – early June (Wells, 1999).

- **Brahminy kite:** Two nests were recorded, one in Sungei Kadut Forest the other in the western part of Kranji Marshes. In total, ten foraging events were observed. A higher density of flight paths was observed in the eastern part (near a nest), and south-western part of the reservoir beyond the Reservoir Project Site, suggesting that these two areas are well used by the species.

  Brahminy kite are Global LC and Nationally LC. The species is uncommon more than a few kilometers in land of the coast and large estuaries, comprising broad, muddy mangrove-backed intertidal flats. The species is often found at busy harbours, fish-processing sites and waterside settlements. The Thai-Malay Peninsular, the Johor Straits and Malaka are the core areas where it's distributed. Prey species include young birds, amphibians, carrion including fish and snakes, and insects. Breeding can occur between October to mid-August but mostly in the first half of the year (Wells, 1999).

- Looking at foraging of **all focal bird species**, statistical analysis could not verify valid relationships between foraging events and fish biomass, benthic habitat or vegetation. Visual analysis indicates, however, that most foraging events took place in shallow waters in the middle western part of the Reservoir Project Site and south eastern part of the reservoir beyond the Reservoir Project Site (*Figure 7-15*). VP surveys recorded 35.4 foraging events per hour over the 332.7 ha of the VP survey area over the Kranji Reservoir for all focal species combined, equivalent to 0.1 foraging events per hectare per hour over this area. This is considered a very low level of foraging across the VP survey area.

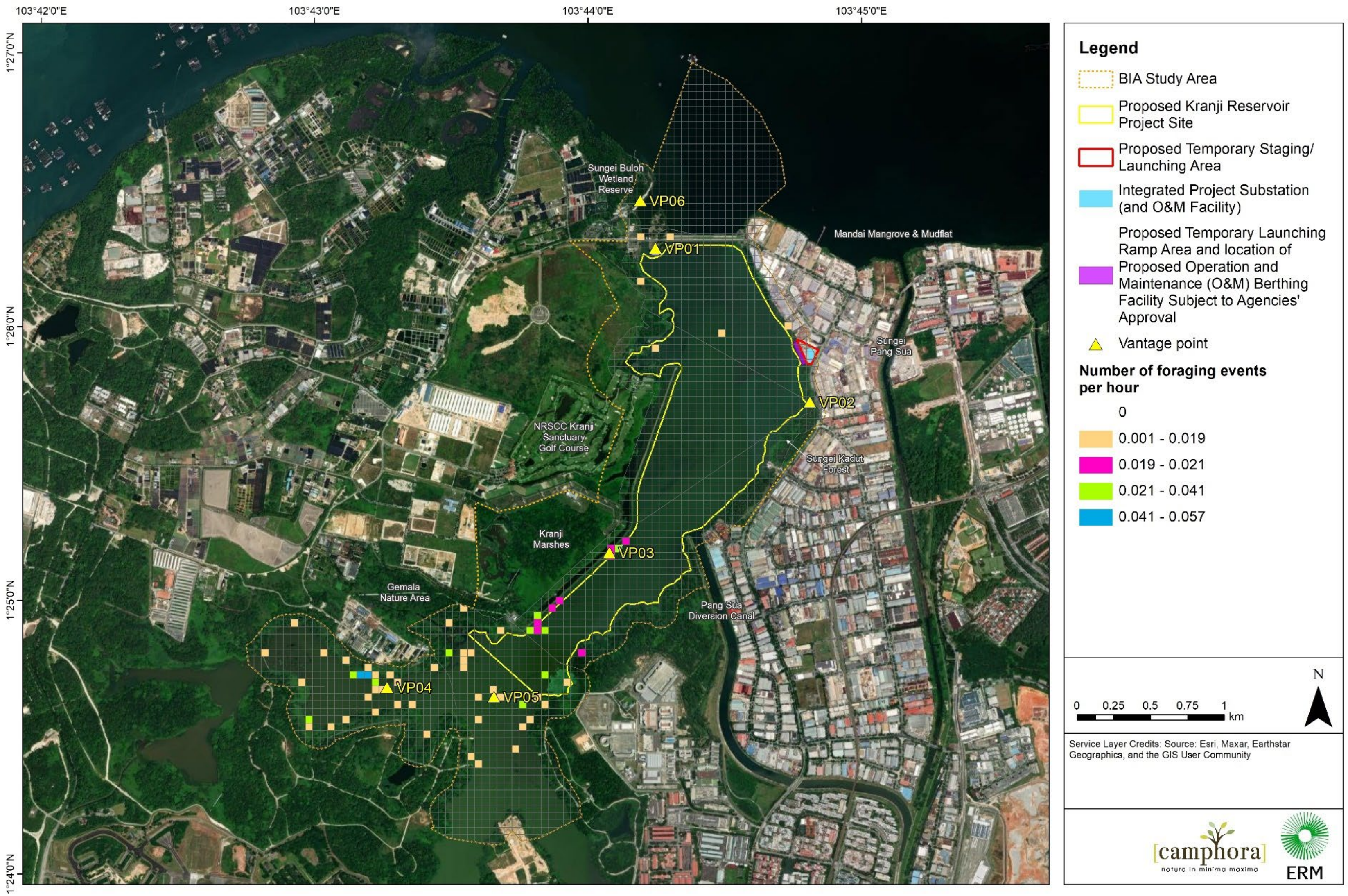


Figure 7-7: Foraging Locations of the Purple Heron (*Ardea purpurea*)

Figure 7-8: Sighting of Black-Crowned Night Heron from Baseline and Verification Surveys

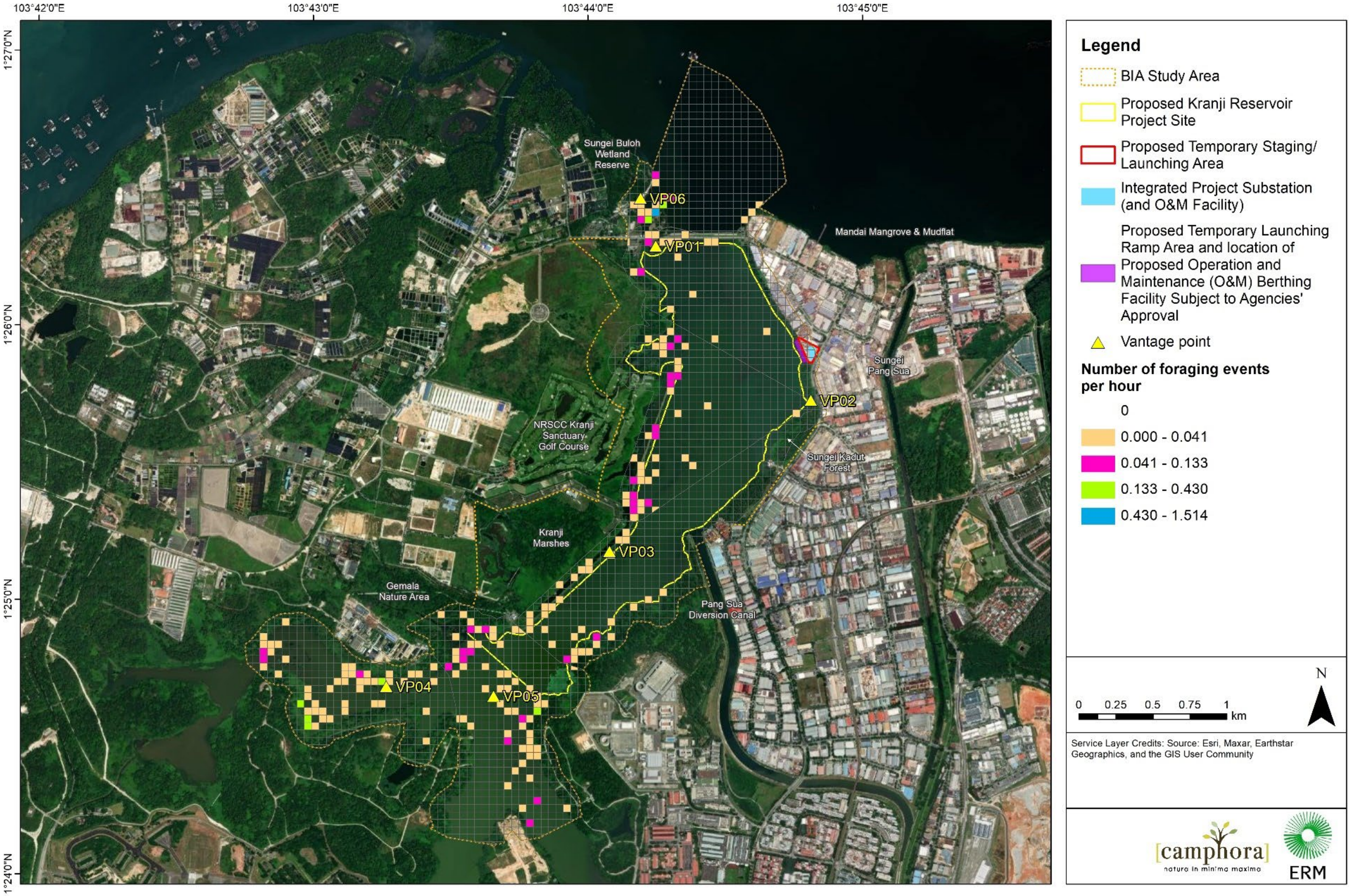


Figure 7-9: Foraging Locations of Other Herons

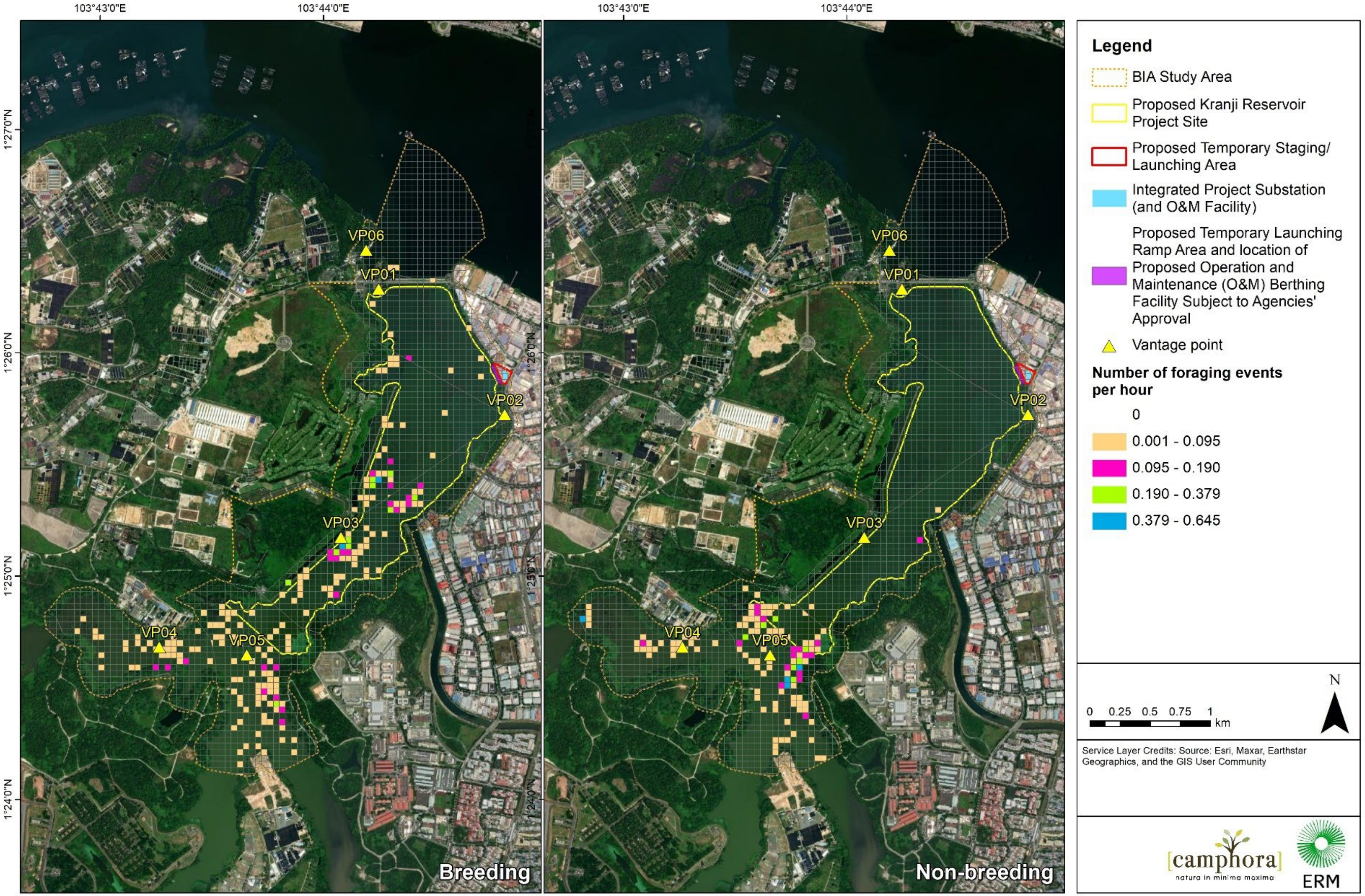


Figure 7-10: Foraging Locations of Little Tern (*Sternula albifrons*) between Breeding Season (May-September) and Non-breeding Season

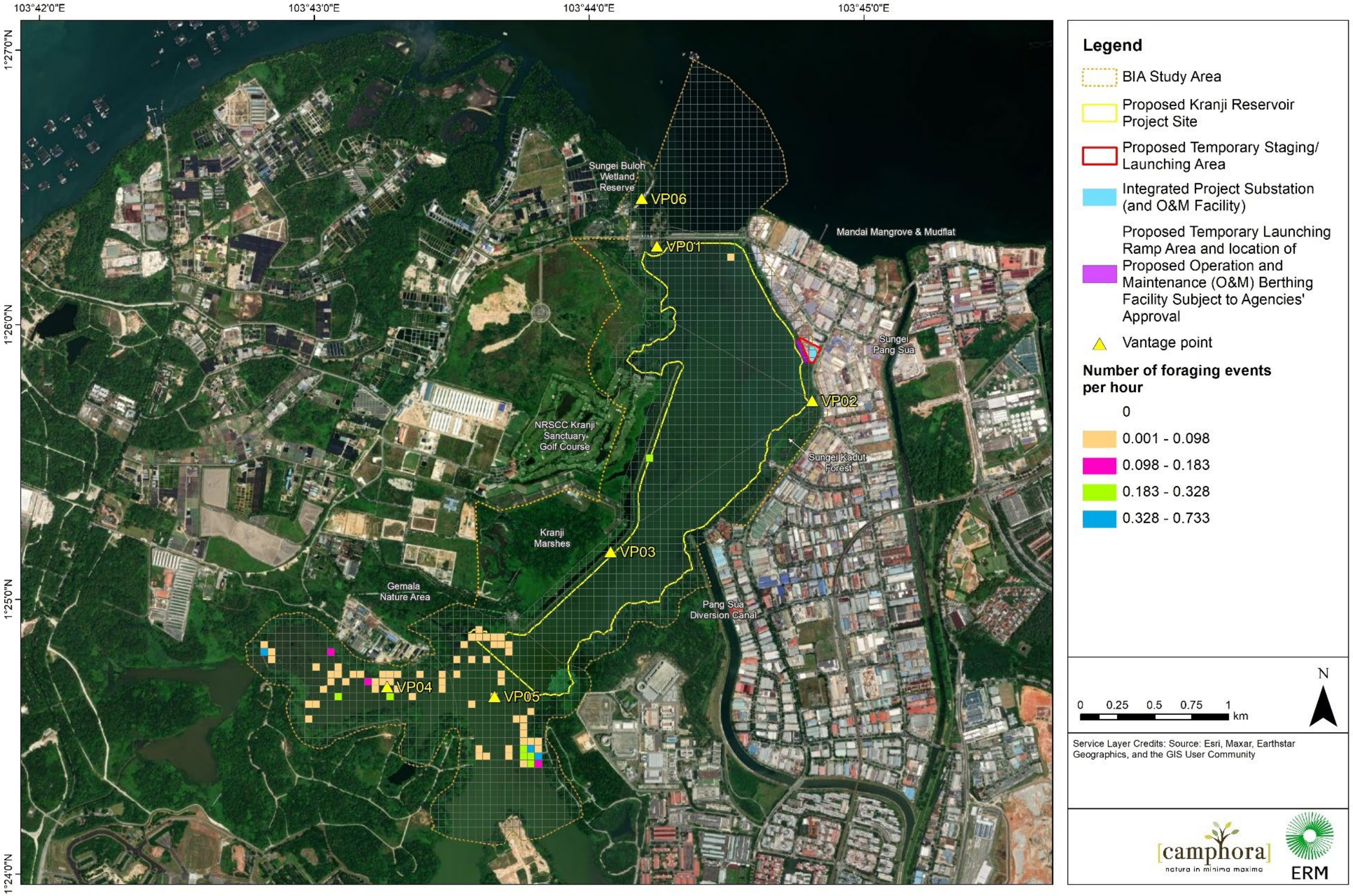


Figure 7-11: Foraging Locations of Other Terns (*Chlidonias* species and *Laridae* species)

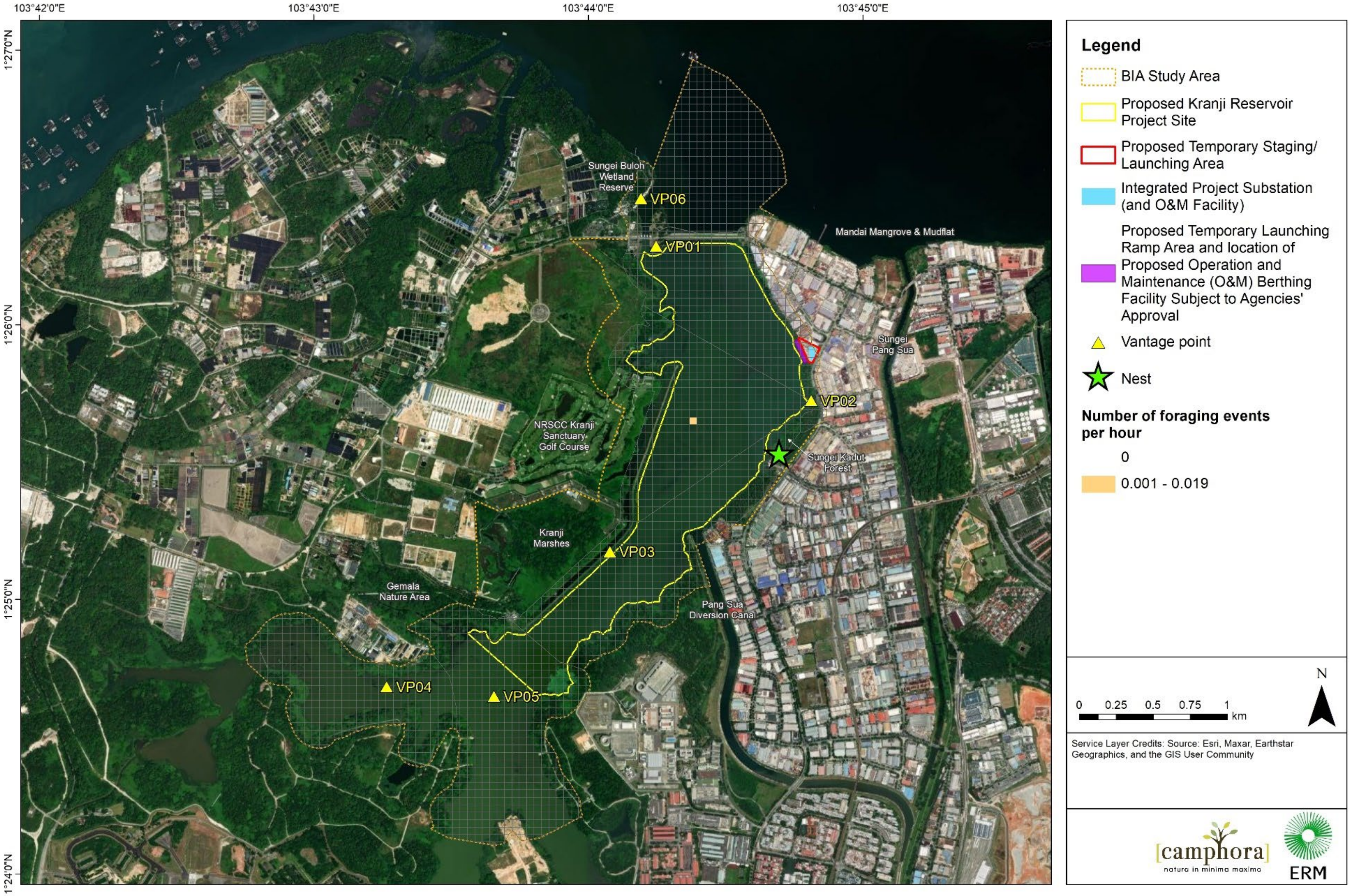


Figure 7-12: Foraging Locations of the Grey-headed Fish Eagle (*Haliaeetus ichthyaetus*)

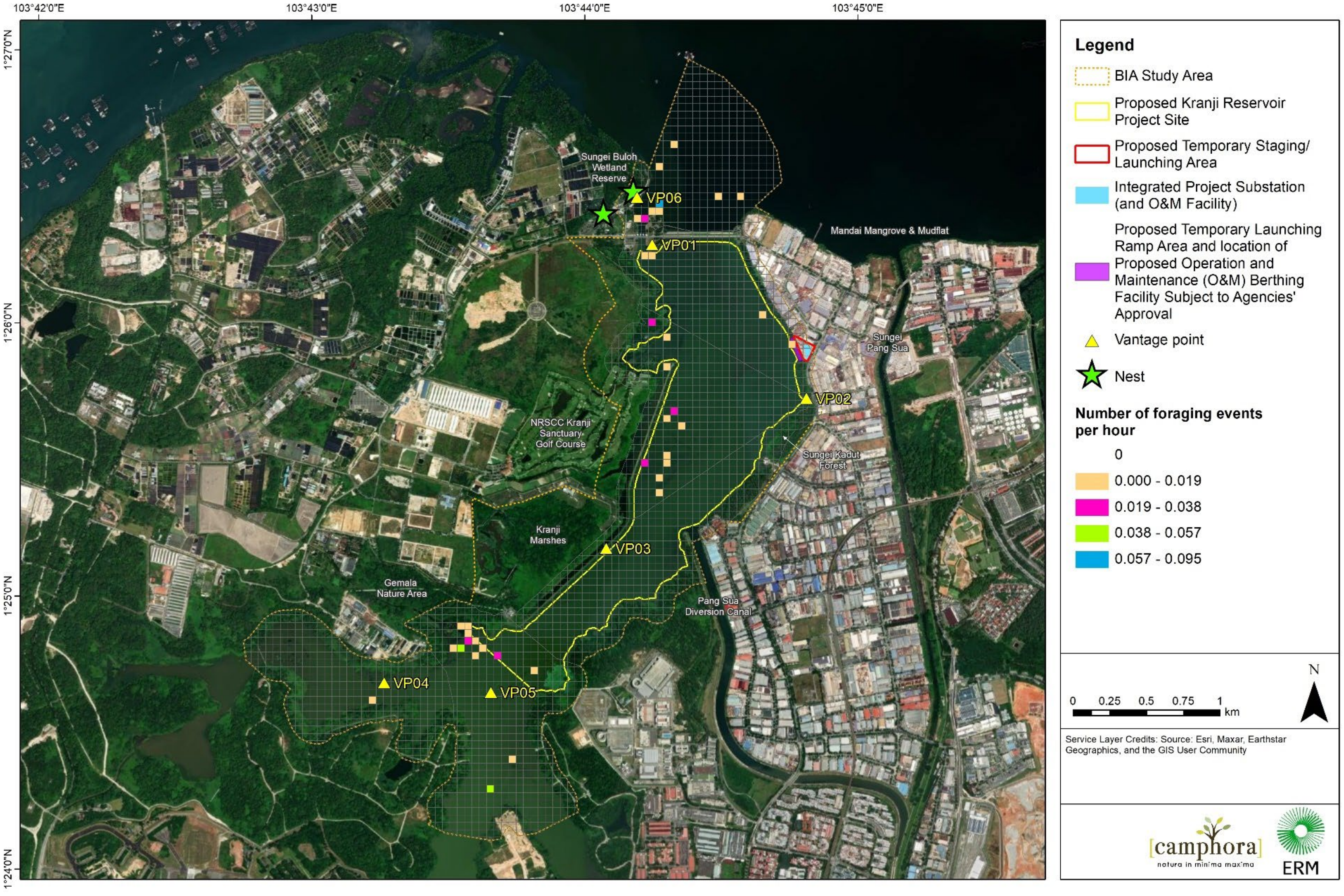


Figure 7-13: Foraging Locations of the White-bellied sea eagle (*Haliaeetus leucogaster*)

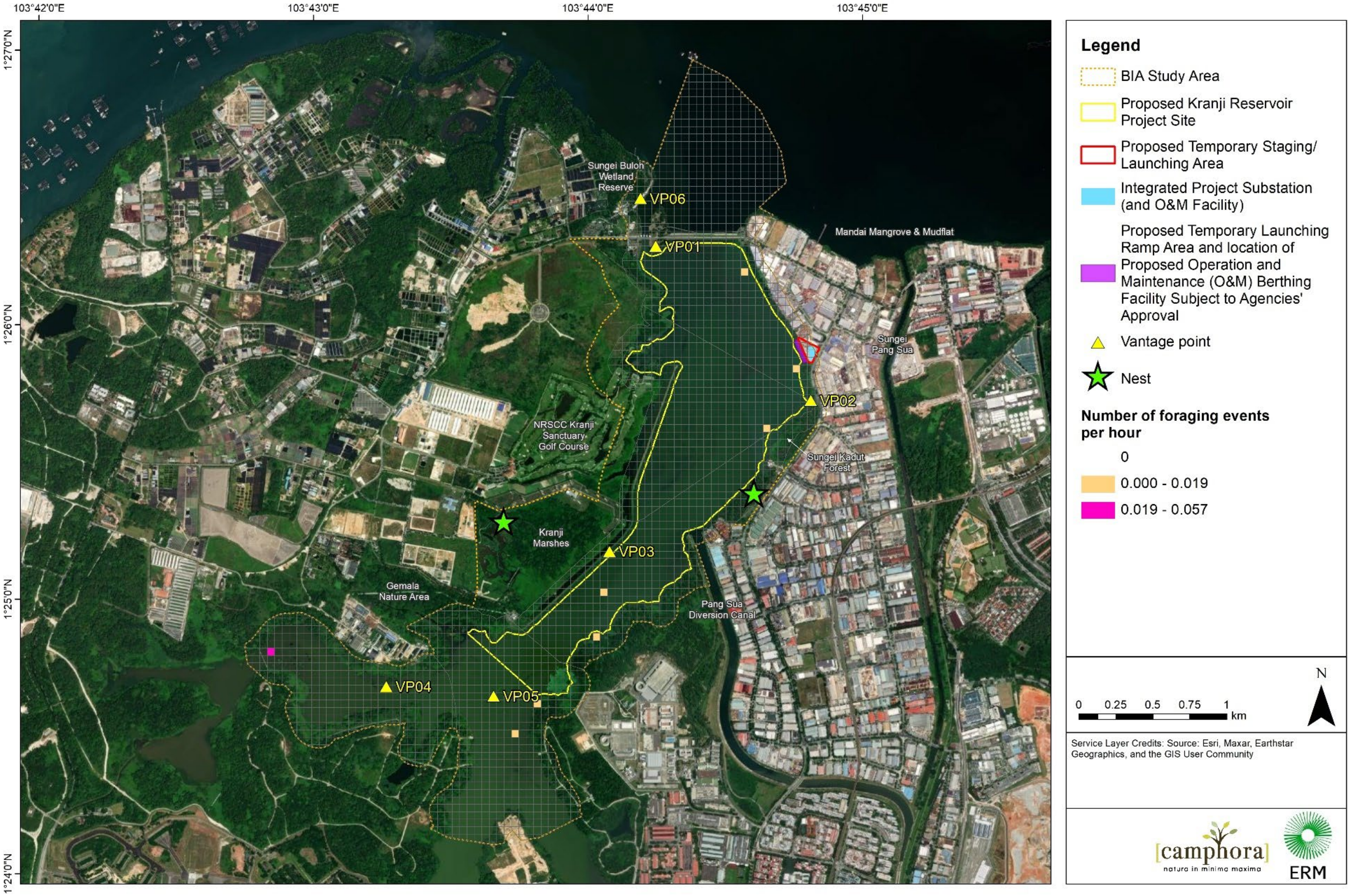


Figure 7-14: Foraging Locations of the Brahminy Kite (*Haliastur indus*)

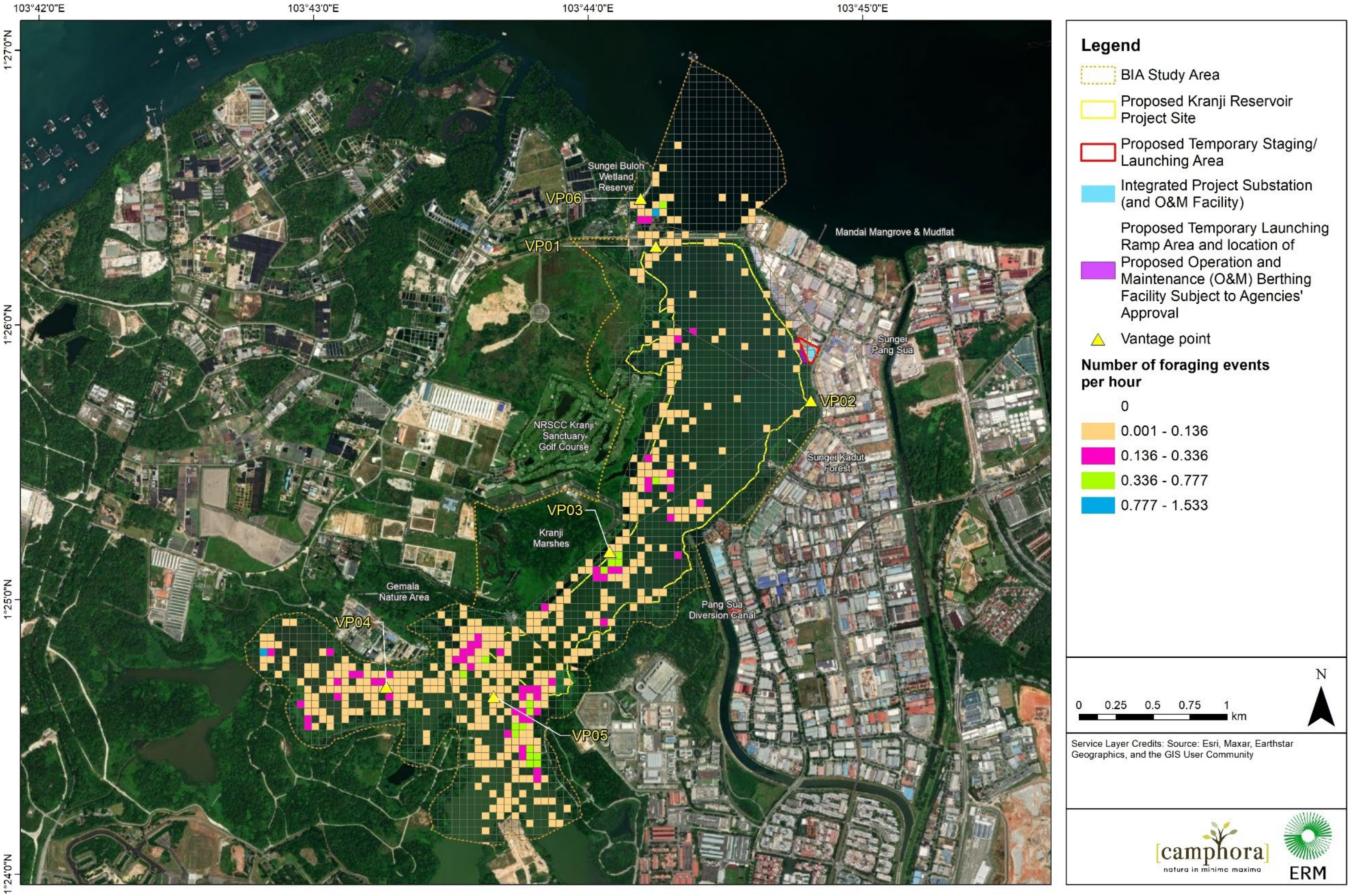


Figure 7-15: Foraging Locations of All Focal Species during Baseline Survey Period (total 313 observation hours)

7.5.2.11 Bird Flight Initiation Distance

As part of the boat transect surveys, data was gathered on birds' reaction to disturbance (i.e. the distances at which they took flight from boats passing). This indicated that the maximum and minimum average flight initiation distances were 25 m and 5 m, respectively, across 24 species recorded.

7.5.2.12 Bat Foraging on the Reservoir

- Five species of insectivorous bat were recorded foraging above or around the edge of the reservoir. None of them are of conservation concern.
  - Horsfield's bat (*Myotis horsfieldii*);
  - Pouch-bearing bat (*Saccolaimus saccolaimus*);
  - Asiatic lesser yellow house bat (*Scotophilus kuhlii*);
  - Black-bearded tomb bat (*Taphozous melanopogon*); and
  - Whiskered myotis (*Myotis muricola*).
- Asiatic lesser yellow house bat was the most common bat within the BIA Study Area (terrestrial and aquatic habitats).
- Whiskered myotis were only recorded over land, and black-bearded tomb bat only in the southern part of the reservoir, outside the Reservoir Project Site.
- Overall, a higher number of feeding buzzes were recorded at the western reservoir edge near the Kranji bund followed by the southern eastern part of the reservoir outside of the Reservoir Project Site. This is likely due to greater connectivity with surrounding vegetation (*Figure 7-16*).
- Four species were recorded foraging within the Kranji Reservoir. Assuming a natural feeding buzz rate of 1.3 per minute (Hügel et al 2017), pouch-bearing bat, Asiatic lesser yellow house bat, and black bearded tomb bat made negligible use of the reservoir, particularly the more open areas, with feeding rates significantly lower than this level. Only Horsfield's bat was recorded at one location where the feeding rate met or exceeded 1.3 buzzes per minute. The site is located around the western edge of the reservoir (*Figure 7-16*).

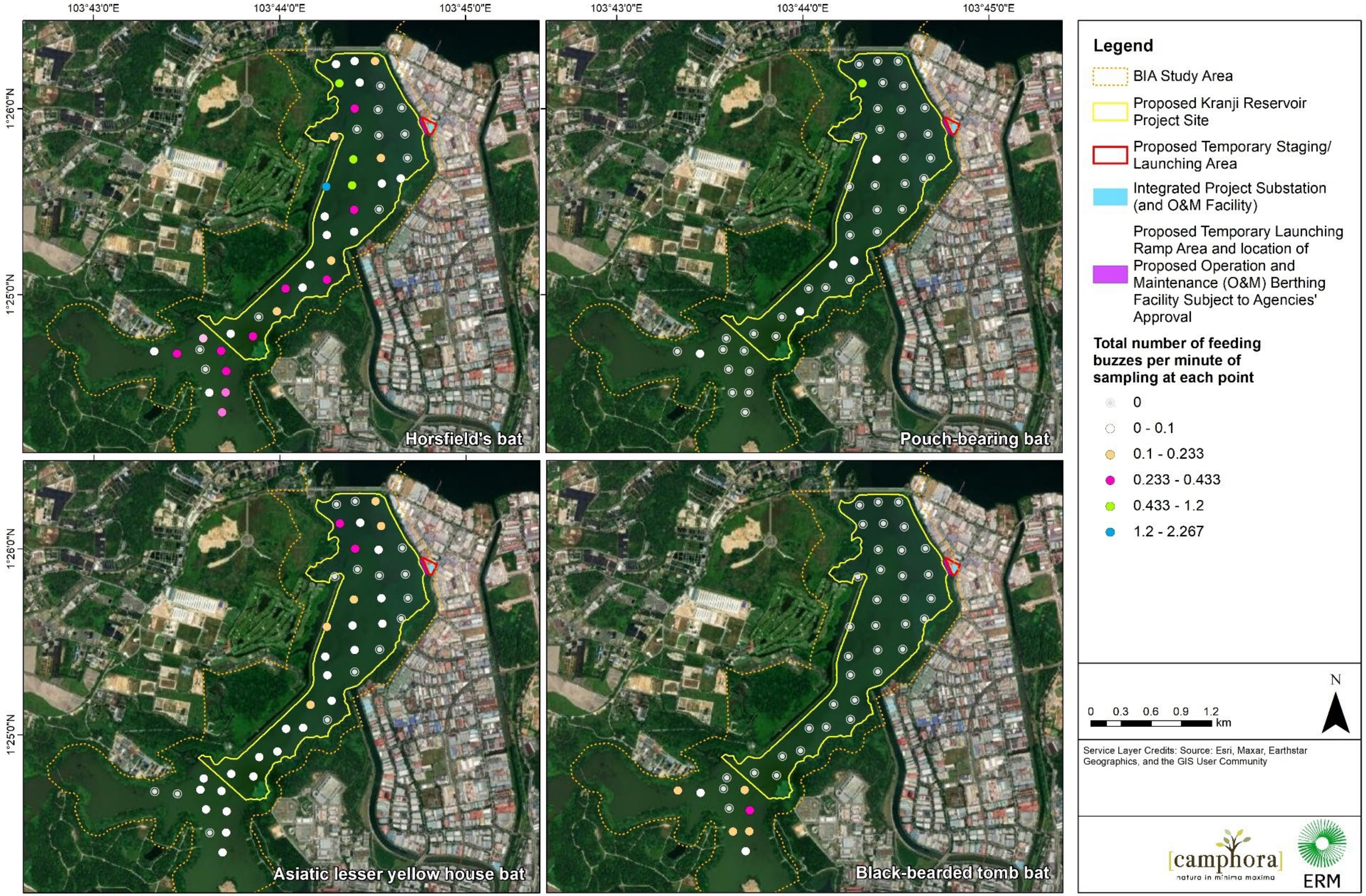


Figure 7-16: Total Number of Bat Feeding Buzzes per Species over Kranji Reservoir

7.5.2.13 Terrestrial Vegetation and Flora

- Scrubland comprised the largest terrestrial habitat type within the BIA Study Area *(Figure 7-17* and *Table 7-8).*
- 222 flora species were recorded plus two plants which could not be identified to species-level. 112 flora species were native and 16 of conservation concern (*Table 7-9*).
- Sungei Kadut forest contained flora species of particular note (*Figure 7-18):*
  - One individual *Philydrum lanuginosum* – nationally Critically Endangered (CR) – and two individuals of Tetrastigma sp. are nationally CR;
  - *Melicope lunu-ankenda* (CR); and
  - *Connarus semidecandrus* (CR).
- Sungei Kadut forest also supported a number of groups of species of conservation significance (*Figure 7-18*), comprising species typically associated to coastal habitats (and probably relics of the area’s previous condition before the river was impounded to form Kranji Reservoir).

Table 7-8: Terrestrial Habitat Areas and Descriptions

Habitat	Description of Habitat	Location in Project Site	Area (ha)
Scrubland	Typically made up of shrubs, climbing/ creeping plants, and grasses as a result of any tree fall, which encourages the colonisation of sun-loving herbaceous plants, resulting in formation of scrubland vegetation (Yee et al., 2016).	This habitat type was found in almost all flora sampling areas.	~36.4
Urban Vegetation	Vegetation that are either situated within the urban areas and/ or are periodically managed by humans for aesthetic or maintenance purposes (NParks, 2020).	This habitat was found along Sungei Kadut Drive and Kranji Way, Kranji Carpark B, Kranji Reservoir Fishing Ground B, NSRCC, and a large section of the Kranji Marshes accessible to the public.	~34.2
Freshwater Marsh	Typically a wetland area that is covered by water and comprises of flora species that can tolerate flooding (NParks, 2020).	Found at Kranji Marshes and along the NSRCC boundary. Water hyacinth was observed on areas where the water level is higher.	~22.6
Abandoned-land Forest	Characterised by fruit trees and other crop plants that have persisted from past cultivation. Although generally dominated by exotic cultivated species, existing and recruited native forest species can establish themselves over time.	Found within the Sungei Kadut forest and Kranji Marshes.	~18.1
Exotic-dominated Secondary Forest (dominated by *Falcataria moluccana*)	Characterised by a canopy dominated by exotic, and even invasive, fast-growing species that can quickly establish themselves on poor soils of recently cleared areas (Yee et al., 2016).	Mostly recorded within the Kranji Reservoir Carpark B Forest, Kranji Marshes and a short strip along the edge of Kranji Reservoir south of Pang Sua Diversion Canal.	~8.7
Mixed Forest (Coastal and Abandoned-land Forest)	Typically comprise of species that are found in coastal areas and flora species that usually occur in an abandoned-land forest, such as fruit trees.	Found on the northern portion and the centre of the Sungei Kadut forest.	~2.4
Cleared Area	Area cleared for development that is not vegetated.	A small portion of land located on the south-west of Kranji Marshes cleared for future development.	~2.3
Infrastructure	Area with built infrastructure that is not vegetated.	Turut Track and BBC Radio Transmission Station, PUB utility station at the end of Neo Tiew Lane 2 and PUB Kranji II Pumping Station which is located in the middle of Sungei Kadut forest.	~2.2
Native Cluster	Patches of area which have distinctively more native species dominating and recruiting within the region.	Recorded mostly along the south eastern shore of Reservoir Project Site and Sungei Kadut forest.	~1.8

Habitat	Description of Habitat	Location in Project Site	Area (ha)
Man-made Waterbodies	An artificially created body of water, such as canals/ drains and ponds, often used for flood control, as a drinking water supply or recreation.	Concrete drains as well as man-made ponds mainly within NSRCC golf course.	~0.8
Total Area			**~129.5**

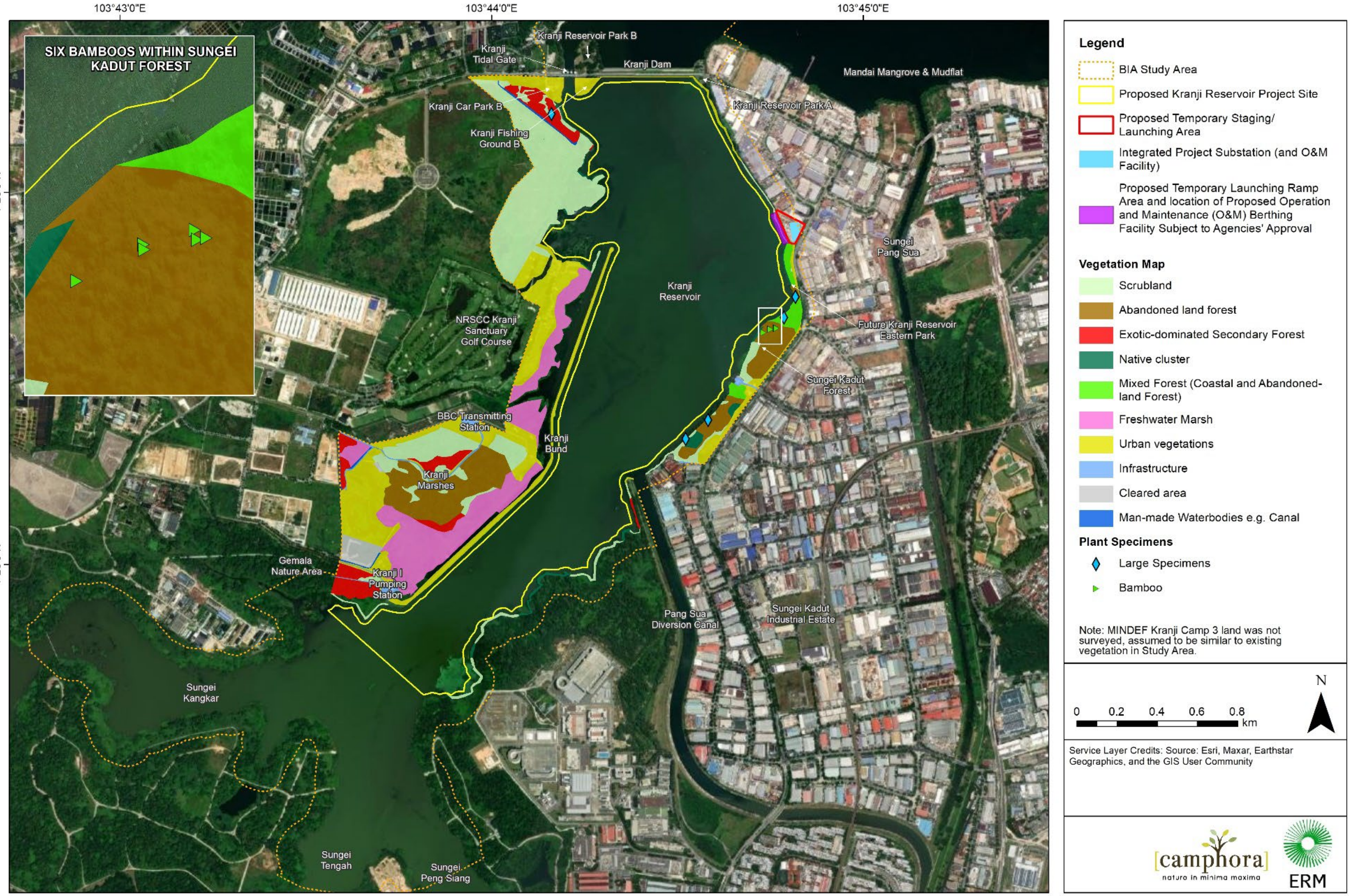


Figure 7-17: Distribution of Habitat and Vegetation Types in the Flora Sampling Area

Table 7-9: Flora Species of Conservation Significance Recorded

No.	Scientific name	Global Status	National Status[a] (bold indicates species of conservation concern)	Habitat
1	*Aporosa benthamiana*	NE	**VU**	Mixed forest
2	*Connarus semidecandrus*	NE	**CR**	Abandoned-land forest
3	*Cyperus brevifolius*	LC	**VU**	N/A[b]
4	*Digitaria bicornis*	NE	**CR**	N/A[b]
5	*Eleocharis dulcis*	LC	**VU**	N/A[b]
6	*Garcinia celebica*	LC	**EN**	Native cluster
7	*Glochidion zeylanicum* var. *zeylanicum*	NE	**VU**	Abandoned-land forest
8	*Litsea umbellata*	LC	**VU**	Native cluster
9	*Lygodium salicifolium*	NE	**VU**	N/A[b]
10	*Melicope lunu-ankenda*	LC	**CR**	Abandoned-land forest
11	*Nypa fruticans*	LC	**VU**	Scrubland; Native cluster
12	*Philydrum lanuginosum*	NE	**CR**	Sungei Kadut forest
13	*Sandoricum koetjape*	**VU**	**EN**	Native cluster
14	*Symplocos fasciculata*	NE	**VU**	Abandoned-land forest
15	*Tetrastigma* sp.	-	**CR**	Mixed forest at northern portion of Sungei Kadut forest
16	*Trema tomentosum*	NE	**VU**	N/A[b]

*Notes: **Bold**: Species of conservation concern (VU – Vulnerable; EN – Endangered; CR – Critically Endangered).*

(a) Red List status of species as of 28 July 2023. This may be subject to change.

(b) The national statuses of six plant species were revised in the latest Singapore Red Data Book (2023). Previously, these plant species were either assessed as exotic/ non-native species or common native species but are now considered to be species of conservation significance. As the revisions were only published after surveys were completed, the locations of specimens of these species were not recorded during the field surveys in 2020–2021.

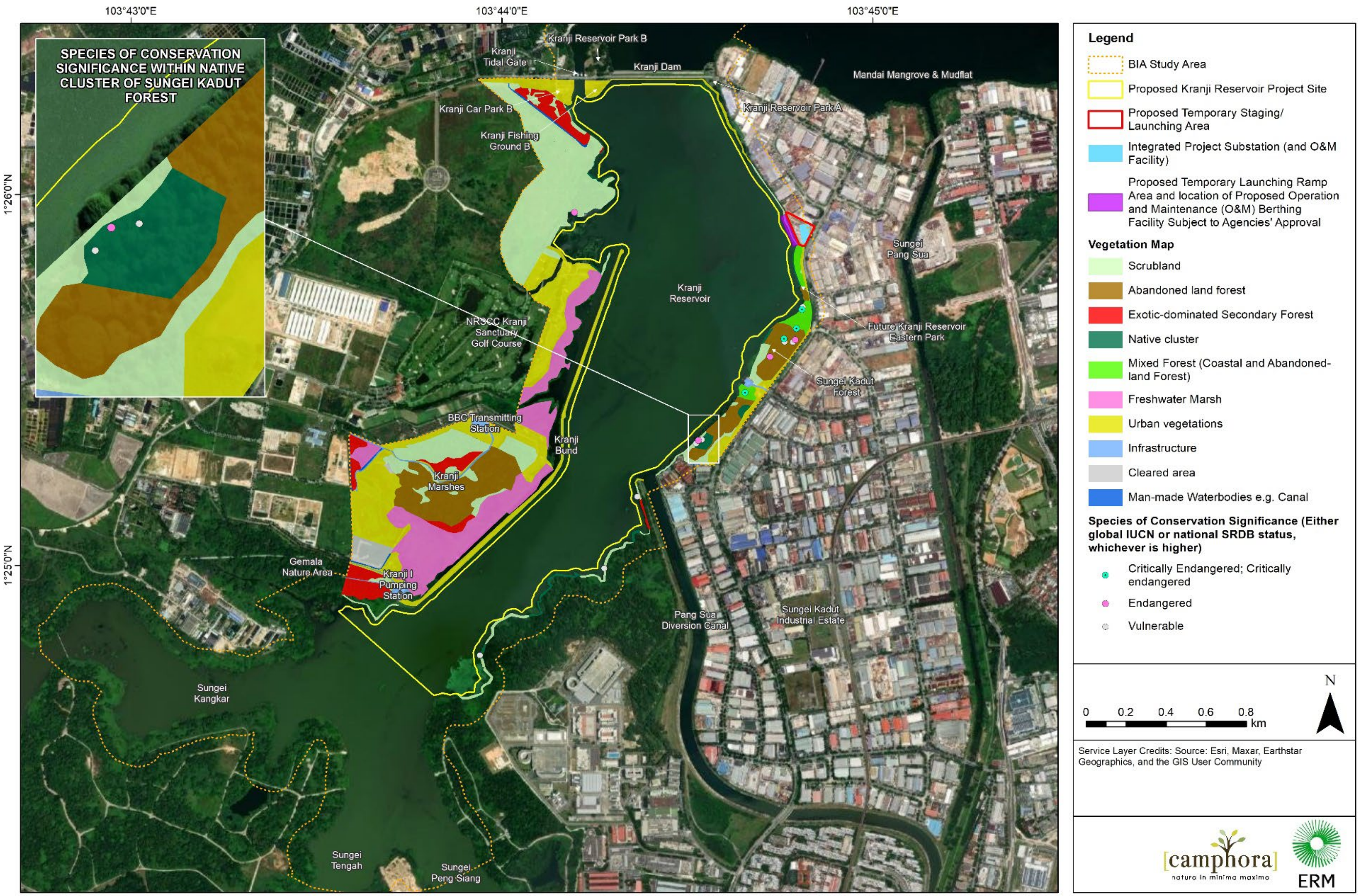


Figure 7-18: Distribution of Flora Species of Conservation Significance in the Flora Sampling Area

7.5.2.14 Terrestrial Fauna

- 404 fauna species were recorded. 23 are species of conservation concern[2] *(Table 7-10).* The main locations for species of conservation concern included: Kranji Marshes and along the Kranji bund (wetland birds), Sungei Kadut forest (birds, odonata), and the forested area beside Carpark B (birds, butterflies and odonata) (*Figure 7-19* and *Figure 7-20*).
- Estuarine crocodile (*Crocodylus porosus*) have been reported from Kranji Reservoir and it is suspected these may be females seeking waterbodies unaffected by tidal movements to lay eggs (Singapore Blue Plan, 2018). This species is known to occur regularly at SBWR. Whilst crocodiles are relatively long-lived reptiles it is unlikely any individuals regularly use the reservoir and no crocodiles have been observed during this Project's frequent baseline studies within the Reservoir. The latest public record at Kranji Reservoir was a carcass discovered on 18 April 2014 (The Straits Times, 2014).

[2] These are defined as nationally or globally CR, EN or VU species. The exact number is subject to revision due to ongoing review of IUCN/ Singapore Red Data Book status (accessed 28 July 2023).

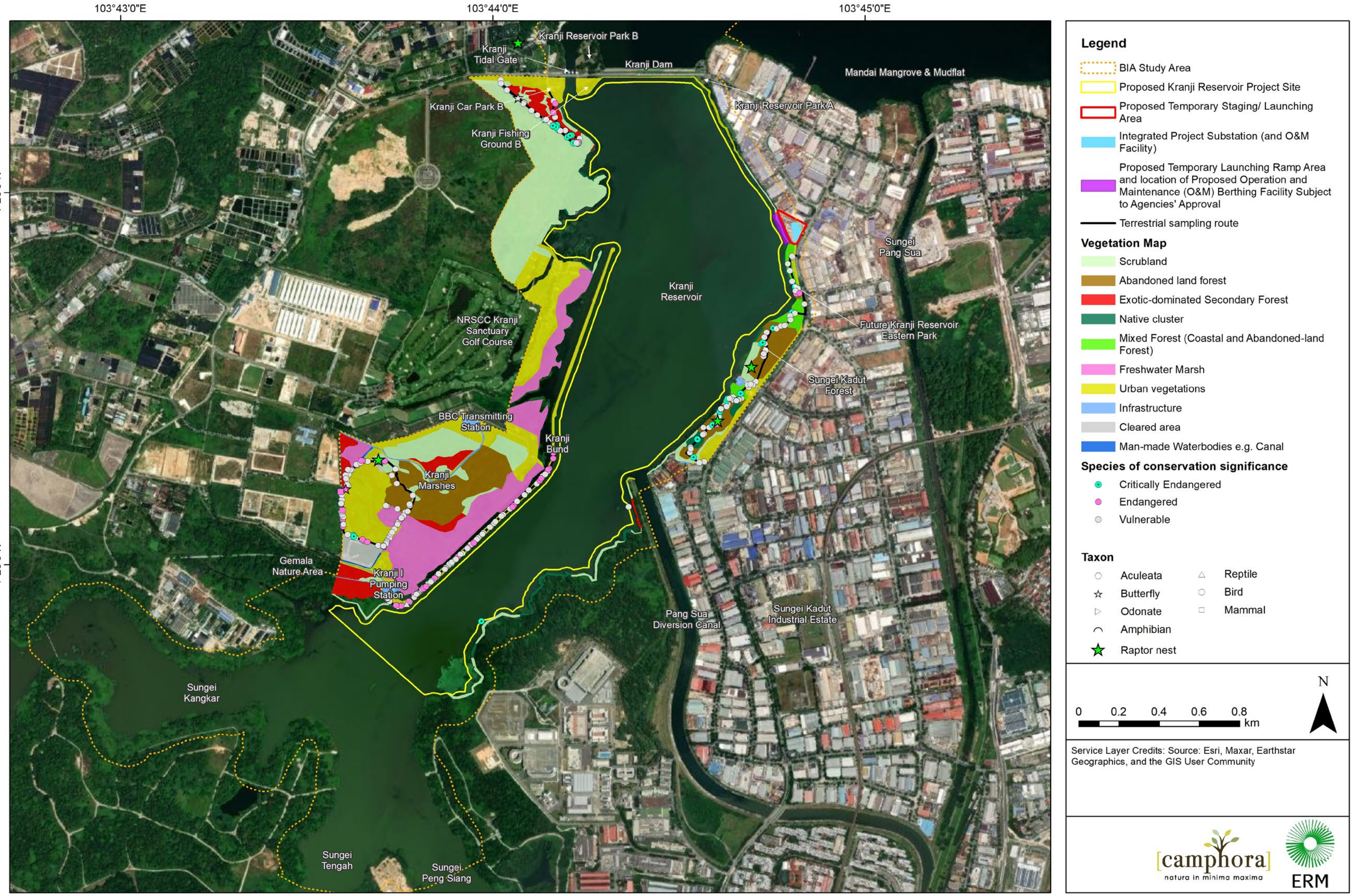


Figure 7-19: Locations of Faunal Species of Conservation Significance along Terrestrial Sampling Routes

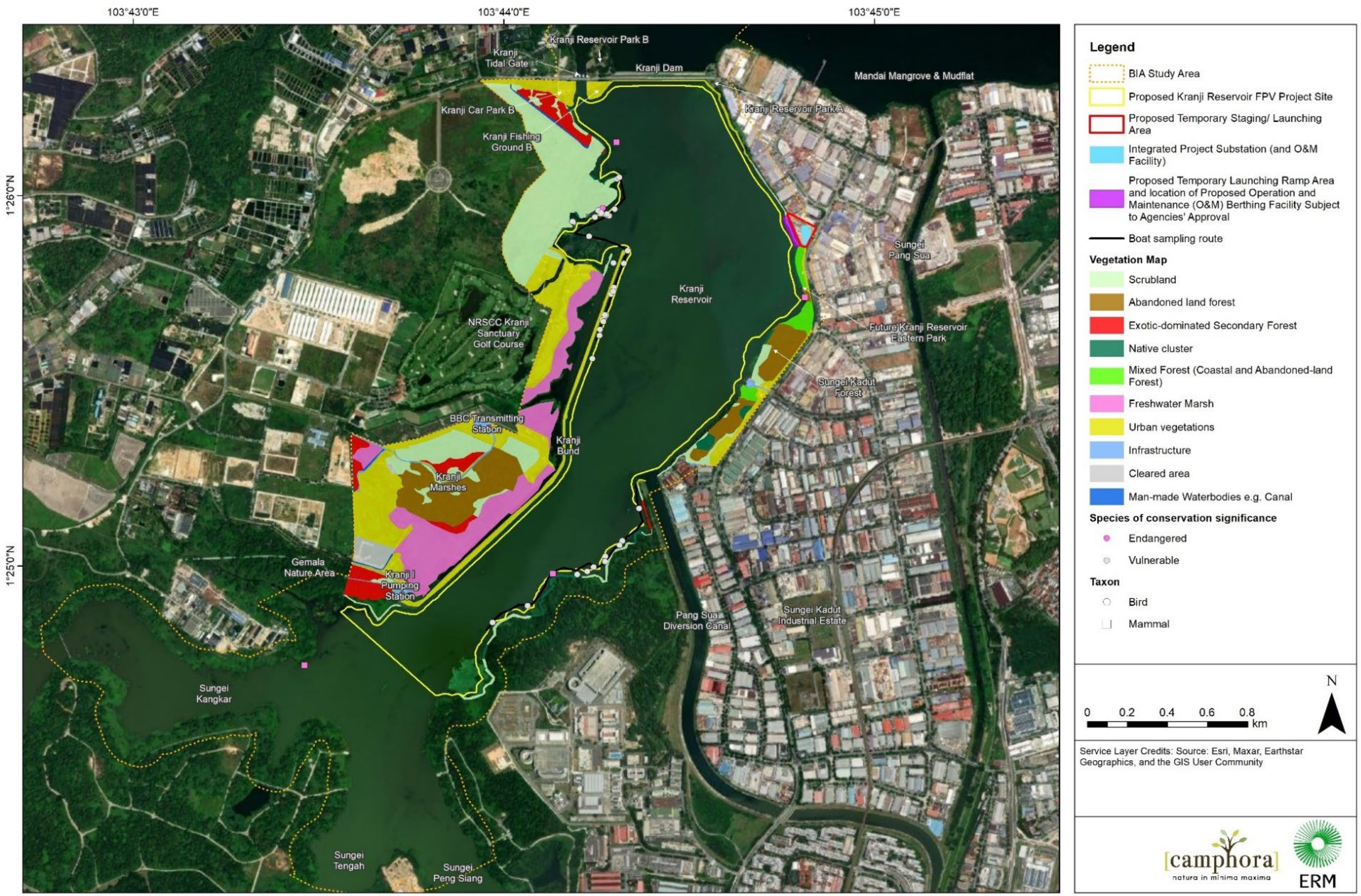


Figure 7-20: Locations of Faunal Species of Conservation Significance along Boat Sampling Routes

Table 7-10: List of Faunal Species of Conservation Significance Recorded along Terrestrial and Boat Sampling Routes and Camera Traps

Taxon	Name	Global Status	National Status[(a)]	Habitat	Comment
Wasp	*Megascolia procer*	NA	**VU**	Exotic-dominated Secondary Forest (dominated by *Falcataria moluccana)*	This species is rare and currently only known from Sungei Buloh (Lee JXQ, pers. comm.). It was sighted once in the Carpark B forest.
Odonates	Nighthawker *Heliaeschna* sp.[(b)]	LC	**CR**	Abandoned-land forest	Previously recorded from Central Catchment Nature Reserve only.
Butterflies	Great swift *Pelopidas assamensis*	NA	**EN**	Urban Vegetation	Recorded in urban vegetation next to Kranji Marshes.
	Spotted grass dart *Taractrocera ardonia lamia*	NA	**VU**	Scrubland	Recorded at Carpark B Forest.
Herptiles	*Asian softshell turtle Amyda cartilaginea*	**VU**	VU	Pond	Recorded at enclosed pond adjacent to the Kranji Bund.
	Malayan box terrapin *Cuora amboinensis*	**VU**	NT	Abandoned-land forest, scrubland	Recorded at Carpark B Forest, Kranji Marshes and Kranji Bund.
	Red-tailed pipe snake *Cylindrophis ruffus*	LC	**VU**	Exotic-dominated Secondary Forest (dominated by *Falcataria moluccana)*	Recorded at Kranji Marshes near NSRCC.
Birds	Grey-headed fish eagle	NT	**VU**	Abandoned-land forest, mixed forest (coastal and abandoned-land forest)	Increasing in range and numbers in Singapore (Lim & Yong 2013). Species ecology described above in *Section 7.5.2.9.*
	Changeable hawk-eagle *Nisaetus cirrhatus*	LC	**VU**	Abandoned-land forest, Exotic-dominated Secondary Forest (dominated by *Falcataria moluccana)*	Increasing in range and numbers in Singapore (Lim & Yong 2013).
	Lesser whistling duck *Dendrocygna javanica*	LC	**EN**	Urban Vegetation	
	Little tern	LC	**EN**	Reservoir	
	Purple heron	LC	**EN**	Abandoned-land forest, mixed forest (coastal and abandoned-land forest), Urban Vegetation, scrubland	Decreasing in range and numbers in Singapore (Lim & Yong 2013).
	Great-billed heron *Ardea sumatrana*	LC	**CR**	Urban Vegetation/ freshwater marsh	Decreasing in range and numbers in Singapore (Lim & Yong 2013).

Taxon	Name	Global Status	National Status[(a)]	Habitat	Comment
	Black-crowned night heron	LC	**EN**	Abandoned-land forest, scrubland, Exotic-dominated Secondary Forest (dominated by *Falcataria moluccana)*	Roosting occasionally on the east and west banks around the north of the reservoir. East bank roost used occasionally by small numbers. Decreasing in range and numbers in Singapore (Lim & Yong 2013).
	Lesser adjutant *Leptoptilos javanicus*	**VU**	**VU**	Scrubland	
	Oriental magpie robin *Copsychus saularis*	LC	**VU**	All habitat types	Increasing in range and numbers in Singapore (Lim & Yong 2013).
	Long-tailed parakeet *Psittacula longicauda*	**VU**	NT	All habitat types, except mixed forest	
	Straw-headed bulbul *Pycnonotus zeylanicus*	**CR**	EN	All habitat types	It is globally CR due to the songbird trade. This has resulted in its extirpation throughout much of its range and making it necessary to list it as a CITES-protected species. Its global conservation status was recently revised in 2018 from EN to CR as populations have been declining extremely rapidly (BirdLife International, 2022). According to Yong et al. (2018), the estimated population size in Singapore is slightly over 200 birds, possibly making up one-third of the global population. In Singapore, the population appears to be growing more stable but habitat loss to development remains a primary threat to the species. 54 records of the straw-headed bulbul during the field survey, which were recorded along all the terrestrial sampling routes. This species occurs in secondary forests and forest edge along water bodies such as reservoirs. The BIA Study Area provides particularly suitable habitat for this species. The species were also seen and heard along both of the shoreline boat sampling routes.
	Buffy fish owl *Ketupa ketupu*	LC	**VU**	Exotic-dominated Secondary Forest (dominated by *Falcataria moluccana)*, scrubland	National distribution is expanding (OwYong, 2016). Recorded once within the Kranji Marshes and a

Taxon	Name	Global Status	National Status[(a)]	Habitat	Comment
					possible resident pair noted twice in the Carpark B Forest.
	Spotted wood owl *Strix seloputo*	LC	**VU**	Exotic-dominated Secondary Forest (dominated by *Falcataria moluccana)*	
Non-volant Mammal	Smooth-coated otter	VU	**EN**	Abandoned-land forest, urban vegetation, freshwater marsh, reservoir	No holts recorded. Seven records during surveys including one group of 8 individuals and another of 6 individuals. Two families known to inhabit the local area.
	Long-tailed macaque *Macaca fascicularis*	**VU**	LC	Abandoned-land forest, Exotic-dominated Secondary Forest (dominated by *Falcataria moluccana)*, urban vegetation	Carpark B Forest.
Bats	Bamboo bat *Tyloncteris* sp*.*	LC	**VU**	Native cluster	Presence was detected on stationary bat detectors located in Sungei Kadut forest. No roost sites located during emergence surveys.

Notes: CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near-threatened LC –Least Concern, NA – Not Assessed.
***Bold**: Species of conservation concern (CR, EN, VU).*

(a) Singapore Red Data Book status of species as of 28 July 2023. This may be subject to change.

(b) The Heliaeschna sp. recorded was not identified to species level but is likely to be either the Nighthawker (Heliaeschna crassa) which is Nationally CR, or Heliaeschna idea which is currently not in Singapore Red Data Book checklist.

7.5.3 Summary of Baseline Findings

- The aquatic habitats within the BIA Study Area are artificial, created by the damming of the Kranji River. Surface water quality and biodiversity are representative of a eutrophic water body, in 2010 Ng et al. noted such state had been recorded at the site for approximately 13 years. Surface water quality monitoring has been ongoing since 1975.
- The waters of the Kranji Reservoir observed during the survey period are generally classified as eutrophic due to elevated levels of nutrients, TN and TP, and chlorophyll-a concentrations. In general, the reservoir is in a relatively stable, deteriorated ecological state.
- Primary production is driven by macrophytes and phytoplankton. These taxa are in competition for nutrients and light and in the absence of PUB's aquatic vegetation management programme water hyacinth would probably outcompete other primary producers.
- Relatively higher levels of biodiversity are recorded within the upper 3 m of the water column, where phyto- and zoo-plankton are distributed. Their communities are characterised by a low species richness and an abundance of relatively few taxa. Those which are more abundant are highly productive in eutrophic conditions, and fuel consumption by higher trophic levels.
- Macroinvertebrate diversity is higher in littoral zones less than 1 m depth. Deeper areas have negligible biodiversity value although relatively high numbers of species richness and abundance were recorded in the south beyond the Reservoir Project Site. These patterns are driven by variation in abiotic factors and, in particular, increased complexity of conditions.
- Heavy rain is a main source of disturbance washing away benthic taxa. Benthic taxa recovered within reservoir samples two months following a storm.
- The fish community consists mainly of introduced species adapted to lentic water conditions. The largest fish occupy the area south of the Reservoir Project Site, while smaller fish are found to the north in the Reservoir Project Site. The southern area appears to be the most productive for fish and this is likely to be a result of the confluence of the three rivers with the reservoir, where mixing of water occurs. All recorded fishes are omnivorous and adapted to foraging on a range of prey items, meaning they likely have some plasticity to cope with changes in the abundance of taxa lower in the food web.
- The waterbird community comprises native species. A number of the birds using the site are of conservation concern globally and/or nationally. The majority of bird activity was concentrated around the edge of the reservoir, particularly in the central western part (near to Kranji Marshes) and to the south (outside) of the Reservoir Project Site, particularly for terns, herons and egrets. Raptor foraging on the reservoir was comparatively low, although nests were recorded for the grey-headed fish eagle and black-crowned night heron (Nationally VU and EN, respectively). With the exception of Horsfield's bat, which recorded one location where the feeding rate met or exceeded established natural feeding buzz rates (mainly around the western edge of the reservoir), bat foraging over the reservoir was relatively low.
- The terrestrial habitats surrounding the reservoir are also modified, secondary habitats. Pockets of fauna and flora communities were recorded comprising species of conservation concern. Sungei Kadut Forest was of particular interest and the adjacent littoral habitat here was richest for aquatic macroinvertebrates. The notable species found terrestrially are likely relics of what was once an intertidal estuary and, being adapted to dynamic estuarine habitats, have been able to persist within the semi-urban conditions found in the BIA Study Area today.

7.6 Sensitive Receptors

The biodiversity receptors identified by the baseline have been evaluated for their relative level of sensitivity and importance (developed based on the sensitivity criteria in *Table 7-3*) in the *Table 7-11* below. These receptors will be considered through the impact assessment.

Table 7-11: Biodiversity Receptors and Level of Sensitivity (refer to *Table 7-2* above for sensitivity criteria)

Sensitive Receptor	Level of Sensitivity		
	High	**Medium**	**Low**
Aquatic Vegetation	None	None	Aquatic plants within the reservoir are dominated by non-native species with no conservation significance of negligible sensitivity. Floating vegetation is being removed on a regular basis by PUB. Overall, aquatic vegetation does not meet criteria for medium or high level of sensitivity.
Terrestrial Plants	Nationally CR (5 spp): *Connarus semidecandrus, Digitaria bicornis, Melicope lunu-ankenda, Philydrum lanuginosum,* and *Tetrastigma* sp. Nationally EN (2 spp): *Garcinia celebica* and *Sandoricum koetjape*	Nationally VU (9 spp): *Aporosa benthamiana, Cyperus brevifolius, Eleocharis dulcis, Glochidion zeylanicum* var. *zeylanicum, Litsea umbellate, Lygodium salicifolium, Nypa fruticans, Symplocos fasciculata* and *Trema tomentosum.*	Remaining species.
Fish	None	Introduced Globally EN: Asian Arowana	Remaining species.
Invertebrates	Nationally CR: Nighthawker not identified to species level (*Heliaeschna* sp.) Nationally EN: Great swift (*Pelopidas assamensis*)	Nationally VU (2 sp.): *Megascolia procer*, Spotted grass dart (*Taractrocera ardonia lamia*)	Remaining species.
Birds	Globally CR: straw headed bulbul (*Pycnonotus zeylanicus*) Nationally CR: great-billed heron (*Ardea sumatrana*) Nationally EN (4 spp): lesser whistling duck (*Dendrocygna javanica*), purple heron (*Ardea purpurea*), black-crowned night heron (*Nycticorax nycticorax*) and little tern (*Sternula albifrons*).	Globally VU (2 spp): lesser adjutant (*Leptoptilos javanicus*) (also nationally VU) and long-tailed parakeet (*Psittacula longicauda*) Nationally VU (5 spp): grey-headed fish eagle (*Haliaeetus ichthyaetus*), changeable hawk-eagle (*Nisaetus cirrhatus*), oriental magpie robin (*Copsychus saularis*), buffy fish owl (*Ketupa ketupu*) and spotted wood owl (*Strix seloputo*)	Remaining species.
Reptiles	None	Globally VU (2 spp): Asian soft-shelled turtle (*Amyda cartilaginea*) (also nationally VU) and Malayan box terrapin (*Cuora amboinensis*) Nationally VU: red-tailed pipe snake (*Cylindrophis cf. ruffus*)	Remaining species.
Non-flying mammals	Nationally EN: smooth-coated otter (*Lutrogale perspicillata*)	Globally VU: Long-tailed macaque (*Macaca fascicularis*)	Remaining species.
Bats	None	Nationally VU: Bamboo bat (*Tyloncteris* sp.)	Remaining species.
Protected Areas and Designated Sites (outside the Kranji Reservoir)	SBWR is an internationally important site for migratory birds. Mandai Mangrove and Mudflats, Kranji Marshes and Gemala Nature Area are nationally recognised areas. All four sites are managed collectively for nature conservation and function as a network.	None	None
Aquatic Habitats (all habitats i.e. littoral and pelagic/ benthic and planktonic etc.)	None	Kranji Reservoir is a man-made waterbody that is eutrophic. As is typical of aquatic systems with high productivity, the biodiversity levels are low. The majority of its aquatic biodiversity is of no conservation concern, except for the introduced but globally EN Asian arowana fish. The reservoir's biota comprises mostly non-native flora and fauna adapted to lentic and eutrophic conditions. The biota are generalist feeders and adapted to periodic disturbances such as wash outs, pollution pulses and ongoing removal of macrophytes by PUB. In terms of aquatic habitats and the species these support, the sensitivity of the aquatic habitats of Kranji Reservoir itself is low. However, the aquatic habitats in Kranji Reservoir have secondary value through their functioning to support terrestrial species above the surface of the water. The reservoir surface is used for foraging by number of high and medium sensitive fauna (see rows above). It is not considered that this foraging habitat is of critical importance to the conservation of these species and nor does the site support globally or nationally significant concentrations of these CR or EN species (e.g. 0.5% of global population or significant	None

Sensitive Receptor	Level of Sensitivity		
	High	**Medium**	**Low**
		concentration of nationally listed CR or EN species). The reservoir also does not regularly support >1% of the global or national population of migratory or congregatory species[(a)]. The reservoir functions as part of the SBWR network providing a buffer to the Protected Areas. Whilst it does not support similar bird communities as these adjacent Protected Areas, it does act as an ecological buffer between existing development to the east and the designated sites to the north and west. This qualifies the aquatic habitats in Kranji Reservoir as medium sensitivity according to *Table 7-3.*	
Surrounding Terrestrial habitats	■ Urban Vegetation and Mixed Forest and Abandoned-land Forest (mainly in Sungei Kadut Forest which supports a nationally significant population of a previously considered extinct plant *Philydrum lanuginosum* (now CR) and individuals of the Singaporean *Tetrastigma* sp. population. Singapore also supports one-third of the global population of straw-headed bulbul (Globally CR). ■ Freshwater Marsh at Kranji Marshes and along the edge of the NSRCC Golf Course supports freshwater marsh habitat for bird populations of high value species (see rows above) and sits within a nationally designated site. ■ Exotic-dominated Secondary Forest adjacent to Kranji Reservoir Park (habitat for medium value plants and medium and high value birds, see rows above).	■ Scrubland (habitat for medium value plants, see rows above) next to the Sungei Kadut Forest. ■ Native Clusters (habitat for medium value plants, see rows above).	■ Cleared Areas, Infrastructure, and Man-made Waterbodies

Notes:

(a) Definition criterion for item 1 for Critical Habitat by the International Finance Corporation Performance Standards 6 (IFC PS6).

7.7 Impact Assessment – Construction and Operation

7.7.1 Construction Phase

7.7.1.1 Potential Sources of Impact

Land-based construction activities for the proposed temporary Staging/ Launching Area and integrated Project Substation will take place on already-disturbed, cleared land within Sungei Kadut Industrial Estate; vegetation clearance along the shoreline will be required to enable waterfront access for the Launching Ramp and O&M berthing facility construction. In-reservoir construction works could result in potential impacts to the aquatic flora and fauna, and terrestrial fauna.

Impacts are localised within the BIA Study Area only. No regional or global impacts were evaluated as part of this project.

Specific activities within these areas which may result in impacts to biodiversity include the following:

Proposed Temporary Staging/ Launching Area & Integrated Project Substation – Construction Works on Land

- Preparation of the proposed temporary Staging/ Launching Area, including ramp into reservoir;
- Assembly of the FPV system; and
- Construction of Integrated Project Substation and land-based connector cable.

FPV – Construction Works on/ in Water

- Geotechnical/ site investigation in reservoir;
- Deployment of anchors/ ballasted foundations/ piles and mooring lines;
- Launching, towing and installation of FPV and ancillary equipment at designed locations;
- Installation of connector cables (between FPV islands and to shore); and
- Trimming of aquatic vegetation.

Unplanned Events (on water or land)

- Fire and Explosion; and
- Environmental Spill.

The impacts that may arise due to the above activities/ events that are considered in *Section 7.7.1.3* include:

<u>Aquatic Biodiversity:</u>

- Benthic habitat/ fauna loss/ disturbance;
- Elevation of suspended sediments within the reservoir;
- Elevation of pollutants and/ or nutrients within the reservoir;
- Changes due to trimming aquatic vegetation; and
- Disturbance to aquatic fauna (piling, boat movements).

<u>Terrestrial Biodiversity:</u>

- Terrestrial habitat clearing/ fragmentation;
- Disturbance to terrestrial fauna (piling in reservoir);
- Disturbance to terrestrial fauna (land-based worksite);

- Disturbance to terrestrial fauna (in-reservoir piling and land-based worksite night lighting);
- Disturbance to terrestrial fauna (boat movements and use of helicopters); and
- Generation of dust from land-based worksite.

Aquatic and/ or Terrestrial:

- Introduction and spread of invasive alien species.

Protected Areas (Sungei Buloh Nature Reserve Network):

- Release of suspended sediments, pollutants or nutrients outside of the reservoir into the Johor Straits, e.g. to SBWR or Mandai Mudflats due to unplanned events during construction; and
- Loss/ degradation of integrity of Protected Areas.

Unplanned Events:

- Habitat degradation from unplanned event of fire/ explosion and environmental spills.

7.7.1.2 Embedded Controls

Embedded controls measures (physical or procedural) that are planned to be put in place as part of the Project design, construction and operation from the outset. These actions are to manage the Project's compliance with relevant legislation, regulations and guidelines in relation to development and biodiversity. The below are further to the construction embedded controls outlined for Surface Water Quality (*Section 6*), Air Quality (*Section 8*), Airborne Noise and Vibration (*Section 9*), Soil and Groundwater (*Section 10*) and Vectors (*Section 11*).

Embedded controls beyond those identified in *Section 7.2* include good practice to be implemented such as:

For Developer/ Owner and Contractor staff:

- Environmental Manager to monitor, supervise and evaluate works that may impact on biodiversity (as identified in this EIA); and
- Providing tool-box talks and training to all site personnel prior to commencement of construction to communicate the Project's commitments regarding biodiversity and how it shall be managed, including:
  - Ecologically sensitive areas;
  - Proper protocols and reporting procedures to be adopted when wildlife is encountered;
  - Need to be cautious when operating machinery to avoid injury/ mortality to fauna;
  - Need to keep all work places safe for wildlife (e.g. when not being actively worked on), storage and use of hazardous materials, and food/ waste management;
  - All workers will be prohibited from feeding animals; and
  - Refresher training will be provided every 6 months during the construction phase for all new and old personnel.

For tree/ vegetation clearance:

- Regulating contractor movements and activities to areas only within the construction and operational footprint, and prohibiting access to other areas;
- Permit to Clear process to control and limit the clearing of vegetation to the minimum necessary, and staging vegetation clearing where practicable, e.g. seek NParks approval for felling of trees with girth >1m;

- All terrestrial habitat clearing at the shoreline will be minimised to avoid unnecessary tree and vegetation removal to the required footprint only; and
- Seek approval from NParks before carrying out restricted activities as outlined in the *Parks and Trees Regulations*, Part 2, Division 1 and 2.

For FPV Layout:

- Shoreline setbacks and FPV spacing:
  - Minimum 25 m around the reservoir edges, including for boat access;
  - Setback at least 100 m from the Kranji tidal gate and dam and thus SBWR and Mandai Mangroves and Mudflats to the north;
  - 50 m vessel corridors at prescribed water depths for PUB operations, including:
    - North-south vessel corridor on eastern reservoir edge (depth requirements can only be accommodated along the eastern portion of the reservoir) – resulting in generally >50 m eastern shoreline setback to FPV infrastructure; and
    - East-west vessel corridor to PUB intake channel (the channel on the western side of Kranji bund).
  - O&M and fire and emergency vessel corridors, required for operational requirements and SCDF:
    - Spacing between large FPV islands;
    - Breaking up of large FPV islands with 30-40m vessel corridors, to be incorporated in the detailed design stage by the Developer/ Owner.

  These measures will avoid and reduce impacts to the biodiversity-rich littoral areas, especially on the east bank, and enable some continued foraging in the western edges by birds i.e. little tern and herons.

For in-reservoir connector cables:

- No underwater trenching (dredging) to lay connector cables which reduces the direct loss of benthic habitat and the impacts of suspended sediments on surface water quality and biodiversity.

For night-time works on land:

- Use directional lighting at night to avoid lighting directed at, and minimise light spill, especially to Kranji Marshes and Sungei Kadut Forest and reservoir edges; and
- Minimise night-time security lighting as far as practicable whilst enabling a safe and secure site.

For work boats:

- Speed limit of 5 knots will be implemented, particularly in shallow areas or close to the shore to minimise disturbance to the wildlife.

For in-reservoir and on land works:

- Preventing the introduction, movement and spread of invasive species on- and off-site, for example through inspections and washing down of vehicles or boats / barges, and the processes for removing non-native alien species; and
- FPV Panels to be coated with anti-reflective materials to maximise light absorption and minimise glare or reflection in order to reduce risk of bird collisions.

For on land works:

- Locating the proposed temporary Staging/ Launching Area and integrated Project Substation on a brownfield (previously developed) land parcel in Sungei Kadut Industrial Estate to avoid and minimise vegetation clearing for these components;
- Integrated Project Substation to be set back from the Kranji Reservoir shoreline;
- Integrated Project Substation to follow the principles of the Urban Design Guidelines, Guidelines on Greenery Provision and Tree Conservation, and greening/ planting, utilising native species wherever possible;
- Shoreline adjacent of the proposed temporary Staging/ Launching Area to be re-planted after construction, where feasible;
- Using existing roads for construction and maintenance access. No new haul road or access will be created;
- Use only fully biodegradable erosion control blankets (ECB);
- Maintenance of worksite hoarding and repair of damages on a timely basis; and
- Separate storage of top- and subsoils, and reinstatement in correct order.

For emergency planning:

- Prepare and keep up to date a Spill Prevention and Emergency Response Plan detailing how fires/ explosions and spillage, leakage or accidents involving hazardous materials will be dealt with and ensure that workers on site have received adequate training and instruction to enable them to implement the emergency action plan in the event of an emergency.

7.7.1.3 Impact Assessment and Mitigation Measures

A summary of the assessment of impacts to biodiversity and proposed mitigation measures during Project construction is provided in *Table 7-12*.

Table 7-12: Impact Assessment for Biodiversity (Construction Phase)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
AQUATIC BIODIVERSITY					
C1	**Benthic habitat/ fauna loss/ disturbance**	■ **Nature**: Benthic habitat and fauna loss or degradation is considered **negative** for aquatic biodiversity. ■ **Type**: **Direct** loss in active worksites at geotechnical/ site investigation, anchoring and connector cable routing locations. Potential indirect disturbance during shallow workboat/ barge activities outside direct Project footprint. ■ **Duration**: Depending on the final design, these activities are to take place over approximately 104 weeks, which is considered relatively **long term** for biodiversity, and could be reversible upon removal of the Project. ■ **Extent**: **Localised** around the active worksite(s) of deployment. ■ **Scale**: Areas affected by geotechnical/ site investigations, laying anchors/ ballasted foundations/ piles and laying of connector cables (estimated to be approximately 2-2.5 ha, conservatively assuming up to 5,000 anchors at 2 (L)m x 2(W)m, see *Appendix 2.1*), and shallow work boat/ barge working areas. ■ **Frequency**: Deployments and activities will happen **daily/ intermittently** during the specified period of construction phase. ■ **Sensitive Receptor(s)**: Aquatic habitat (Medium, including benthic), Aquatic plants (Low). Within the direct Project footprint (e.g. anchors/ ballasted foundations/ piles and connector cables) benthic habitat and vegetation will be lost. Per the Surface Water Quality impact assessment (*Section 6*), sediment suspension around works areas are anticipated to be limited within less than 100 m of work front, i.e. re-settlement will occur within this area disturbing benthic habitats. Surface water quality embedded controls will be established. Benthic habitats comprise mostly silty, slightly sandy substrates. The benthic fauna is biodiversity-poor and of low value, dominated by filtering collectors that forage fine particulate organic matter, and are expected to be tolerant to sedimentation and the existing lentic and eutrophic environment. Disturbance processes resulting in the removal and recolonisation of macroinvertebrates was observed during the sampling (e.g. site BC05 following rain events in March – May 2021). Rapid recolonisation was observed following disturbance. In areas outside of the Project footprint the benthic habitat/ benthos is expected to recover naturally and relatively quickly (within weeks) with no substantial change to the viability or function of the habitat or the benthic community overall. Impact magnitude is expected to be ***Negligible*** to ***Small*** for the aquatic biodiversity, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/or (ii) not cause substantial change in species population or other species dependent on it, with embedded controls for surface water quality; given the low value benthic fauna, ability to recolonise and the relatively small area of directly lost benthic habitat.	Impact Magnitude: **Small** Receptor Sensitivity: **Medium** Impact Significance: **Minor**	Mitigation measures presented in the Surface Water Quality *Section 6* will be applied. In addition to: ■ Detailed design and construction methodology of reservoir-based geotechnical/ site investigations, FPV layout, anchoring method and connector cables to optimise/ minimise footprint, where feasible.	Impact Magnitude: **Negligible** Impact Significance: **Negligible**
C2	**Elevation of suspended sediments within the reservoir**	■ **Nature**: Elevation of suspended sediments within the reservoir is considered **negative** for aquatic biodiversity. ■ **Type**: **Indirect** adjacent to active worksites (e.g. geotechnical/ site investigation, anchoring and connector cable routing locations). ■ **Duration**: Depending on the final design, these activities are to take place over approximately 104 weeks, which is considered relatively **long term** for	Impact Magnitude: **Small** Receptor Sensitivity: **Medium**	Mitigation measures presented in the Surface Water Quality *Section 6* will be applied to inform need for adaptive management (see *Section 4.7.1* for further details on adaptive management approaches).	Impact Magnitude: **Negligible** Impact Significance: **Negligible**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		aquatic biodiversity. Elevated turbidity from works will subside relatively quickly and the change is temporary. ■ **Extent**: **Localised** around the active worksite(s) of deployment. Note that deployment of geotechnical/ site investigations, anchors/ ballasted foundation, piles and mooring lines will be conducted in phases across the reservoir. This means affected area would be localised at any one time. ■ **Scale**: Elevated levels of suspended solids would likely be limited to less than 100 m from the work front (per *Section 6*) and return towards baseline beyond this. ■ **Frequency**: Deployments and activities will happen **daily/ intermittently** during the specified period of construction phase. ■ **Sensitive Receptor(s)**: Aquatic habitats (Medium), Fish (Medium), Aquatic plants (Low). The in-reservoir work activities are expected to result in temporary and localised disturbance of reservoir bed sediment. Per the Surface Water Quality impact assessment (*Section 6*), it is estimated that the elevation of suspended solids would likely be at the level of 5.3 mg/L at 100 m from the active works area and would be even lower at further distances. Surface water quality embedded controls will be established. Any increased load of suspended sediments could reduce light penetration and the depth of photosynthetic activity by phytoplankton and submerged macrophytes. In addition, it could increase heat absorption and consequently reduce dissolved oxygen concentrations. This would negatively affect zooplankton and fish. The increased turbidity also could reduce predation pressure of fish on zooplankton, and perhaps increase grazing pressure on phytoplankton. The tolerance of each organism to the concentration of suspended sediment will vary between taxa (macrophyte, phytoplankton, zooplankton and fish) and their different life stages (larva, juvenile and adult). Fish have been shown to experience sub-lethal stress from suspended sediments rather than mortality because they are able to relocate to more suitable habitat (Kjelland, M. et al 2015). Total suspended solid (TSS) levels were recorded at or around 10mg/L throughout this EIA baseline. The fish and other fauna within the reservoir are adapted to conditions typical of high suspended sediment and turbidity. The recommended safe limit of TSS is 30mg/l for controlled watercourses as per NEA. Griffiths and Watson (1978) showed that the tolerance for TSS for macroinvertebrates was between 10 – 15 mg/L, and Nicholls et al. 2003 showed increased mortality at TSS levels >300 mg/L for some macroinvertebrates. Impact magnitude is expected to conservatively be ***Small*** for the aquatic biodiversity, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/or (ii) not cause substantial change in species population or other species dependent on it, with embedded controls for surface water quality; given the current baseline and tolerances of aquatic flora and fauna to suspended sediments	Impact Significance: **Minor**		
C3	**Elevation of pollutants and/or**	■ **Nature**: Elevation of pollutants and/ or nutrients within the reservoir is considered **negative** for aquatic biodiversity. ■ **Type**: **Indirect** adjacent to active worksites (e.g. at geotechnical/ site investigation, anchoring and connector cable routing locations).	Impact Magnitude: **Medium**	Mitigation measures presented in the Surface Water Quality *Section 6* will be applied to inform need for adaptive management. Monitoring and adaptive management measures including:	Impact Magnitude: **Small**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
	nutrients within the reservoir	■ **Duration**: Depending on the final design, these activities are to take place over approximately 104 weeks, which is considered relatively long term for aquatic biodiversity. Release of porewater will result in temporary elevation of ambient levels of nutrients and contaminants, which will be diluted in the surrounding water, the change is considered temporary. ■ **Extent**: **Localised** around the active worksite(s) of deployment. Note that deployment of geotechnical/ site investigations, anchors/ ballasted foundation, piles and mooring lines will be conducted in phases across the reservoir. This means affected area would be localised at any one time. ■ **Scale**: Changes in surface water quality would likely be limited to less than 100 m from the work front (per *Section 6*) and return towards baseline beyond this. ■ **Frequency**: Deployments and activities will happen **daily/ intermittently** during the specified period of construction phase. ■ **Sensitive Receptor(s)**: Aquatic habitats (Medium), Fish (Medium), Aquatic plants (Low). The in-reservoir work activities are expected to result in temporary and localised disturbance of reservoir bed sediment. Per the Surface Water Quality impact assessment (*Section 6*), it is estimated that for release of sediment-bound nitrogen and phosphorus that the released total nitrogen and total phosphorus from the piling works would be below 0.25% and 0.03% of the catchment load, respectively. For sediment-bound contaminants including arsenic, cadmium and lead, analysis indicated the potential release of these contaminants would be negligible. Surface water quality embedded controls will be established. The increased pollutant concentrations in the water could affect fish survival. Should there be a pulse of phosphorus into the water, this may trigger a change in the phytoplankton community (as observed following storm events during the baseline). Potentially, in a conservative case, a phytoplankton bloom could possibly occur if warmer meteorological conditions prevail at the same time. However, it is understood blooms have not occurred during the construction of other FPVs on Singapore reservoirs (Yang et al., 2022). The impact magnitude is expected to conservatively be ***Medium*** for the aquatic biodiversity, where impacts are expected to (i) affect part of the habitat but not threaten long-term habitat viability/ function, and/or (ii) cause a substantial change in abundance and/or the reduction in distribution of a population over one or more generations but does not threaten the long-term viability / function of that population, or any population dependent on it, with embedded controls for surface water quality; and given the potential affect on fish survival and implications of phosphorus on phytoplankton,	Receptor Sensitivity: **Medium** Impact Significance: **Moderate**	■ Establish construction phase biodiversity monitoring programme in agreement with relevant Government authorities prior to works commencement, to inform the Developer/ Owner on any potential disturbance to biodiversity from the works. - Biodiversity monitoring to include: plankton (zooplankton and phytoplankton), fish biomass and size.	Impact Significance: **Minor**
C4	**Changes due to trimming of aquatic vegetation**	■ **Nature**: Trimming and decomposition of aquatic vegetation could lead to **negative** impacts for aquatic biodiversity. ■ **Type**: Trimming of aquatic vegetation in the top 1m of the water column would **directly** impact aquatic plants. Trimming and decomposition (assuming conservative case of waste vegetation not being collected and being allowed to decompose in the water column), would **indirectly** impact aquatic habitat and both aquatic and terrestrial species. ■ **Duration**: Trimming of aquatic vegetation would be carried out in phases before works activities in different areas of the reservoir commence (due to rapid regeneration of the aquatic vegetation) throughout the in-reservoir construction period (approximately 104 weeks), which is considered to be relatively **long-term** for aquatic biodiversity. If any trimmings of aquatic	Impact Magnitude: **Small** Receptor Sensitivity: **Medium** Impact Significance: **Minor**	Mitigation measures presented in the Surface Water Quality *Section 6* will be applied to inform need for adaptive management. In addition to: ■ Detailed design and construction methodology of reservoir-based works to manage aquatic vegetation trimming, as appropriate in consultation with PUB. Monitoring and adaptive management measures including: ■ Establish construction phase biodiversity monitoring programme in agreement with relevant Government authorities prior to works commencement, to inform the Developer/ Owner on any potential deterioration of biodiversity from the works. - Biodiversity monitoring to include: fish biomass and size.	Impact Magnitude: **Negligible** Impact Significance: **Negligible**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		vegetation are left in-reservoir they would likely settle into the sediment and decay slowly. The effect of decomposition of these cut vegetation would diminish over time but could linger beyond the construction period. The effect of vegetation trimming and FPV shading will be permanent throughout the Project operational phase. ■ **Extent**: Conservatively, vegetation trimming works could cover the entirety of the Reservoir Project Site within the Kranji Reservoir, to be carried out in phases. Direct impacts would be **localised** within the work areas of the current work phase and the immediate surroundings, whereas indirect impacts may extend across the reservoir. ■ **Scale**: Conservatively, the effect of the release of nutrients and depletion of dissolved oxygen associated with the decomposition of trimmed vegetation left in-reservoir would likely be limited to less than 100 m from the work front given the small vegetation amounts and the lack of notable change in surface water quality from existing regular aquatic vegetation removal works. ■ **Frequency**: Trimming of aquatic vegetation will happen **intermittently** during the specified period of construction phase. ■ **Sensitive Receptor(s)**: Aquatic habitat (Medium, also considering secondary values for supporting terrestrial species), Aquatic plants (Low), Fish (Medium). It should be noted that existing removal of aquatic vegetation is regularly conducted (daily) in Kranji Reservoir by PUB without notable adverse surface water quality impacts being recorded. Such regular operations results in controlling the spread of aquatic (floating) vegetation coverage which typically serves as additional habitats for the wildlife. It is noted PUB indicate that they have not observed fauna using the vegetation as nesting grounds. Removal of aquatic (floating) vegetation will increase/ maintain light penetration into the reservoir temporarily prior to FPV deployment. This will benefit phytoplankton growth and submerged macrophytes growing below trimming depth. Aquatic vegetation removal may restrict the additional provision of habitat complexity (increased homogeneity) and shelter used by fish and zooplankton. The Asian arowana (introduced globally EN) spends the day hiding and forages at night. The species is practicing mouthbrooding and is therefore not relying on vegetation for reproduction (Scott & Fuller, 1976). Fringing aquatic vegetation along the shoreline (within the minimum 25 m setback areas) will continue to provide habitat for sheltering. Given most of the aquatic vegetation is non-native and/ or invasive, its trimming may potentially have an overall ***<u>Positive</u>*** impact for biodiversity. For the conservative case of the trimmings of aquatic vegetation in the top 1m of the water column being left to decompose in the reservoir, the trimmed cuttings would sink to the reservoir bed and enrich the benthos with nutrients. Bacteria will decompose the cuttings and increase in abundance, which will likely reduce oxygen concentrations and pH. The lower pH is likely to result in the release of Phosphorus from benthic sediment, making it available to algal growth. This internal loading process could possibly reduce dissolved oxygen and result in an algal bloom and/or fish deaths. Per the Surface Water Quality impact assessment (*Section 6*), were the top 1m of all the aquatic vegetation within the Reservoir Project Site to be cut off at the same time (unlikely), and start decomposing and releasing nutrients immediately (unlikely), the addition of total phosphorus, total		■ Should monitoring show a decline in fish biomass, the Developer/ Owner to consider opportunities, in consultation with relevant Government authorities, for additional nature based solutions, e.g. for fish habitat enhancement in the retained habitats areas within the reservoir, for example: - Patches of floating vegetation to be retained, where feasible, in the Reservoir Project Site, subject to the FPV system's and PUB's reservoir operational requirements. - If the fish population is observed to be significantly affected despite above adaptive measures then consider other adaptive management which may include, for example, potential layout changes, removal of FPV panels, etc where appropriately agreed between responsible agencies and the Developer/ Owner.	

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		nitrogen and total carbon in the 1st month will be approximately 3%, 3% and 2% of the existing fluxes into the reservoir (catchment loadings, mineralisation, and atmospheric deposition). These nutrient inputs are less than the variation in monthly fluxes for the catchment runoff. Daily release will be very small and limited to local areas. Overall, impact magnitude is expected to be ***Small*** for the aquatic and terrestrial biodiversity, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/or (ii) not cause substantial change in species population or other species dependent on it, with embedded controls for surface water quality; and given the existing regular (daily) removal of aquatic vegetation, species of concern (Asian arowana), very small changes in nutrients from the conservative vegetation decomposition, and potential positive removal of non-native/ invasive species.			
C5	**Disturbance to aquatic fauna (piling, boat movements)**	■ **Nature**: Disturbance to aquatic fauna is considered **negative** for aquatic biodiversity. ■ **Type**: Both **direct** within active worksites, and **indirect** impacts within the reservoir are expected to aquatic fauna. ■ **Duration**: In-reservoir activities will be carried out throughout the in-reservoir construction period (approximately 104 weeks), whereas depending on the anchoring approach, the installation of piles/ anchors/ ballasted foundations could take up to 70 weeks, both of which are considered to be relatively **long-term** for aquatic biodiversity. The change is considered temporary. ■ **Extent**: Direct impacts are **localised** within the active worksite(s) and the immediate surroundings. Note that activities will be conducted in phases across the reservoir. This means affected area would be localised at any one time. Whereas indirect impacts may extend across the reservoir. ■ **Scale**: Areas affected by active worksites in Reservoir Project Site, and wider reservoir. ■ **Frequency**: Activities will happen **daily/ intermittently** during the specified period of construction phase. ■ **Sensitive Receptor(s)**: Aquatic habitat (Medium). See also item C7 below on terrestrial fauna disturbance from piling. Construction works will include geotechnical/ site investigations, piling (conservatively assuming up to 4 simultaneous driven piles at the same location in the western portion of the reservoir, and 2 simultaneous driven piles at the same location in the eastern portion of the reservoir) and up to 8 working boats installing FPV and other in-reservoir infrastructure. Underwater noise and vibration might deter fish from important feeding and reproduction areas, interrupt critical activities or cause stress-induced reduction in growth and reproductive output. However, there is a lack of data regarding these behavioural responses of increased noise in fish (Slabbekoorn et al. 2010). It is assumed, that construction works in the reservoir would temporarily displace fish to the south of the reservoir, or to other areas in the reservoir away from active work fronts or designated, regularly used vessel routes. Overall, impact magnitude is expected to be ***Medium*** for the aquatic biodiversity, where impacts are expected to (i) affect part of the habitat but not threaten long-term habitat viability/ function, and/or (ii) cause a substantial change in abundance and/ or the reduction in distribution of a population over one or more generations but does not threaten the long-term viability/ function of that population, or any	Impact Magnitude: **Medium** Receptor Sensitivity: **Medium** Impact Significance: **Moderate**	Mitigation measures presented in the Surface Water Quality *Section 6* will be applied to inform need for adaptive management. Monitoring and adaptive management measures including: ■ Establish construction phase biodiversity monitoring programme in agreement with relevant Government authorities prior to works commencement, to inform the Developer/ Owner on any potential deterioration of biodiversity from the works. - Biodiversity monitoring to include: plankton (zooplankton and phytoplankton), fish biomass and size. Also see mitigation measures presented in item C7 below on terrestrial fauna disturbance from piling.	Impact Magnitude: **Small** Impact Significance: **Minor**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		population dependent on it, with embedded controls for surface water quality; and given the small worksites and ability of aquatic fauna to temporarily move to non-affected areas of the reservoir and embedded controls.			
TERRESTRIAL BIODIVERSITY					
C6	**Terrestrial habitat clearing/ fragmentation**	■ **Nature**: Terrestrial habitat clearing/ fragmentation is considered **negative** for terrestrial biodiversity. ■ **Type**: **Direct** loss along approximately 150m strip of shoreline habitat at the proposed temporary Staging/ Launching Area and integrated Project Substation worksite. ■ **Duration**: Vegetation clearance to be over 2 to 4 weeks, relatively short term for terrestrial biodiversity. The gap/ fragmentation of habitat will remain throughout the construction period (approximately 3 years), which is considered to be relatively **long-term** for terrestrial biodiversity. Change is considered temporary based on embedded controls (e.g. re-planting/ landscaping). Future land use planning for this eastern shoreline is designated as a Park. ■ **Extent**: **Localised** at the approximate 150 m at the proposed temporary Staging/ Launching Area worksite and surrounding habitats. ■ **Scale**: Clearance of vegetation along the approximately 150m shoreline (conservatively estimated to be less than 1 ha). ■ **Frequency**: **Direct** vegetation clearance will be one-off. Fragmented habitat will remain throughout construction. ■ **Sensitive Receptor(s)**: Terrestrial habitats at clearance area (Low), Terrestrial habitats to south of clearance area (Sungei Kadut forest, High), Terrestrial plants (High), Invertebrates (High), Birds including black-crowned night heron (High), Reptiles (Medium), Otter (High), Bats (Medium). The proposed temporary Staging/ Launching Area and integrated Project Substation will take place on already-disturbed, cleared land within Sungei Kadut Industrial Estate. The vegetation in the shoreline of this worksite and further north is largely dominated by tall grasses with scattered trees. No semi-natural or natural terrestrial habitats of high value will be cleared for the waterfront access for the proposed temporary Staging/ Launching Area (including launching ramp), and connector cable launching point and O&M Berthing Facility (location subject to approval from agencies). These areas to be cleared have negligible biodiversity value. The shoreline is to be re-planted after construction. To the south of the worksite is the Sungei Kadut forest (High sensitivity), and black-crowned night herons (nationally EN, High sensitivity) temporary roosts have been identified in the shoreline habitat to the north. The area to be cleared does not represent good quality habitat for connectivity, and the habitat to the north is considered of low value. No other species of conservation concern have been identified in the area to be cleared. Embedded controls apply the Urban Design Guidelines and greening/ planting for the final integrated Project Substation. With the future land use of the shoreline (to the north and south) designated as a Park, some future modification of these habitats is anticipated. Impact magnitude is expected to conservatively be ***Small*** for the terrestrial biodiversity, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/ or (ii) not cause substantial change in species population or other species dependent on it, with embedded controls; given the	Impact Magnitude: **Small** Receptor Sensitivity: **High** Impact Significance: **Moderate**	■ Detailed design and construction methodology of the proposed temporary Staging/ Launching Area and integrated Project Substation worksite to optimise/ minimise footprint and vegetation clearance, where feasible. ■ Avoid felling trees and clearing vegetation during the peak bird breeding season (March to July). ■ Pre-felling fauna inspection by qualified Biodiversity Specialist should be conducted before felling any trees or removing any vegetation. ■ Re-plant shoreline vegetation as early as possible in the construction schedule: - Plant keystone flora such as fig trees. They provide important food source for avian fauna and small mammals. It is recommended that only native plant species are planted. - It is recommended to select a diversity of flowering and fruiting plants species so that the area will be flowering and fruiting throughout the year to provide food and improve ecological processes. - Consult with NParks on the land-based worksite re-planting/ landscaping scheme considering the future land use of the shoreline as Park. ■ Ensure there are no works outside of the in-reservoir and land-based worksites. Also see mitigation measures presented in item C7 below on terrestrial fauna disturbance.	Impact Magnitude: **Negligible** Impact Significance: **Negligible**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		status of the current surrounding habitats and species identified in the baseline, and future land use designation.			
C7	**Disturbance to terrestrial fauna (piling in reservoir)**	■ **Nature**: Disturbance to terrestrial fauna from piling in reservoir is considered **negative**. ■ **Type**: **Indirect** impacts within the reservoir are expected to terrestrial fauna. ■ **Duration**: Depending on the final design of anchoring to be adopted, the installation of in-reservoir piles could take up to 56 weeks (see *Appendix 2.1*), which is considered to be relatively **long-term** for terrestrial biodiversity. Works activities are considered temporary. ■ **Extent**: **Localised** around the active worksite(s) and the immediate surroundings. ■ **Scale**: Within the Reservoir Project Site. ■ **Frequency**: Activities will happen **daily/ intermittently** during the specified period of construction phase. ■ **Sensitive Receptor(s)**: Protected Areas and Designated Sites (High), Birds (High), Smooth-coated Otter (High). Construction works will include daytime geotechnical/ site investigations, piling (conservatively assuming up to 4 simultaneous driven piles at the same location in the western portion of the reservoir, and 2 simultaneous driven piles at the same location in the eastern portion of the reservoir) and up to 8 working boats installing FPV and other in-reservoir infrastructure. A minimum 25 m shoreline setback is established on the western shoreline (under the unmitigated maximum FPV layout). Typically in-reservoir infrastructure is over 50m from the eastern shoreline, due to PUB reservoir operations requirements for a 50 m north-south vessel corridor at prescribed water depths. The driven piling activities (conservatively assessed as the more impactful installation method) will be carried out in phases across the reservoir in daytime throughout the construction period, hence active worksites will be restricted to very small areas. The anticipated airborne noise and vibration levels from piling activities have been evaluated in *Section 9*, Airborne Noise & Vibration, based on human receptor thresholds. These thresholds are not directly applicable to fauna, since some species have sensory receptors which have perception ranges and sensitivities that are above and/ or below the ranges of human perception and sensitivity (Fraser et al. 2000). Accordingly, additional assessment is provided below. An assessment matrix for disturbance by piling noise for sensitive terrestrial fauna receptors can also be found in *Appendix 7.6*. An assessment of noise propagation from piling on the reservoir (based on conservative assumptions) has been carried out, see *Appendix 7.7.* The main receptors to in-reservoir driven piling include: ■ SBWR, Mandai Mangroves and Mudflats, Kranji Marshes and Gemala Nature Area. ■ High value species nesting or roosting, i.e. black-crowned night heron (nationally EN), grey headed fish eagle (nationally VU), straw-headed bulbul (globally CR), and White-bellied sea eagle (nationally LC). ■ Other forest birds (globally and nationally EN and VU) in Sungei Kadut Forest. ■ Wetland birds foraging around the reservoir edges (nationally EN and VU), including little tern (nationally EN), herons and egrets. ■ Smooth-coated otter (nationally EN).	Impact Magnitude: **Negligible to Small** Receptor Sensitivity: **Medium to High** Impact Significance: **Minor to Moderate**	<u>In-reservoir Piling</u> ■ Detailed design and construction methodology of reservoir-based piles to optimise/ minimise extent and number of piles, simultaneous piling workstations (e.g. in-reservoir piling activities could be controlled according to works phasing, intensity, distance between piling workstations, distance from the shoreline, etc.), etc where feasible, with due consideration of this C7 and *Appendix 7.7*. - Minimise use of driven piling. Use low-noise piling methods instead, e.g. vibratory piling or bored/drilling piling. If driven piles is selected, apply noise mitigation measures, e.g. ramp up piling gradually, install enclosed shrouds around the piling equipment etc. Based on ERM's existing database, the noise level reduction for enclosed shrouds is predicted to be up to 9 dB(A). ■ A setback of distance of 50 m from FPV panels to western shoreline of Kranji Reservoir, where relatively higher bird foraging was observed, will be established as a biodiversity mitigation, as suggested by stakeholders, to give greater confidence in the ability of the mitigated biodiversity FPV layout to reduce impacts on biodiversity associated with disturbance and displacement along the western shoreline. With the 50 m western shoreline setback to the FPV layout and pile enclosed shrouding (see *Appendix 7.7*, *Tables 1B to 6B*): - The noise level for 4 <u>mitigated</u> (enclosed shrouded), simultaneous adjacent piling workstations would be 66 dB(A) (i.e. <70 dB(A)) at Kranji Marshes and Gemala Nature Area boundary. To achieve noise levels of 62 dB(A) at Kranji Marshes and Gemala Nature Area boundary, the 4 <u>mitigated</u> (enclosed shrouded), simultaneous adjacent piling workstations would need to be 80 m away from the boundaries of these areas. - The noise level for 3 <u>mitigated</u> (enclosed shrouded) simultaneous adjacent piling workstations would be <70dB(A) at 30 m away, and <62 dB(A) at 75 m away, from the boundaries of these areas. - The noise level for 2 <u>mitigated</u> (enclosed shrouded) simultaneous adjacent piling workstations would be <70dB(A) at 25 m away, and <62 dB(A) at 60 m away, from the boundaries of these areas, i.e. given the 50 m mitigated biodiversity western setback to FPV layout and 20 m Kranji bund width to the Kranji Marshes boundary (total 70 m), 2 mitigated (enclosed shrouded), simultaneous adjacent piling workstations achieves the 70 dB(A) and 62 dB(A) guideline and baseline thresholds for the Kranji Marshes. - The noise level for 1 <u>mitigated</u> (enclosed shrouded) piling workstation would be <62 dB(A) at 40 m away from the boundaries of these areas, i.e. given the 50 m mitigated biodiversity western setback to FPV layout 1 mitigated (enclosed shrouded) piling workstation achieves the 62 dB(A) baseline thresholds for the Gemala Nature Area. ■ On the eastern shoreline, to achieve noise levels of <70 dB(A) and <64 dB(A) the 2 <u>mitigated</u> (enclosed shrouded), simultaneous adjacent piling workstations would need to be 25 m and 45 m away, respectively, i.e. given the eastern 50 m PUB north-south vessel corridor, 2 mitigated (enclosed shrouded), simultaneous adjacent piling workstations achieves the 70 dB(A) and 64 dB(A) guideline and baseline thresholds. ■ Apply mitigation related to vessel navigation (see Surface Water Quality, *Section 6*), e.g. regular traffic routes should be established for routine works. Offset from shoreline as well as corridors between FPV islands allow safe navigation access, this will minimise the risk of disturbing bird shoreline foraging areas. <u>General</u> ■ Regulate contractor movements and activities to areas only within the construction and operational footprint (i.e. in the Reservoir Project Site), and prohibiting access to other areas without prior agreement of the Site's Environmental Manager (e.g. retained terrestrial and aquatic habitats and parts of the setback zone around the reservoir edges not required for access). ■ Establish a Wildlife Incident Response Plan and Reporting (including for birds, bats, snakes, crocodiles etc.) to be enacted when a trapped/ injured/ dead/ dangerous animal is encountered around or within the worksite.	Impact Magnitude: **Negligible to Small (retained on precautionary basis)** Impact Significance: **Minor to Moderate (retained on precautionary basis)**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		The Cutts et al. 2009 study entitled *"Construction and Waterfowl: Defining Sensitivity, Response, Impacts and Guidance"* (by the Institute of Estuarine and Coastal Studies, University of Hull, UK) found moderate to high disturbance effects on foraging waterbirds for irregular piling noise > 70 dB(A) and low to moderate effects for regular piling noise < 70 dB(A) with birds habituating to effects over time. Birds were found to react differently in different situations and at different times of the year. In addition, per *Section 9* (Airborne Noise & Vibration), *Table 9-13* background noise monitoring considered representative of the western shoreline of the reservoir, i.e. at NSRCC Kranji Sanctuary Golf Course, identified daytime (7am – 7pm) levels to be 62 dB(A). On the eastern shoreline, background noise monitoring (*Section 9, Table 9-11*) indicated average noise levels adjacent to the shoreline forest strip at the proposed temporary Staging/ Launching Area to be approximately 64 dB(A) (ranging from 57-72 LAeq, 12 hours; and 38-89 LAeq, 5 mins) in the daytime (7am – 7pm). On a precautionary basis, the following assessment considers the background noise monitoring levels of 62 (western shoreline) - 64 (eastern shoreline) dB(A) along with the identified 70 dB(A) noise threshold by Cutts et al. 2009. In the western portion of the reservoir, modelled noise levels (see *Appendix 7.7*, *Table 1A*) predict sound levels to be <70 dB(A) at a distance of approximately 90 m from the conservative piling works scenario (i.e. 4 piling workstations carrying out piling simultaneously at the same location). In other words, disturbance to waterbirds would likely be caused within 90 m of 4 unmitigated, simultaneous adjacent piling operations. To achieve levels of <62 dB(A), a distance of 225 m is required from 4 unmitigated, simultaneous adjacent piling operations. <u>SBWR and Mandai Mangroves and Mudflats</u> SBWR and Mandai Mangroves and Mudflats are more than 225m from the Reservoir Project Site works area. Therefore, the impact magnitude is expected to be <u>*Negligible*</u> at these Protected Areas, where impacts are expected to be within normal range of natural variation for the habitat, or population of the species, including migratory birds resting at SBWR. <u>Kranji Marshes (570,000 m^2)</u> The nearest potential piling location to the Kranji Marshes is east of the Kranji bund. It is noted that Kranji Marshes' nearest boundary to the Reservoir Project Site is on the western side of Kranji bund. The Kranji bund is on average (based on satellite analysis) 20 m wide. A minimum setback of 25 m from the reservoir shoreline to the Reservoir Project Site is also established as an embedded control. Therefore, it is assumed that piling will be at least 45m (i.e. 20 m + 25 m) from the Kranji Marsh boundary at its nearest. Assuming 4 unmitigated, simultaneous adjacent piles took place at the nearest point to the Kranji Marshes boundary (i.e. 45 m away), then noise levels would be 76 dB(A) (see *Appendix 7.7, Table 1A*). An estimated maximum area of around 5,550 m^2 within Kanji Marshes would be affected by noise over 70 dB(A), and an area of around 60,780 m^2 would be affected by noise over 62 dB(A). Given the		■ Conduct regular inspections to ensure compliance and identify impacts to adjacent biodiversity areas, fauna entrapments etc. ■ Train site personnel on biodiversity awareness and actions to take when encountering wildlife. ■ Erosion control blankets should be removed after construction to avoid trapping fossorial fauna. Monitoring and adaptive management measures including: ■ Establish construction phase noise monitoring programme in agreement with relevant Government authorities prior to works commencement, to inform the Developer/ Owner on any potential impact of noise from the works, e.g. in the vicinity of Kranji Marshes, the black-crowned night heron roosts, and the proposed temporary Staging/ Launching Area and the integrated Project Substation worksite. ■ Establish construction phase biodiversity monitoring programme in agreement with relevant Government authorities prior to works commencement, to inform the Developer/ Owner on any potential disturbance to biodiversity from the works. - Biodiversity monitoring to include: focal/ waterbird species and smooth-coated otters. Although the mitigation proposed is likely to reduce the noise level to less than the 70 dB(A) and 62dB(A) (western shoreline) and 64dB(A) (eastern shoreline) as discussed, the residual impact magnitude and significance has been retained at pre-mitigation levels on a precautionary basis subject to Developer/ Owner selection of detailed construction approaches (e.g. location of piling, phasing, number of simultaneous piles etc) and related mitigation measures described above. Establishment of monitoring, datasets and analysis (see *Section 12* EMMP) are to validate post-mitigation impact significance, and further support management of this impact and determination of deteriorating trends (if any).	

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		total area of Kranji Marshes is 570,000 m^2, the conservative impact area from 4 unmitigated simultaneous adjacent piling workstations 25 m from the reservoir shoreline would equal <1% (70dB(A)) and <11% (62 dB(A)) of the total Kranji Marshes area and the impact magnitude is expected to be *Negligible to Small*, given the ability of affected fauna to move away from noise disturbance into other areas of the Protected Area, where impacts are expected to be within normal range of natural variation for the habitat, or population of the species with embedded controls. To achieve noise levels of <70 dB(A) and <62 dB(A) at Kranji Marshes boundary for 4 unmitigated, simultaneous adjacent piles, the 4 piling workstations would need to be 90 m and 225 m away, respectively, from the boundary of Kranji Marshes (see *Appendix 7.7, Table 1A*). Assuming, for example, 1 unmitigated piling workstation was 25m setback from the western shoreline (i.e. 45 m from Kranji Marshes boundary at its nearest), then noise levels would be 70 dB(A) at the nearest edge of Kranji Marshes and 62 dB(A) would be achieved at a distance of 115 m (see *Appendix 7.7, Table 4A*). A maximum area of around 90 m^2 (0.02%) of Kranji Marshes would be affected by noise over 70 dB(A), and an area of 11,500m^2 (2%) would be affected for noise over 62 dB(A) in this scenario. Gemala Nature Area (201,000 m^2) The nearest distance between the Reservoir Project Site and the Gemala Nature Area is approximately 40 m. If 4 unmitigated, simultaneous piles took place at a distance of 40 m, the noise level at the boundary of the Gemala Nature Area would be 77 dB(A) (see *Appendix 7.7, Table 1A*). An area of approximately 4,500 m^2 would be affected by noise over 70 dB(A), and an area of around 44,700m^2 would be affected by noise over 62 dB(A). Given the total area of Gemala Nature Area is approximately 201,000 m^2, the impact would equal 2.2% (70dB(A)) and 22% (62 dB(A)) of the area. In order to achieve noise levels of <70 dB(A) and <62 dB(A) unmitigated, simultaneous adjacent piles, the 4 piling workstations would need to be 90 m and 225 m away, respectively, from the boundary of the Gemala Nature Area (see *Appendix 7.7, Table 1A*). Assuming, for example, 1 unmitigated piling took place at a distance of 45 m (see *Appendix 7.7, Table 4A*) from the Gemala Nature Area boundary, only approximately 89 m^2 of Gemala Nature Area would be affected by over 70 dB(A), which equals 0.04% its total area, and an area of 8,800 m^2 (4.4%) would be affected for noise over 62 dB(A) in this scenario. The impact magnitude is expected to be *Negligible to Small* for the Gemala Nature Area, given the areas affected by over 70 dB(A) and over 62 dB(A) are relatively small compared to their total areas, and the ability of affected fauna to move away from noise disturbance into other areas of the Protected Area, where impacts are expected to be within the normal range of natural variation for the habitat, or population of the species with embedded controls. Bird Foraging at western and southern area of the reservoir (herons, egrets and little tern)			

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		The western shoreline and southern area of the reservoir (south of the Reservoir Project Site) are where most bird foraging was recorded, in particular by herons, egrets and little tern. Noise levels in locations where these nationally EN and VU wetland birds are foraging will likely cause disturbance, for example, should 4 unmitigated, simultaneous adjacent piling workstations be located within 90 m to 225 m from the western shoreline or the southern boundary of the Reservoir Project Site. However, as the noise source will be temporary and shift with the construction phasing, and these birds are highly mobile, it is expected that the birds would relocate to avoid noise should they need to, and indeed may habituate to it over the course of the works across the Reservoir Project Site. Given this and the likely scale of the species' home range, that extends to areas outside Kranji Reservoir, any displacement would be localised and not affect the conservation status species, for example the little tern. Overall, the impact magnitude is expected to be *Negligible* overall for foraging birds, where impacts are expected to be within normal range of natural variation for the habitat, or population of the species, given embedded controls, the species' home range and availability of habitat. High Value Birds roosting and foraging on the Eastern edge of the reservoir (black-crowned night heron, straw-headed bulbul, grey-headed fish eagle) A number of high value species were recorded on the eastern edge of the reservoir. Assuming works took place at least 50 m from the majority of the shoreline on the east of the reservoir (due to PUB's 50m requirement for a north-south vessel corridor) by 2 unmitigated, simultaneous adjacent piles then noise levels at the eastern shoreline and the black-crowned night heron roost (see *Appendix 7.6* and *7.7, Table 5A*) would be 72 dB(A); a distance of 130 m would be required to achieve 64 dB(A) on the eastern shoreline in this scenario. Assuming, for example, 1 unmitigated piling took place at a 50 m from the eastern shoreline then noise levels would be 69 dB(A), and 64 dB(A) would be achieved at a distance of 90 m in this scenario (see *Appendix 7.7, Table 6A*). The impact magnitude is expected to be *Small* for the black-crowned night heron roost and any other birds foraging at the eastern shoreline (see *Appendix 7.6*), where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/or (ii) not cause substantial change in species population or other species dependent on it, with embedded controls, the species' home range and availability of habitat. For the straw-headed bulbul and the other species of conservation concern within Sungei Kadut Forest adjacent to the eastern shoreline (see *Appendix 7.6*), the conclusion of impact magnitudes of *Small* is drawn for the same reasons (see above paragraph), based on 2 unmitigated simultaneous adjacent piling workstations. A grey-headed fish eagle nest was recorded at Sungei Kadut Forest. The tolerance levels of eagles have been shown to be higher than waterbirds: nesting bald eagles (*Haliaeetus leucocephalus)* in Canada have been shown to be resistant to noise disturbance as loud as 94 dB(A) (Diamond Head Consulting Ltd, 2017). Further considering habituation from existing background noise levels from			

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		Sungei Kadut Industrial Estate (maximum approximately 62.6 dB(A)[3]) and the shielding vegetation in Sungei Kadut Forest (vegetation was found to reduce noise levels for road traffic on average by 9 - 11 dB according to Ow & Ghosh 2017), the impact magnitude is expected to be ***Negligible*** for the nesting grey-headed fish eagle at the eastern shoreline, where impacts are expected to be within normal range of natural variation for the habitat, or population of the species, given embedded controls, the species' home range and availability of habitat. White-belled sea eagle Assuming 4 unmitigated simultaneous piles on the western/ northern shore, noise levels at the two white-belled sea-eagle nests at SBWR, or the BBC transmission towers used by this species for perching, would be well below 94 dB(A) and even below 70 dB(A) at the nests given the separation distance to the nearest piling workstations. The impact magnitude is expected to be ***Negligible*** for the nesting/ perching white-bellied sea-eagle, where impacts are expected to be within normal range of natural variation for the habitat, or population of the species, given embedded controls, the species' home range and availability of habitat. Smooth-coated otter The smooth-coated otter is known to be resilient in Singapore to the presence of human activity and even to use human-made structures. However, having a secure and undisturbed holt for resting also was found to be a main factor for the species (Khoo & Sivasothi 2018). For its close relative, the Eurasian otter (*Lutra lutra*), a distance of 150 m to holts with breeding females is recommended to avoid disturbance and the abandonment of territory (NRA 2008[4]). The 20 month baseline surveys did not identify any holts of smooth-coated otter along the reservoir shoreline. The impact magnitude is expected to be ***Negligible*** for smooth-coated otter during reservoir piling works with disturbance to foraging otters only, where impacts are expected to be within normal ranges of natural variation for habitats and populations of the species, with embedded controls and habitualisation to human activity and availability of other foraging habitat. Vibration Vibration caused by piling activities in the water might disrupt sensory communication between animals, interfering with mating, hunting and predator-evasion success. The effect of vibration from construction works will differ for different fauna types. Fauna that are ground-dwelling, nesting and/ or utilise vibration for environmental sensing and communication are more susceptible to vibration impacts, compared to other fauna types such as those in flight that are less exposed to vibration. There are no available studies establishing thresholds for wildlife tolerance to vibration. However, vibration exposure caused by the Project's in-reservoir construction will be transient and shift with construction phasing. Therefore, the impact magnitude is expected to be ***Negligible*** for vibration to terrestrial fauna during piling, where impacts are expected to be within normal			

[3] Short term (15 min) noise monitoring in the northern portion of Sungei Kadut forest indicated night-time noise levels of up to 62.9 dB(A).

[4] National Roads Authority (2008): Guidelines for the treatment of otters prior to the construction of national road schemes. Environmental series on construction impacts. Submitted by Dr. Chris Small, Ecological Solutions, Wicklow, Ireland. (https://cieem.net/resource/guidelines-for-the-treatment-of-otters-prior-to-the-construction-of-national-road-schemes/)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		ranges of natural variation for habitats and populations of the species, with embedded controls. Overall, the impact magnitude is expected to conservatively be ***Negligible*** to ***Small*** for the daytime in-reservoir piling on terrestrial fauna, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/ or (ii) not cause substantial change in species population or other species dependent on it, with embedded controls, the species' home range and availability of habitat. See item C9 below on potential impacts to terrestrial fauna from night lighting on land.			
C8	**Disturbance to terrestrial fauna (land-based worksite)**	■ **Nature**: Disturbance to terrestrial fauna from land-based worksite is considered **negative**. ■ **Type**: **Indirect** impacts from land-based worksite are expected to terrestrial fauna. ■ **Duration**: Impact will remain throughout the construction period (approximately 3 years), which is considered to be relatively **long-term** for terrestrial biodiversity. Works activities are considered temporary. ■ **Extent**: **Localised** around the land-based worksite and the immediate surroundings. ■ **Scale**: Within the proposed temporary Staging/ Launching Area worksite. ■ **Frequency**: Activities will happen **daily/ intermittently** during the specified period of construction phase. ■ **Sensitive Receptor(s)**: Birds (High), Smooth-coated Otter (High), Long-tailed macaque (Medium). The proposed temporary Staging/ Launching Area and integrated Project Substation worksite could potentially lead to disturbance by day- and night-time works of the nearby black-crowned night heron temporary roosting areas at the eastern bank of the reservoir and other birds of conservation concern within Sungei Kadut Forest. Unmitigated noise levels are expected to be at approximately 75 dB(A) at the black-crowned night heron roosting site to the south of the worksite (see *Figure 7-21*). Baseline studies found this roost to be only temporary and used by a maximum of 3 individuals at one time. It is noted that location of such roosting sites are regularly shifting. Conservatively, the impact magnitude is expected to be <u>*Small*</u>, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/or (ii) not cause substantial change in species population or other species dependent on it, with embedded controls; given the status of the current surrounding habitats and species identified in the baseline, and future land use designation. The main black-crowned night heron roost, where 16 individuals were recorded, is >250 m to the north of the worksite. Unmitigated noise levels are expected to be 69 dB(A) at this location. A grey-headed fish eagle nest was found on the eastern shore >500 m south of the worksite. Overall, because noise levels at both locations are <70 dB(A), impact magnitude is expected to be <u>*Negligible*</u>, where impacts are expected to be within normal ranges of natural variation for habitats and populations of the species, with embedded controls and separation distances from the worksite.	Impact Magnitude: **Negligible to Small** Receptor Sensitivity: **Medium to High** Impact Significance: **Minor to Moderate**	Mitigation measures presented in the Airborne Noise and Vibration *Section 9* will be applied, including: ■ Install 4 m noise barrier around north, east and south boundaries of proposed temporary Staging/ Launching Area and integrated Project Substation worksite. This will reduce noise levels to approximately 74 dB(A) at the location of the temporary black-crowned night heron roost to the south of the worksite (see *Figure 7-21*). Monitoring and adaptive management measures including: ■ Establish construction phase noise monitoring programme in agreement with relevant Government authorities prior to works commencement, to inform the Developer/ Owner on any potential impact of noise to biodiversity from the works, e.g. in the vicinity of the black-crowned night heron roosts near the proposed temporary Staging/ Launching Area and the integrated Project Substation worksite.  **Figure 7-21: Noise levels at land-based worksite with mitigation**	Impact Magnitude: **Negligible** Impact Significance: **Negligible**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		The 20 month baseline surveys did not identify any holts of smooth-coated otter along the reservoir shoreline, including the land-based worksite. Therefore, no disturbance by land-based construction is expected to occur. The long-tailed macaque is considered widespread in Singapore. The species is common in urban areas and adapted to human presence. No individuals were found at or near the planned land-based worksite during the baseline surveys. No disturbance by land-based construction is expected to occur. Impact magnitude for smooth-coated otter and long-tailed macaque is expected to be ***Negligible***, where impacts are expected to be within normal ranges of natural variation for habitats and populations of the species. Overall, the impact magnitude is expected to be ***Negligible*** to ***Small*** for the disturbance from land-based construction on terrestrial fauna, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/ or (ii) not cause substantial change in species population or other species dependent on it, with embedded controls, the species' home range and availability of habitat. See item C9 below on potential impacts to terrestrial fauna from night lighting on land.		General ■ Refer to general mitigation identified under item C7 above.	
C9	**Disturbance to terrestrial fauna (in-reservoir piling and land-based worksite night lighting)**	■ **Nature**: Disturbance to terrestrial fauna from in-reservoir piling and land-based worksite night lighting is considered **negative**. ■ **Type**: **Indirect** impacts within the reservoir and on land are expected to terrestrial fauna. ■ **Duration**: Depending on the final design of anchoring to be adopted, the installation of in-reservoir piles could take up to 56 weeks (see *Appendix 2.1*). Land-based worksite impacts will remain throughout the construction period (approximately 3 years). Both durations are considered to be relatively **long-term** for terrestrial biodiversity. Works activities are considered temporary. ■ **Extent**: **Localised** around the active worksite(s) and the immediate surroundings. ■ **Scale**: Within the Reservoir Project Site and the proposed temporary Staging/ Launching Area worksite. ■ **Frequency**: Activities will happen **daily/ intermittently** during the specified period of construction phase. ■ **Sensitive Receptor(s)**: Protected Areas and Designated Sites (High), Birds (High), Smooth-coated Otter (High), long-tailed macaque (Medium). See also item C5 above on aquatic fauna disturbance. Whilst in-reservoir works are to be in daylight hours only (due to health and safety), conservatively it is assumed some form of security and/ or navigation lighting may be required on the construction barges/ piling workstations etc within the reservoir. In addition, conservatively, potential 24 hour works and/ or security lighting is assumed for the land-based construction worksite. Illumination of working areas might result in avoidance by light-intolerant species or attraction to such areas by light-tolerant species, altering natural competition dynamics. It might also alter the circadian rhythms of wildlife and disorient and disrupt orientation in nocturnal animals.	Impact Magnitude: **Small** Receptor Sensitivity: **Medium to High** Impact Significance: **Moderate**	■ Use minimal number of luminaires, at low positions in relation to the ground, directed and shielded to provide the least amount of spill to adjacent habitats. Baffles, hoods, or louvres can be used to reduce light spill and direct it to only where it is needed. ■ Set up dark buffers, illuminance limits, and zonation. ■ Limit the duration of lighting, e.g. where peak nocturnal fauna activity is avoided, where possible. ■ Lights with reduced or filtered blue, violet and ultra-violet wavelengths should be used. As a general rule, only lights with little or no short wavelength (400–500 nm) violet or blue light should be used to avoid unintended effects. ■ Where wildlife is sensitive to longer wavelength light (e.g. some bird species), consideration should be given to wavelength selection on a case by case basis. Where possible, warm colour temperature light sources to be employed preferably at <2,700 Kelvin. General ■ Refer to general mitigation identified under item C7 above.	Impact Magnitude: **Negligible** Impact Significance: **Negligible**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		Use of directional lighting at night to avoid lighting directed at, and minimise light spill, to Kranji Marshes and Sungei Kadut Forest and reservoir edges, wherever possible, to minimise disturbance effects for light sensitive species. Conservatively, the smooth-coated otter is the main terrestrial fauna considered to be mainly nocturnal. It is known to be resilient in Singapore to the presence of human activity and even to use human-made structures. However, having a secure and undisturbed holt for resting was also found to be a main factor for the resilience of the species (Khoo & Sivasothi 2018). For its close relative, the Eurasian otter (*Lutra lutra*), a distance of 150 m to holts with breeding females is recommended to avoid disturbance and the abandonment of territory (NRA 2008). The 20 month baseline surveys did not identify any holts of smooth-coated otter along the reservoir. The impact magnitude is expected to be <u>*Negligible*</u> for smooth-coated otter, where impacts are expected to be within normal ranges of natural variation for habitats and populations of the species, with embedded controls and habitualisation to human activity, disturbance to foraging otters only, and availability of other foraging habitat. Night-time works might be carried out on land-based worksites, which is adjacent to the existing artificially lit Sungei Kadut Industrial Estate. The impact magnitude is expected to be <u>*Small*</u> for terrestrial fauna (such as long-tailed macaque) at the proposed temporary Staging / Launching Area worksite at night, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/or (ii) not cause substantial change in species population or other species dependent on it, with embedded controls; given the status of the current surrounding habitats and species identified in the baseline, and future land use designation. The black-crowned night heron's foraging opportunities may benefit from night-time lighting if there is an increase in prey availability/ visibility at night. Overall, impact magnitude is expected to be ***Small*** for the terrestrial fauna related to night lighting on land, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/or (ii) not cause substantial change in species population or other species dependent on it, given embedded controls, the species' home range and availability of habitat and roosts.			
C10	**Disturbance to terrestrial fauna (boat movements and use of helicopters)**	■ **Nature**: Disturbance to terrestrial fauna from boat movements and use of helicopters is considered **negative**. ■ **Type**: **Indirect** impacts within the reservoir and on land are expected to terrestrial fauna. ■ **Duration**: Boat movement impacts will remain throughout the construction period (approximately 3 years), which is considered to be relatively long-term for terrestrial biodiversity. Use of helicopters will be short term. Works activities are considered temporary. ■ **Extent**: **Localised** around the active worksite(s) and the immediate surroundings, for boats; and broader Kranji Reservoir area for helicopters. ■ **Scale**: Within the Reservoir Project Site. ■ **Frequency**: Activities will happen **daily** (work boats)**/ intermittently** (helicopters) during the specified period of construction phase. ■ **Sensitive Receptor(s)**: Protected Areas and Designated Sites (High), Birds (High), Smooth-coated Otter (High), long-tailed macaque (Medium).	Impact Magnitude: **Small** Receptor Sensitivity: **Medium to High** Impact Significance: **Moderate**	<u>Boat Movements</u> ■ Apply mitigation related to vessel navigation (see Surface Water Quality, *Section 6*), e.g. regular traffic routes should be established for routine works. Offset from shoreline as well as corridors between FPV islands allow safe navigation access, this will minimise the risk of disturbing bird shoreline foraging areas. <u>Helicopters</u> ■ No fly zone for helicopters within 100 m of grey-headed fish eagle nest and/ or black-crowned night heron roosts, or Protected Areas. This distance is based on Grubb et al. (2007) guideline for helicopter effects on golden eagles (*Aquila chrysaetos*) in Utah, USA and is considered appropriate to apply to this Project. <u>General</u> ■ Refer to general mitigation identified under item C7 above. Mitigation measures presented in the Airborne Noise and Vibration *Section 9* will be applied.	Impact Magnitude: **Negligible** Impact Significance: **Negligible**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		<u>Boat Movements</u> Currently there are various boat/ barge (including excavator equipment etc) movements throughout the reservoir on a daily basis from PUB's operational management. Boat/ barge movements are likely to generate activity which are avoided by wetland and waterbirds. Disturbance effects during nesting and migrating periods are likely to have relatively greater impact. Smooth-coated otters and long-tailed macaques are expected to keep away from working areas and, being adapted to coexisting with human activities, are not expected to be impacted. Cutts et al. (2009) found, that in order to minimise disturbance to waterbirds by boat movements, speeds should be kept to <25 km/h (<13.5 knots) and a minimum distance of 100 m should separate boats from colonies. However, the Project's embedded controls include limiting vessel speeds to <5 knots (PUB requirement); and the flight initiation survey conducted for this Project found 25 m to be the maximum average flight distance for disturbed birds. With a generally >50 m works boundary from the eastern reservoir edge (due to PUB's 50 m vessel corridor) and an unmitigated 25 m set back from the western edge to the in-reservoir FPV infrastructure, boats are therefore unlikely to completely disturb birds using foraging habitats around the reservoir edges and in protected areas (SBWR, Mandai Mangroves and Mudflats, Gemala Nature area). Overall, the impact magnitude is expected to be ***Small*** for the terrestrial fauna related to boat movements, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/or (ii) not cause substantial change in species population or other species dependent on it, given embedded controls, the species' home range and availability of habitat and habitualisation to existing boat operations by PUB in-reservoir. <u>Helicopters</u> Helicopters may be used to hoist the PCU's (between 18 to 36 no.) into their positions in the east of the reservoir. These activities will create noise and movement. However, helicopters will only occasionally be deployed for transportation of large equipment into the reservoir, and for short periods of time (< 1 hour) each time. It is noted that due to the proximity of the military air base, military jet noise is common over the reservoir. The noise impacts from helicopter use are not expected to significantly trigger displacement of wildlife from grey-headed fish eagle nest and/or black-crowned night heron roosts, or Protected Areas over a long period of time. The impact magnitude is expected to be ***Small*** for the terrestrial fauna related to helicopters, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/or (ii) not cause substantial change in species population or other species dependent on it, given embedded controls, and the availability of habitat and to move away from impact area.			
C11	**Generation of dust from land-based worksite**	▪ **Nature**: Increased dust pollution is considered to be **Negative**. ▪ **Type**: **Direct** and **indirect** impacts to terrestrial flora and fauna ▪ **Duration**: This worksite will be active throughout construction (3 years) which is considered relatively **long-term** and is reversible upon removal of the Project.	Impact Magnitude: **Small** Receptor Sensitivity:	Mitigation measures presented in the Air Quality *Section 8* will be applied.	Impact Magnitude: **Negligible** Impact Significance:

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		■ **Extent**: Impacts are **localised** within the Project area land-based worksite and the immediate surroundings. ■ **Scale**: Per air quality guidelines, receptors within 350 m may be affected (see *Section 8*). ■ **Frequency**: Activities will happen **daily/ intermittently** during the specified period of construction phase with most dust emissions likely in the initial few months related to land clearance, site levelling and site establishment for the proposed temporary Staging / Launching Area, and then for the integrated Project Substation construction period. ■ **Sensitive receptor(s)**: Terrestrial plants (Medium-High), Terrestrial Habitats (High). See Air Quality (*Section 8*) to assessment related to human receptors. During land clearance, excavation or backfill activities, track out of soil may occur when heavy duty vehicles leave the construction sites with dusty material which may then spill onto the road, and/or when heavy duty vehicles transfer dust and dirt onto the road having travelled over muddy ground on site. It is assumed that at the peak there will be approximately 4 to 5 trucks moving in and out the land-based worksite per day. This worksite is adjacent to Sungei Kadut Forest. Good practice embedded control measures discussed in Air Quality *Section 8* will be implemented. Considering the permanent building volume is approximately 25,000 m^3, earthwork material is anticipated to be only 3,500 tonnes, the existing industrial nature of the nearby Sungei Kadut Estate, and embedded controls, it is anticipated that there will be limited dusty activities during FPV assembly activities after initial proposed temporary Staging/ Launching Area establishment. Dust deposition might impact terrestrial plants of conservation concern that were detected in Sungei Kadut Forest adjacent to the land-based worksite, negatively. Also, the Sungei Kadut Forest as terrestrial habitat, that supports these plant species, might be impacted. Impact magnitude is expected to be ***Small*** for terrestrial plants/ habitats, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/or (ii) not cause substantial change in species population or other species dependent on it, given embedded controls.	**Medium to High** Impact Significance: **Moderate**		**Negligible**
AQUATIC AND/OR TERRESTRIAL BIODIVERSITY					
C12	**Introduction and spread of invasive alien species**	■ **Nature**: Introduction and spread of invasive alien species is considered **negative** for both aquatic and terrestrial biodiversity. ■ **Type**: Introduction will have a **direct** impact on aquatic and terrestrial biodiversity. ■ **Duration**: Throughout the construction period (approximately 3 years), which is considered to be relatively **long-term** for aquatic and terrestrial biodiversity. ■ **Extent**: **Localised** around the worksite(s) and the immediate surroundings, and Kranji Reservoir. ■ **Scale**: Potentially localised patches across the reservoir and surrounding terrestrial habitats. ■ **Frequency**: **Intermittently** during the specified period of construction phase. ■ **Sensitive Receptor(s)**: Aquatic habitat (Medium), Surrounding terrestrial habitats (Low to High, for Sungei Kadut Forest).	Impact Magnitude: **Negligible** Receptor Sensitivity: **Medium to High** Impact Significance: **Negligible**	No mitigation measures are required as embedded controls are considered to be adequate to manage impact significance to be **Negligible**. However, it is noted that mitigation measures presented in the Surface Water Quality *Section 6* will be applied, for example: ■ Establish an Aquatic Vegetation/ Invasive Species Management Plan (includes removal of aquatic vegetation). This plan should be prepared and submitted to PUB for agreement prior to commencement of the removal works for construction.	N/A (refer to Pre-Mitigation Impact Significance Column)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		The site has an existing significant issue with invasive non-native species. Regular management of aquatic vegetation within the Kranji Reservoir is already undertaken by PUB. Additional aquatic vegetation trimming and management, and therefore also increased management of invasive plant species, is expected to occur during construction period within the Reservoir Project Site. Therefore, the project might overall exert a positive impact regarding invasive species. Toxic blooming species of phytoplankton already occur in the reservoir. No invasive species have been identified on the land-based worksite. The impact magnitude is expected to be ***Negligible*** for invasive species, where impacts are expected to be within normal ranges of natural variation for habitats and populations of the species, given embedded controls and the existing baseline.			
PROTECTED AREAS (SBNP NETWORK)					
C13	**Release of suspended sediments, pollutants or nutrients outside of the reservoir into the Johor Straits, e.g. to SBWR or Mandai Mudflats, due to FPV construction**	■ **Nature**: Release of suspended sediments, pollutants or nutrients into the Johor Straits is considered **negative** for aquatic biodiversity. ■ **Type**: **Indirect** impacts to the Johor Straits when tidal gates are opened. ■ **Duration**: Depending on the final design, these activities are to take place over approximately 104 weeks, which is considered relatively **long-term** for aquatic biodiversity. Release of pore water will result in temporary elevation of ambient levels of nutrients and contaminants, which will be diluted in the surrounding water, of which the change is considered temporary. ■ **Extent**: Impacts of tidal gate opening are to the Johor Straits, with potential **regional extent**. ■ **Scale**: Elevated levels of suspended solids as well as other changes in surface water quality would likely be limited to less than 100 m from the work front and return towards baseline beyond this. ■ **Frequency**: Deployments and activities will happen **daily/ intermittently** during the specified period of construction phase. ■ **Sensitive Receptor(s)**: SBWR and Mandai Mangrove and Mudflats (Protected Areas) (High) Per the Surface Water Quality impact assessment (*Section 6*), it is expected that sediments, nutrients and contaminant outflows from the tidal gate are relatively small compared to the existing baseline of the reservoir outflows. In the context of the littoral environment north of the Kranji tidal gate, adjacent to SBWR and Mandai Mangrove and Mudflats (high value sensitive receptors) in the Johor Straits, any sediment plume would likely be relatively small compared to the natural sediment load influx naturally in this environment. No coral reefs are located nearby which could be affected. Impact magnitude is expected to conservatively be ***Small*** for the release of suspended sediments, pollutants or nutrients into the Johor Straits, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/or (ii) not cause substantial change in species population or other species dependent on it, given embedded controls for surface water quality given the current baseline and tolerances of aquatic flora and fauna to suspended sediments.	Impact Magnitude: **Negligible** Receptor Sensitivity: **High** Impact Significance: **Negligible**	No mitigation measures are required as embedded controls are considered to be adequate to manage impact significance to be **Negligible**.	N/A (refer to Pre-Mitigation Impact Significance Column)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
C14	**Loss/ degradation of integrity of Protected Areas**	■ **Nature**: Loss/ degradation of integrity of Protected Areas is considered **negative**. ■ **Type**: **Indirect** impacts given the Protected Areas are outside the Project Site(s). ■ **Duration**: Throughout the construction period (approximately 3 years), which is considered to be relatively **long-term** for aquatic and terrestrial biodiversity. ■ **Extent**: Impacts to Protected Areas surrounding the Project Site(s), potential regional extent. ■ **Scale**: Within SBNP Network. ■ **Frequency**: **Infrequent** during the specified period of construction phase. ■ **Sensitive Receptor(s):** Protected areas (High) outside the Project Site(s). Although the conservation objectives for the Protected Areas within the SBNP Network are not publicly available, the integrity of these Areas likely depends on the maintenance of the following: ■ The extent and distribution of wetland habitats of the designating features. ■ The structure and function of those wetland habitats of the designating features. ■ The supporting processes on which the habitats of the designating features rely. ■ The population of each designating feature. ■ The distribution of designating features within the Protected Areas. The designating features for each site within the SBNP Network are listed above in *Table 7-6*. Of the impacts addressed in this table, only the following could potentially affect the integrity of the Protected Areas: ■ Disturbance from noise emissions from daytime in-reservoir piling could disturb migratory birds (present September to March). The disturbance of migratory birds could be significant at the national population level given the importance of the Protected Areas to these species – with reference to item C7 above, this has been assessed to have an impact magnitude of ***Negligible*** for the SBWR and Mandai Mangroves and Mudflats, and ***Negligible*** to ***Small*** for the Gemala Nature Area and Kranji Marshes. ■ Helicopter noise – with reference to item C10 above, this has been assessed to have an impact magnitude of ***Small***. ■ Introduction/ spread of invasive species – with reference to item C12 above, this has been assessed to have an impact magnitude of ***Negligible***. ■ Release of suspended sediments, pollutants or nutrients outside of the reservoir, in particular SBWR and Mandai Mangroves and Mudflats to the north – with reference to item C13 above, this has been assessed to have an impact magnitude of ***Negligible***. ■ Unplanned events from fire/ explosion or spills – with reference to item U1 below, this has been assessed to have an impact magnitude of ***Negligible*** (land-based) to ***Small*** (in-reservoir). In all cases above, expected impact magnitudes for Protected Areas would not cause a (i) loss of habitat viability/ function, and/or (ii) substantial change in species population or other species dependent on it, with embedded controls.	Impact Magnitude: **Negligible to Small** Receptor Sensitivity: **High** Impact Significance: **Minor to Moderate**	All of the mitigation measures described above/ below to control the impacts in relation to works in and around the reservoir for aquatic and terrestrial biodiversity will also avoid and minimise their impact magnitude on the Protected Areas. Taking these into account, no significant impacts are expected on the integrity of the Protected Areas.	Impact Magnitude: **Negligible** Impact Significance: **Negligible**
UNPLANNED EVENTS					
U1	**Habitat degradation from**	■ **Nature**: Habitat degradation from unplanned events is considered **negative** for aquatic and terrestrial biodiversity.	Impact Magnitude:	Likelihood Evaluation	Pre-Likelihood Significance: **Negligible** (land-based) to

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
	unplanned event of fire/ explosion and environmental spills	■ **Type**: Fire/ explosion or spills can **directly** or **indirectly** affect habitats and species, depending on the event location. ■ **Duration**: Impacts are short term and temporary, and biodiversity is expected to return to baseline in the **longer-term** after the event. ■ **Extent**: Impacts are **localised** at area around the fire/ explosion or spill, with potential to spread across further into surrounding habitats if uncontrolled. ■ **Scale**: Scale of impact depends on location and nature of the fire/ explosion or environmental spill. Effect of land-based event would likely be limited to the immediate vicinity and its immediate surroundings habitat. Per the Surface Water Quality impact assessment (*Section 6*), an in-reservoir event could affect habitat up to a few hundred meters. ■ **Frequency**: **Infrequent,** fire/ explosion and spill are unlikely to happen with embedded controls. ■ **Sensitive Receptor(s):** Protected areas (High), Aquatic habitats (Medium), Surrounding terrestrial habitats (Low to High), Aquatic plants (Low), Terrestrial Plants (Low to High), Fish (Low to Medium), Invertebrates (Low to High), Birds (Low to High), Reptiles (Low to Medium), Smooth-coated otter (High), Long-tailed macaque (Medium), Bats (Low to Medium). ■ **Likelihood:** Unlikely Spills and leaks may occur accidentally during maintenance works, for example, during fuelling of a boat engine or other maintenance equipment, as required. Any impact would be localised due to the small volume of any spill. Dilution effects in the reservoir are expected to be high. Embedded controls include establishing a Spill Prevention and Emergency Response Plan. Fire could spread to native vegetation. If the fire reached Sungei Kadut Forest this could be of large magnitude. Embedded controls include compliance with the Fire Safety Act and SCDF requirements, as well as establishing an Emergency Response Plan. Also, setting back the FPV's from shore prevents fires from spreading on terrestrial habitats; and spacing between FPV islands avoids fires spreading in the reservoir between FPV islands, and also enables firefighting access. In view of embedded controls implemented outlined in *Appendix 2.2* and Surface Water Quality impact assessment (*Section 6*) for land and in-reservoir fire/ explosion and spill events, the impact magnitude is expected to be ***Negligible*** for land-based events on terrestrial habitats and species, and to conservatively be ***Small*** for the aquatic habitat and species of Kranji Reservoir.	**Negligible** (land-based) **to Small** (in-reservoir) Receptor Sensitivity: **High** (aquatic and terrestrial habitats, fauna and flora) Pre-Likelihood Significance: **Negligible** (land-based) **to Moderate** (in-reservoir)	See likelihood evaluation in *Section 6* (Surface Water Quality). In summary, a spillage on land is unlikely, and in-reservoir is unlikely; a fire/ explosion on land is unlikely, and in-reservoir is unlikely. <u>Mitigation</u> Mitigation measures presented in the Surface Water Quality *Section 6* will be applied. The following measures would also be implemented to further mitigate the consequence of the unplanned event of fire and explosion, and environmental spills to biodiversity: ■ Spill Prevention and Emergency Response Plan to have inclusions for addressing wildlife and biodiversity concerns from events.	**Moderate** (in-reservoir) Likelihood of Occurrence: **Unlikely** Post-Likelihood Impact Significance: **Negligible** (land-based) to **Minor** (in-reservoir)

7.7.1.4 Summary of Construction Impacts

Adoption of the abovementioned mitigation measures are expected to reduce the construction residual impact magnitudes of the described impacts on biodiversity. Potential construction residual impact significance for biodiversity are anticipated to be reduced to ***Negligible*** to ***Moderate***.

Taking a precautionary approach, significant (above minor) residual construction impacts to biodiversity are anticipated to remain for:

- Moderate (residual) = Disturbance to terrestrial fauna (piling in reservoir) (C7) – retained on a precautionary basis.

Although the mitigation proposed is likely to reduce the noise level to less than the 70 dB(A) and 62dB(A) (western shoreline) and 64dB(A) (eastern shoreline), the residual impact magnitude and significance for the above impact (C7) has been retained at pre-mitigation levels on a precautionary basis subject to Developer/ Owner selection of detailed construction approaches (e.g. location of piling, phasing, number of simultaneous piles etc) and related mitigation measures.

Establishment of monitoring, datasets and analysis (see *Section 12* EMMP) are to validate residual (post-mitigation) impact significance, and further support management of this impact and determination of deteriorating trends (if any).

A programme of monitoring and adaptive management is proposed to verify and minimise impacts on biodiversity during construction, see *Section 7.7.3* and *Section 12* (EMMP) for further details.

It is noted that positive impacts may result from the management of non-native and invasive aquatic vegetation in the Reservoir Project Site.

Unplanned events for fire/ explosion and environmental spills during construction on biodiversity are considered unlikely to occur with embedded controls. The residual impact significance (considering their likelihood and mitigation measures) are anticipated to be ***Negligible*** (land-based) to ***Minor*** (in-reservoir) for unplanned events.

Should any of the design and/ or construction assumptions assessed in this Section change (i.e. be considered to be greater, or more impactful, than those assumed in this assessment) as a result of the Developer/ Owner's detailed design and construction methodology, the above impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein.

A summary of the impact assessment for the construction phase is presented in *Table 7-13* and construction unplanned events in *Table 7-14.*

Table 7-13: Impact Summary of Biodiversity during Construction

<table>
<tr><td rowspan="1">Impacts</td><td colspan="4">Aquatic Biodiversity:
■ Benthic habitat/ fauna loss/ disturbance (C1)
■ Elevation of suspended sediments within the reservoir (C2)
■ Elevation of pollutants and/ or nutrients within the reservoir (C3)
■ Changes due to trimming aquatic vegetation (C4)
■ Disturbance to aquatic fauna (piling, boat movements) (C5)
Terrestrial Biodiversity:
■ Terrestrial habitat clearing/ fragmentation (C6)
■ Disturbance to terrestrial fauna (piling in reservoir) (C7)
■ Disturbance to terrestrial fauna (land-based worksite) (C8)
■ Disturbance to terrestrial fauna (in-reservoir piling and land-based worksite night lighting) (C9)
■ Disturbance to terrestrial fauna (boat movements and use of helicopters) (C10)
■ Generation of dust from land-based worksite (C11)
Aquatic and/ or Terrestrial:
■ Introduction and spread of invasive alien species (C12)
Protected Areas (Sungei Buloh Nature Reserve Network):
■ Release of suspended sediments, pollutants or nutrients outside of the reservoir into the Johor Straits, e.g. to SBWR or Mandai Mudflats due to FPV construction (C13)
■ Loss/ degradation of integrity of Protected Areas (C14)</td></tr>
<tr><td rowspan="2">Impact Nature</td><td colspan="2">Negative</td><td>Positive</td><td>Neutral</td></tr>
<tr><td colspan="4">Overall the nature of the impacts would be negative.
A positive impact may result from the management of non-native and invasive aquatic vegetation in the Reservoir Project Site.</td></tr>
<tr><td rowspan="2">Impact Type</td><td colspan="2">Direct</td><td>Indirect</td><td>Induced</td></tr>
<tr><td colspan="4">Direct impacts may occur to aquatic and terrestrial habitats (and related flora/ fauna species) within the Project footprint, Reservoir Project Site and immediate surroundings. Indirect impacts and disturbance from Project construction activities may occur in surrounding reservoir and terrestrial habitats (outside the reservoir).</td></tr>
<tr><td rowspan="2">Impact Duration</td><td>Temporary</td><td>Short-term</td><td>Long-term</td><td>Permanent</td></tr>
<tr><td colspan="4">These impacts will be present at different stages and durations throughout the construction phase, which is estimated to take approximately 3 years (total in-reservoir construction period is approximately 104 weeks).</td></tr>
<tr><td>Impact Extent</td><td colspan="2">Local</td><td>Regional</td><td>Global</td></tr>
</table>

	Typically, impacts are localised within the work areas, the immediate surroundings and Kranji Reservoir. Note that activities will be conducted in phases across the Reservoir Project Site. This means affected area would be localised at any one time. Whereas indirect impacts may extend across the reservoir, potentially into nearby Protected Area (potential regional extent).
Impact Scale	Areas affected by active in-reservoir and on-land worksites, and wider reservoir. Typically, Surface Water Quality impact assessment (*Section 6*) estimates that waters up to a hundred meters away from the work fronts could be affected, and hence aquatic biodiversity.
Impact Frequency	Typically, impacts may occur daily or intermittently based on the specific period for each construction activity.
Impact Magnitude	Positive | **Negligible** | **Small** | **Medium** | Large Conservatively, without mitigation the impact magnitude for impacts during construction ranges from **Negligible** to **Medium**. An impact magnitude of Medium is defined where impacts are expected to (i) affect part of the habitat but does not threaten the long-term viability/ function of the habitat, and/ or (ii) cause a substantial change in abundance and/ or the reduction in distribution of a population over one or more generations but does not threaten the long-term viability/ function of that population, or any population dependent on it.
Receptor Sensitivity	**Low** | **Medium** | **High** ▪ Protected Areas and Designated Sites (outside the Kranji Reservoir) (High) ▪ Aquatic Habitats (all habitats i.e. littoral and pelagic/ benthic and planktonic etc.) (Medium) ▪ Surrounding Terrestrial habitats (Low to High) ▪ Aquatic Plants/ Vegetation (Low) ▪ Terrestrial Plants (Low to High) ▪ Fish (Low to Medium) ▪ Invertebrates (Low to High) ▪ Birds (Low to High) ▪ Reptiles (Low to Medium) ▪ Non-flying mammals - smooth-coated otter (High), Long-tailed macaque (Medium) ▪ Bats (Low to Medium)
Key Embedded Controls (beyond legislation, regulations, standards and guidelines)	▪ Environmental Manager to monitor, supervise and evaluate works that may impact on biodiversity, including providing training on Project's biodiversity commitments to site personnel ▪ Shoreline setbacks and FPV spacing: - Minimum 25 m around the reservoir edges, including for boat access - Setback at least 100 m from the Kranji tidal gate and dam and thus SBWR and Mandai Mangroves and Mudflats to the north - 50 m vessel corridors at prescribed water depths for PUB operations – including north-south vessel corridor on eastern reservoir edge (depth requirements can only be accommodated along the eastern portion of the reservoir) – resulting in generally >50 m eastern shoreline setback to FPV infrastructure; and east-west vessel corridor to PUB intake channel (the channel on the western side of Kranji bund)

	- Spacing between large FPV islands and breaking up of large FPV islands (in subsequent detailed design by Developer/ Owner) required for maintenance vessel and firefighting access (required by SCDF) ■ No trenching (dredging) underwater to lay connector cables ■ Use directional lighting at night to avoid lighting directed at, and minimise light spill, especially to Kranji Marshes and Sungei Kadut Forest and reservoir edges ■ FPV Panels to be coated with anti-reflective materials to maximise light absorption and minimise glare ■ Integrated Project Substation to be set back from the Kranji Reservoir shoreline and to follow the principles of the Urban Design Guidelines and greening/ planting			
Significance (without mitigation)	**Negligible**	**Minor**	**Moderate**	Major
	The impact significance is **Negligible to Moderate** without mitigation. Significant (above minor) impacts are: ■ Moderate (without mitigation): - Elevation of pollutants and/or nutrients within the reservoir (C3) - Disturbance to aquatic fauna (piling, boat movements) (C5) - Terrestrial habitat clearing/ fragmentation (C6) - Disturbance to terrestrial fauna (piling in reservoir) (C7) - Disturbance to terrestrial fauna (land-based worksite) (C8) - Disturbance to terrestrial fauna (in-reservoir piling and land-based worksite night lighting) (C9) - Disturbance to terrestrial fauna (boat movements and use of helicopters) (C10) - Generation of dust from land-based worksite (C11) - Loss/ degradation of integrity of Protected Areas (C14)			
Key Mitigation and Monitoring Measures	■ Mitigation measures presented in the Surface Water Quality *Section 6,* Air Quality *Section 8* and Airborne Noise and Vibration *Section 9* will be applied. ■ Detailed design and construction methodology of reservoir-based geotechnical/ site investigations, aquatic vegetation trimming, FPV layout, anchoring method and connector cables to optimise/ minimise footprint; and optimise/ minimise extent and number of piles, piling types, simultaneous piling workstations (e.g. in-reservoir piling activities could be controlled according to works phasing, intensity, distance between piling workstations, distance from the shoreline, etc), etc where feasible. ■ If driven piles is selected, apply noise mitigation measures, e.g. ramp up piling gradually, install enclosed shrouds around the piling equipment etc. ■ Establish an Aquatic Vegetation/ Invasive Species Management Plan (includes removal of aquatic vegetation). This plan should be prepared and submitted to PUB for agreement prior to commencement of the removal works for construction. ■ Avoid felling trees and clearing vegetation during the peak bird breeding season (March to July) ■ Pre-felling fauna inspection before felling any trees or removing any vegetation. ■ Re-plant shoreline vegetation as early as possible in the construction schedule, consult with NParks on the land-based worksite re-planting/ landscaping scheme considering the future land use of the shoreline as Park. ■ Minimise the construction works during sunrise and sunset periods. ■ Conduct regular inspections to ensure compliance and identify impacts to adjacent biodiversity areas, fauna entrapments etc.			

<table>
<tr><td></td><td colspan="5">

Train site personnel on biodiversity awareness and actions to take when encountering wildlife.
Install 4 m noise barrier around north, east and south boundaries of the proposed temporary Staging/ Launching Area and integrated Project Substation worksite.
Ensure there are no works and disturbances to areas outside of worksite.
Regulate contractor movements and activities to areas only within the construction and operational footprint (Reservoir Project Site)
Establish a Wildlife Incident Response Plan and Reporting.
Use minimal number of luminaires, positioned to minimise light spill to adjacent habitats (use baffles, hoods, or louvres etc to direct light). Set up dark buffers, illuminance limits, and zonation, where feasible, and limit the duration of lighting, use little or no short wavelength lights and measures to minimise light spill.
No fly zone for helicopters within 100 m of grey-headed fish eagle nest and/or black-crowned night heron roosts, or Protected Areas.

Monitoring and adaptive management measures:

Establish construction phase noise monitoring programme in agreement with relevant Government authorities prior to works commencement, to inform the Developer/ Owner on any potential impact of noise from the works, e.g. in the vicinity of Kranji Marshes, the black-crowned night heron roosts, the grey-headed fish eagle nest and the proposed temporary Staging/ Launching Area and the Integrated Project Substation worksite.
Establish construction phase biodiversity monitoring programme in agreement with relevant Government authorities prior to works commencement.
Biodiversity monitoring to include: plankton (zooplankton and phytoplankton), fish biomass and size, focal-/ waterbird species and smooth-coated otters.

Monitoring to support adaptive management:

Should monitoring show a decline in fish biomass, the Developer/ Owner to consider opportunities, in consultation with relevant Government authorities, for additional nature based solutions, e.g. for fish habitat enhancement in the retained habitats areas within the reservoir, for example:

Patches of floating vegetation to be retained, where feasible, in the Reservoir Project Site, subject to the FPV system's and PUB's reservoir operational requirements.
If the fish population is observed to be significantly affected despite above adaptive measures then consider other adaptive management which may include, for example, potential layout changes, removal of FPV panels, etc where appropriately agreed between responsible agencies and the Developer/ Owner.

</td></tr>
<tr><td rowspan="2">Residual Impact Magnitude (with mitigation)</td><td>Positive</td><td>Negligible</td><td>Small</td><td>Medium</td><td>Large</td></tr>
<tr><td colspan="5">The residual impact magnitude is expected to be reduced to Negligible to Small with mitigation. An impact magnitude of Small is defined where impacts are expected to (i) affect only a small area of habitat, such that there is no loss of viability/ function of the habitat, and/ or (ii) not cause a substantial change in the population of the species, or other species dependent on it.</td></tr>
<tr><td rowspan="2">Residual Impact Significance (with mitigation)</td><td>Negligible</td><td>Minor</td><td>Moderate</td><td colspan="2">Major</td></tr>
<tr><td colspan="5">The impact significance with mitigation ranges from Negligible to Moderate. Significant (above minor) impacts are:
Moderate (residual, with mitigation):</td></tr>
</table>

	- Disturbance to terrestrial fauna (piling in reservoir) (C7) – retained on a precautionary basis Although the mitigation proposed is likely to reduce the noise level to less than the 70 dB(A) and 62dB(A) (western shoreline) and 64dB(A) (eastern shoreline) as discussed, the residual impact magnitude and significance for the above impact has been retained at pre-mitigation levels on a precautionary basis subject to Developer/ Owner selection of detailed construction approaches (e.g. location of piling, phasing, number of simultaneous piles etc) and related mitigation measures described above. Establishment of monitoring, datasets and analysis (see *Section 12* EMMP) are to validate post-mitigation impact significance, and further support management of this impact and determination of deteriorating trends (if any). A positive impact may result from the management of non-native and invasive aquatic vegetation in the Reservoir Project Site. A programme of monitoring and adaptive management is proposed to verify and minimise impacts on biodiversity during construction, see *Section 6.6.3* and *Section 12* (EMMP) for further details.

Table 7-14: Impact Summary of Biodiversity during Construction Unplanned Event

Impact	■ Habitat degradation from unplanned event of fire/ explosion and environmental spills (U1)				
Impact Nature	**Negative**	Positive	Neutral		
	The nature of the impacts would be negative.				
Impact Type	**Direct**	**Indirect**	Induced		
	Directly and indirectly affecting habitats and species, depending on the event location.				
Impact Duration	**Temporary**	**Short-term**	Long-term	Permanent	
	Impacts are short term and temporary, and biodiversity is expected to return to baseline in the longer term after the event.				
Impact Extent	**Local**	Regional	Global		
	Impacts are localised within the work areas and the immediate surroundings, with potential to spread across further into surrounding habitats if uncontrolled.				
Impact Scale	■ Effect of land-based event would likely be limited to the immediate vicinity and its immediate surroundings habitat. Surface Water Quality impact assessment (*Section 6*) considers an in-reservoir event could affect habitat up to a few hundred meters.				
Impact Frequency	Infrequent, with embedded controls.				
Impact Magnitude	Positive	**Negligible**	**Small**	Medium	Large
	Without mitigation impact magnitude for impacts during construction phase unplanned events is considered **Negligible** (land-based) to **Small** (in-reservoir).				
Receptor Sensitivity	**Low**	**Medium**	**High**		
	■ Protected Areas and Designated Sites (outside the Kranji Reservoir) (High) ■ Aquatic Habitats (all habitats i.e. littoral and pelagic / benthic and planktonic etc.) (Medium) ■ Surrounding Terrestrial habitats (Low to High) ■ Aquatic Plants / Vegetation (Low) ■ Terrestrial Plants (Low to High) ■ Fish (Low to Medium) ■ Invertebrates (Low to High) ■ Birds (Low to High) ■ Reptiles (Low to Medium) ■ Non-flying mammals - smooth-coated otter (High), Long-tailed macaque (Medium)				

	■ Bats (Low to Medium)
Key Embedded Controls (beyond legislation, regulations, standards and guidelines)	In addition to key embedded controls identified in *Table 7-12*: ■ Spill Prevention and Emergency Response Plan detailing how fires/ explosions will be managed and spillage, leakage or accidents involving hazardous materials will be dealt with will be prepared
Pre-likelihood Significance (without mitigation)	**Negligible** / **Minor** / **Moderate** / Major
	The pre-likelihood significance ranges from **Negligible** (land-based) to **Moderate** (in-reservoir). Significant (above minor) impacts are: ■ Moderate (without mitigation): - Habitat degradation from unplanned event of fire/ explosion and environmental spills (U1)
Key Mitigation and Monitoring Measures	In addition to key embedded controls identified in *Table 7-12*: ■ Spill Prevention and Emergency Response Plan to have inclusions for addressing wildlife and biodiversity concerns from events
Likelihood of Occurrence	**Unlikely** / Possible / Likely
	Fire and explosions and ECM failure/ environmental spills are considered unlikely to happen during construction phase with embedded controls.
Post-likelihood Residual Significance (with mitigation)	**Negligible** / **Minor** / Moderate / Major
	The post-likelihood residual significance with mitigation ranges from **Negligible** (land-based) to **Minor** (in-reservoir). No significant (above minor) residual impacts are anticipated.

7.7.2 Operation Phase

7.7.2.1 Potential Sources of Impact

The scope of potential operational impacts and mitigation measures were identified through a literature review on the effects of solar facilities on biodiversity, or other circumstances where shading of waterbodies occurs (e.g. beneath water hyacinth). Direct impacts are localised within the BIA Study Area. Specific Project activities which may result in operational impacts to biodiversity include but are not limited to the following:

FPV – Operation in reservoir

- Presence of FPV in reservoir; and
- Operation and maintenance (O&M) of FPV Facilities (including cleaning of PV panels) in reservoir.

Unplanned Events

- Fire and Explosion; and
- Environmental Spill.

The impacts that may arise due to the above activities/ events that are considered in *Section 7.7.2.4* include:

Aquatic Biodiversity:

- Changes to the planktonic and/ or benthic communities; and
- Changes to the fish community.

Terrestrial Biodiversity:

- Reduced foraging opportunities on reservoir surface for terrestrial fauna;
- Bird and/ or bat collision with FPV panels; and
- Barrier effects/ habitat fragmentation across reservoir surface and integrated Project Substation site.

Aquatic and/or Terrestrial:

- Maintenance; and
- Introduction and spread of invasive alien species.

Protected Areas (Sungei Buloh Nature Reserve Network):

- Loss/ degradation of integrity of Protected Areas.

Unplanned Events

- Habitat degradation from unplanned event of fire/ explosion and environmental spills.

7.7.2.2 Embedded Controls

Embedded controls measures (physical or procedural) that are planned to be put in place as part of the Project design, construction and operation from the outset. These actions are to manage the Project's compliance with relevant legislation, regulations and guidelines in relation to development and biodiversity. To control the biodiversity impacts from the operation phase, the following design features or approaches are taken into account. The below are further to the operational embedded controls outlined for Surface Water Quality (*Section 6*), Air Quality (*Section 8*), Airborne Noise & Vibration (*Section 9*), Soil and Groundwater (*Section 10*) and Vectors (*Section 11*).

As stated in *Section 2.3* (Project-specific Alternatives), *Table 2-2*, the feasibility of an extension of the original FPV layout south ("southern extension"), beyond the Reservoir Project Site, was initially considered during the preliminary concept design development for this EIA (see *Section 6, Figure 6-3*). However, further to the analysis of bird baseline survey data in particular, the Project decided to retain the southern areas as "no build" to avoid impacts to these observed higher bird usage areas. As such, this southern area was not taken forward and was avoided as an embedded control. The unmitigated maximum FPV layout (of 113 ha) within the Reservoir Project Site assessed (pre-mitigation) in this biodiversity impact assessment is indicated in *Figure 7-22* below.

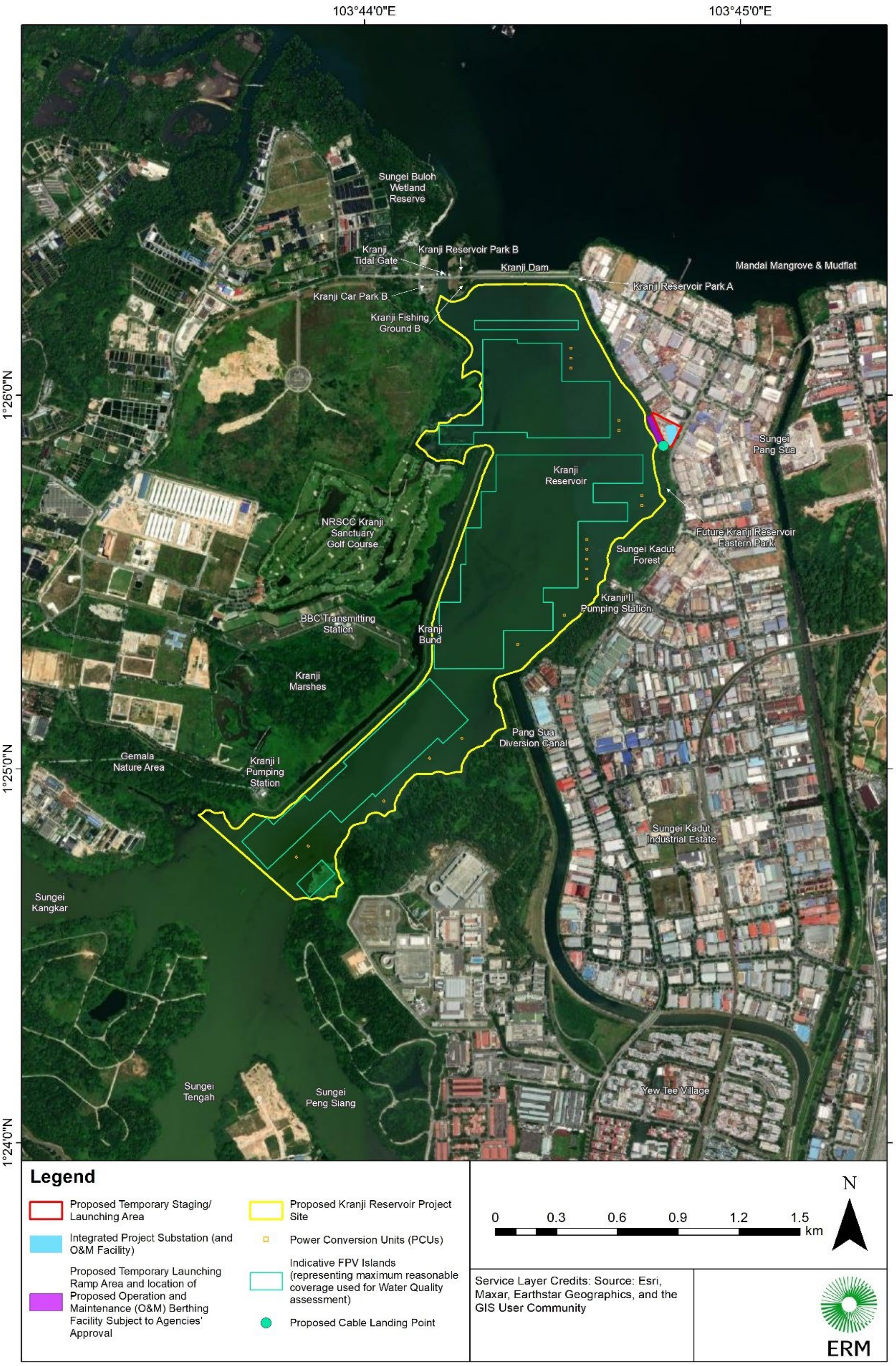


Figure 7-22: Unmitigated Maximum FPV Layout (25 western shoreline setback to FPV panels) Considered in the Pre-mitigation Biodiversity Impact Assessment

Embedded controls beyond those identified in *Section 7.2* include good practice to be implemented such as:

- A conservative operational surface water quality modelling and assessment presented in *Section 6* (Surface Water Quality) and documented in *Appendix 6.1* (Water Quality Modelling Technical Appendix) covers a larger, maximum possible extent (thus more impactful) FPV coverage (of 122 ha) than that ultimately proposed by this EIA for approval (112 ha coverage, see *Figure 2-4*). See *Table 7-18* for biodiversity mitigation recommendations related to the FPV layout.

For Developer/ Owner staff:

- Environmental Manager to monitor, supervise and evaluate works that may impact on biodiversity (as identified in this EIA); and
- Providing tool-box talks and training to all site personnel prior to commencement of operation, and as part of all new staff inductions, and regular annual refresher training, to communicate the Project's commitments regarding biodiversity and how it shall be managed, including:
  - Ecologically sensitive areas;
  - Proper protocols and reporting procedures to be adopted when wildlife is encountered;
  - Need to be cautious when operating machinery (e.g. work boats) to avoid injury/mortality to fauna;
  - Need to keep all work places safe for wildlife (e.g. when not being actively worked on), storage and use of hazardous materials, and food/ waste management;
  - All workers will be prohibited from feeding animals; and
  - Biodiversity induction training should be provided for all new personnel, with refresher training provided annually during the operational phase.

For FPV Panels and Layout:

- Shoreline setbacks and FPV spacing:
  - Minimum 25 m around the reservoir edges, including for boat access;
  - Setback at least 100 m from the Kranji tidal gate and dam and thus SBWR and Mandai Mangroves and Mudflats to the north;
  - 50 m vessel corridors at prescribed water depths for PUB operations, including:
    - North-south vessel corridor on eastern reservoir edge (depth requirements can only be accommodated along the eastern portion of the reservoir) – resulting in generally >50 m eastern shoreline setback to FPV infrastructure; and
    - East-west vessel corridor to PUB intake channel (the channel on the western side of Kranji bund).
  - O&M and fire and emergency vessel corridors, required for operational requirements and SCDF:
    - Spacing between large FPV islands;
    - Breaking up of large FPV islands with 30-40m vessel corridors, to be incorporated in the detailed design stage by the Developer/ Owner.

These measures will avoid and reduce impacts to the biodiversity-rich littoral areas, especially on the east bank, and enable some continued foraging in the western edges by birds i.e. little tern and herons.

- No development of the area south of the Reservoir Project Site, for fish and the terrestrial fauna they support;
- Optimise angle of FPV panels to will allow for some light to penetrate the water surface and reduce shading, wherever feasible; and
- FPV Panels to be coated with anti-reflective materials to maximise light absorption and minimise glare or reflection in order to reduce risk of bird collisions.

For night-time works on land:

- Use directional lightning at night to avoid lighting directed at, and minimise light spill, especially to Kranji Marshes and Sungei Kadut Forest and reservoir edges; and
- Minimise night-time security lighting as far as practicable whilst enabling safe and secure site.

For work boats/ in-reservoir works:

- Speed limit of 5 knots will be implemented, particularly in shallow areas or close to the shore to minimise disturbance to the wildlife;
- Preventing the introduction, movement and spread of invasive species on and off site, for example through inspections and washing down of vehicles or boats/ barges, and the processes for removing non-native alien species; and
- Ensure good housekeeping controls such as food consumption at designated food and rest areas with storage areas and wildlife proof bins, away from natural habitat where possible, to prevent attracting wildlife to the area as a food source.

For maintenance:

- For cleaning of FPVs in reservoir, no detergent or soap would be allowed. Water (pressurised if needed) drawn from the reservoir directly would be used.

For emergency planning:

- Prepare and keep up to date a Spill Prevention and Emergency Response Plan detailing how fires/ explosions and spillage, leakage or accidents involving hazardous materials will be dealt with and ensure that workers on site have received adequate training and instruction to enable them to implement the emergency action plan in the event of an emergency.

7.7.2.3 Understanding the Kranji Reservoir Ecosystem – through an Ecological Character Description (ECD)

As discussed in *Section 4.8*, an Ecological Character Description (ECD) was prepared to conceptualise the key abiotic (non-living) and biotic (living) ecosystem processes and components within Kranji Reservoir and the interactions between them. ECD is a process usually applied to inform the management of Ramsar Wetlands[5]. Kranji Reservoir does not qualify as a Ramsar Wetland, however, the principles of the ECD process are applied to describe the reservoir ecosystem. Beyond the typical application of the ECD process, in this EIA, the conceptual model developed through the ECD was used to conceptualise the changes that may occur to the reservoir ecosystem as a result of the proposed Project. Limits of Acceptable Change (LACs) for the Kranji Reservoir ecosystem were identified through this conceptual model, such LACs identify when the ecological character of the ecosystem could be approaching a tipping point and trigger the need for additional monitoring, investigation of the change and, the need and type of intervention required, so that adaptive management measures can be designed and implemented before significant impacts occur to features of conservation interest.

The ECD method informs the understanding of the Kranji Reservoir ecosystem, taking into account historical factors, existing management and pressures, and future anticipated changes to the reservoir

[5] The Ramsar Convention on Wetlands of International Importance is the intergovernmental treaty that provides the framework for the conservation and wise use of wetlands and their resources.

in response to changes in those pressures. Full details of the ECD can be found in *Appendix 7.3*. The ECD conceptual framework draws upon the same baseline as the biodiversity impact assessment (see *Section 7.5 and Appendix 7.1* and *7.2*) as well as Surface Water Quality impact assessment and model (see *Section 6* and *Appendix 6.1*) (which includes modelling of future climate change impacts to 2050 on surface water quality).

The core elements of the key ecosystem processes and components within Kranji Reservoir, identified through the ECD, are summarised in *Table 7-15*.

Table 7-15: ECD Components, Processes and Services in Kranji Reservoir Ecosystem

	Components	**Processes**	**Services**
Key	C1 - Water reservoir	P1 - Surface water quality P2 - Fish spawning P3 - Waterbird support	S1 - Water reservoir S2 - Flood control S3 - Climate and water regulation S4 - Public recreation and spiritual enrichment S5 - Education and aesthetics S6 – Maintenance of biodiversity
Supporting	Aquatic vegetation Waterbirds Aquatic fauna Aquatic invertebrates Phytoplankton Zooplankton	Climate Geology Soils Bathymetry Hydrology and surface water quality Sediment quality	Water and nutrient cycling Habitat for biota

The ECD identified the following important existing pressures on Kranji Reservoir:

- Proliferation of exotic/ non-native flora;
- Proliferation of exotic/ non-native fauna;
- Loss of biodiversity;
- Future developments in and around the reservoir;
- Changes in fish habitats and nursery grounds;
- Waste production and water pollution; and
- Climate change (increased temperature and rainfall variability).

Primary productivity (phytoplankton and macrophytes) is largely driven by nutrients, solar radiation/ light penetration, and water column mixing (this is largely dependent on wind movement and temperature inversions). It is this primary productivity that in turn supports the food web, including the species of conservation concern such as birds, that are supported by this otherwise highly modified, hyper-eutrophic water reservoir. The extent to which the operation of the FPV changes these elements helps the understanding of likely effects from both the FPV and other external pressures such as climate change.

Understanding the natural variability within these components, processes and services and more importantly these underlying drivers, helps identify the LACs (*Table 7-17*). Where the LACs are informed by relatively short data periods or poor quality data, it may also signal the need to regularly monitor and review the LACs, and possibly adjust them as the understanding of what constitutes natural variability within the system evolves (as more monitoring data becomes available, see *Section 12* EMMP).

The ECD conceptual model, inclusive of the FPV panels, is presented in *Figure 7-23* below, indicating the key components and processes and where key changes may occur in the Kranji Reservoir after the installation of FPVs. *Table 7-16* describes each of the key components and processes in *Figure 7-23*.

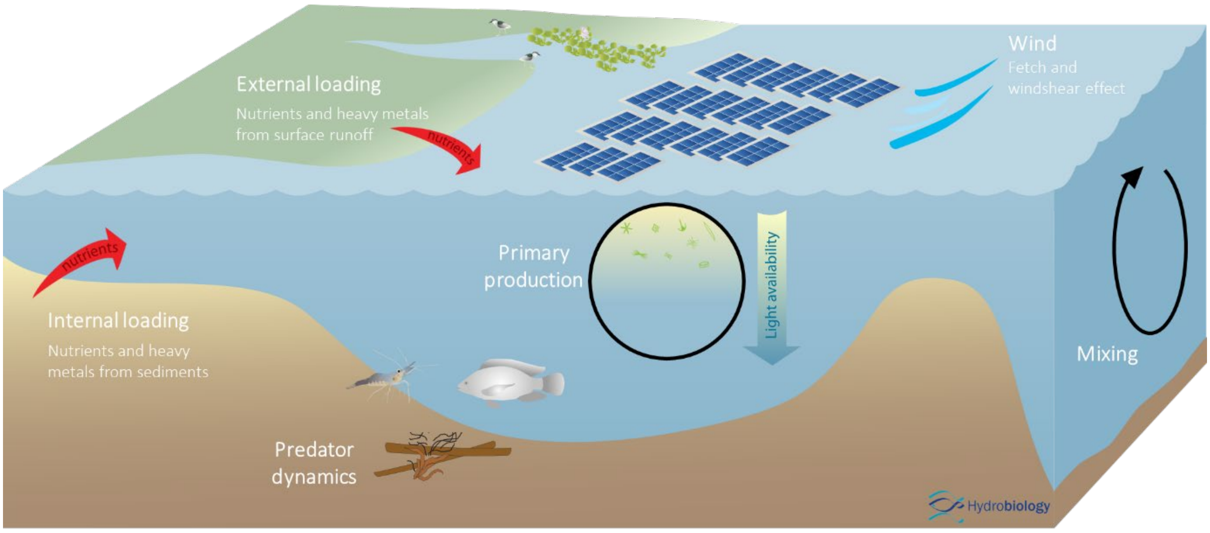


Figure 7-23: Conceptual Model of Kranji Reservoir Ecosystem and the Key Components and Processes Assessed for Change under Project Development Conditions

Table 7-16: Potential Changes in Key Components and Processes in the Kranji Reservoir Ecosystem from the Project Development (Summary of ECD)

Key Components and Processes	Description of Potential Main Changes due to the Project
1. Wind	Limiting windshear across the reservoir surface through the installation of FPV systems may lead to locally reduced vertical water column mixing and larger horizontal mixing and likely reduced oxygen exchange at the air-water interface. As a result, the replenishment of low oxygenated water at the reservoir bed with oxygen-rich water closer to the surface may be slightly reduced. The changes in vertical and horizontal mixing also may result in reservoir temperature modification and stratification. However, based on an understanding of the processes operating within the reservoir, vertical and horizontal mixing may be a larger driving force for mixing than wind in Kranji Reservoir. This would mean the perceived risks associated with reduced wind shear are probably unlikely to occur. Modelling of the potential impacts of the FPVs assumed a conservative 90% reduction in wind shear at the reservoir surface under the FPV panels. Under these future conditions reduced mixing and DO levels were predicted.
2. Light	By limiting light penetration (through FPV coverage of the water surface), submerged macrophytes, found outside the photic zone, may experience reduced growth rates or result in the die-off of plants and phytoplankton in the littoral zones. Furthermore, reduced light penetration might inhibit the predation success of aquatic predatory species that rely on light to pursue and catch prey. Scientific literature indicates that surface covers (e.g. FPVs, ice, cloth etc.) reduce solar irradiance and photosynthesis by a factor between 50%-88% depending on the waterbody type (Exley, 2021).
3. Heating and Mixing	Mixing within the reservoir shows a diurnal pattern. Daytime solar heating increases near-surface stratification with a peak surface temperature occurring around 2pm – 4pm. Overnight, convective cooling (heat loss from the reservoir surface) drives turbulent mixing and homogenises the water column over the whole depth. Complete mixing is generally achieved by 6am. Periods of prolonged stratification occur for more than 3 days a few times per year. This appears to be caused by reduced overnight cooling combined with

Key Components and Processes	Description of Potential Main Changes due to the Project
	high inflows of colder water that propagates downstream into the main reservoir along the reservoir bed. These conditions inhibit vertical exchange and cause DO depletion in deep waters. By installing FPV in the Kranji Reservoir, water below the panels is shaded, which may result in more time being required for reservoir waters to warm up or cool down and reduced evaporative losses. Modelling of the potential impacts of the FPVs assumed a conservative 40% reduction in solar radiation at the reservoir surface under the FPV panels. The reduced night-time surface heat losses effectively counterbalance the reduced daytime solar heating and surface water temperatures actually increase under the FPV area. This increase is generally small and horizontal mixing between the FPV and non-FPV areas rapidly reduces vertical layering effects.
4. Nutrient influx via surface runoff	The abundance of major phytoplankton and macrophyte taxa are influenced by Phosphorus, which is understood to be a main determinant of primary production in freshwater ecosystems like the Kranji Reservoir. Surface runoff can also result in increased Total Suspended Solids (TSS), thus impacting the turbidity of the reservoir.
5. Primary production 6. Nutrient release from sediment 7. Reservoir vertical stratification	Reduced reservoir mixing and light penetration, in addition to nutrient loading in the reservoir may promote anoxic conditions on the benthos. Anoxic conditions may promote the release of phosphate and ammonium from the sediment, resulting from a reduced ration of photosynthesis to respiration. Anoxic “dead zones” or hypoxic conditions may result from increased microbial decomposition caused by, for example, die-off of benthic macrophytes found outside the photic zone. Additionally, high Total Phosphorus and low Total Nitrogen to Total Phosphorus ratios can lead to cyanobacterial blooms. As Kranji Reservoir is a hyper-eutrophic reservoir, primary production increases the pH of the water and thereby promotes Phosphorus release from the sediment, which in turn promotes even higher primary production. Primary productivity is driven by nutrients which enter the reservoir from run off and via release from benthic sediment. It also appears to be driving the abundance and dominance of primary producing taxa. Light and inter- and intra-specific competition affect the distribution and abundance of these taxa too. Due to the eutrophic conditions in the Kranji Reservoir, the amount of organic material in the hypolimnion (lower layer of water) will be relatively large and, when stratification occurs, the rate of oxygen depletion will be faster than if the reservoir were in a less eutrophic state. Dissolved oxygen variability is driven by thermal stratification process via mixing of the water column.
8. Zooplankton-Planktivore population dynamics	Reduced phytoplankton richness in the reservoir may lead to lower zooplankton diversity and abundances, which then influences the size class structure and abundances of predators, i.e. planktivorous fish and avian predators.
9. Piscivourous fish and avian predator dynamics 10. Planktivorous fish and avian predator dynamics	According to Steinmetz, Kohler & Soluk (2003), avian predators consume certain size classes of the most abundant fish. Reduced food availability may have an effect on bird breeding population sizes.

The analysis, based on the data available, indicates that whilst changes to the physical processes occurring in the reservoir can be expected, the key components, processes and services operating within the reservoir are unlikely to significantly change. This information has been used to inform the biodiversity impact assessment as well as the LACs, and their monitoring requirements (included in *Section 12* EMMP), needed to maintain the ecological character of the reservoir.

The ECD (*Appendix 7.3*) defined limits of acceptable change (LAC), which are also presented in *Table 7-17* below.

Establishment of Limits of Acceptable Change Criteria

Seven LACs were determined based on the current baseline findings (see *Appendix 7.3* for further details). These considered the outcomes of the Project and how those could affect the key components, processes, and services. In addition, some LACs could be affected by activities unrelated to the development, such as climate change effects on water temperature or run-off from the catchment affecting benthic sediment quality. The LACs therefore take a “state of nature” approach to proactively monitoring ecosystem changes and provide early indicators to enable effective adaptive management if required. The Developer/ Owner will take responsibility for managing effects directly attributable to the Project. The Developer/ Owner should liaise with relevant Government and Technical Agencies/ Authorities closely on monitoring results and investigation findings and seek agreement on adaptive management action(s) to be conducted. Where observations (through monitoring, see EMMP *Section 12*) are not attributable to the Project, the Developer/ Owner will liaise with relevant Government Agencies responsible for managing the identified effect for their action. In this regard, the monitoring protocol is established in *Section 12* (EMMP).

This impact assessment identifies monitoring to address specific impacts, which also tie into the LAC monitoring programme, and they are seen as complimentary to each other. See *Section 12* (EMMP) for further details on the Project’s monitoring programme during the Project phases including the frequency, duration, relationship to LAC criteria and reporting.

Table 7-17: Summary of Limits of Acceptable Change (LAC) for Kranji Reservoir Ecosystem

No.	Key Component / Process	LAC Justification	LAC Criteria (against which further investigation is recommended)	Confidence Level[(a)] (based on professional judgement)	Secondary Key Components / Processes or Services addressed through this LAC
1	Reservoir Water Temperature	Temperature governs the kinds and types of aquatic life, it partly regulates the maximum dissolved oxygen concentrations, mixing within the Kranji Reservoir and influences the rates of chemical and biological reactions, as well as the toxicity of chemicals. Temperature could be increased via the presence of the FPVs and also climate change effects.	Not more than 0.3°C increase in temperature throughout the whole water column (PUB guideline criteria). Alerts (% of agreed baseline data): - Level 1: 75th-percentile = investigation into cause (both construction and operation) - Level 2: 95th-percentile = cease works (during construction) and implement mitigation agreed with relevant stakeholders (during operation).	Medium	■ Surface water quality ■ Fish fauna ■ Macrophyte growth rates ■ Phytoplankton and Zooplankton ■ Reservoir mixing & stratification
2	Nutrients	The empirical data suggest Kranji is a eutrophic system, where nutrients, in particular phosphorus (P), are readily available. Nutrients entering the reservoir, via surface runoff, appears to be driving the abundance and dominance of primary producing taxa and a main determinant of primary production. Nutrients could be affected by disturbance of the benthos during construction and run-off from the catchment.	Two-tier alert levels are proposed in discussion with PUB, during construction and operation. Limits will be based on latest baseline data sets, within an agreed time period, from PUB in Kranji Reservoir. Exact limit levels are to be agreed with PUB closer to the commencement of construction and operational stages. Parameters (monitored as part of a suite of parameters to be agreed with PUB, see *Table 12-2*): - Total Phosphorous (TP) - Total Nitrogen (TN) Alerts (% of agreed baseline data): - Level 1: 75th-percentile = investigation into cause (both construction and operation) - Level 2: 95th-percentile = cease works (during construction) and implement mitigation agreed with relevant stakeholders (during operation).	High	■ Surface water quality ■ Fish fauna ■ Macrophyte growth rates ■ Phytoplankton and Zooplankton ■ Recreation (fishing, visual amenity)
3	Plankton	Zooplankton and/ or Phytoplankton serve as indicators of environmental conditions, trophic status, and maximum photosynthetic rates, and are sensitive to changes in surface water quality in the Kranji Reservoir, either as a result of the FPV or pressures from the catchment.	Large deviations that exceed those normally found by PUB in abundance of species that are indicative of eutrophic waters should be a trigger for more frequent monitoring surveys and investigation, where appropriate. Follow up investigation should ensure that sampling is representative of the whole project and includes sampling locations both along the shoreline and sites further away from the shoreline where water depth is likely to be greater. Sampling method should be consistent throughout, and replicates expected to produce similar results.	High	■ Surface water quality ■ Fish fauna ■ Macrophytes
4	Submerged aquatic vegetation	Submerged aquatic vegetation forms part of the base of the food chain (along with phytoplankton – see LAC 3 above) and provides a notable food source and habitat for fauna utilising the reservoir (e.g. invertebrates, fish, and herbivorous waterbirds). It also provides foraging habitat for insectivorous and piscivorous birds. Vegetation in the top 1m of the water column will be trimmed as part of the construction phase (vegetation will be retained below 1 m depth). Subsequently shading of aquatic vegetation will occur under the FPVs.	Continued persistence of submerged aquatic vegetation somewhere within the Reservoir Project Site and vicinity, e.g. including shoreline buffers, subject to reservoir operational requirements to ensure FPV system and reservoir operations are not impeded.	Low	■ Surface water quality ■ Fish fauna ■ Habitat for biota
5	Fish biomass and size class	Changes in Kranji Reservoir surface water quality may have an impact on the biomass of fish present in the reservoir.	Fish biomass reduction no more than 50% of baseline values (based on high levels of natural variation reported in other reservoirs and professional judgement) across Reservoir Project Site[(b)]. Greater biomass was recorded in deeper parts of the reservoir and south of the Reservoir Project Site.	Medium	■ Fish fauna ■ Recreation (fishing) ■ Nature conservation (Bird habitat preservation) ■ Terrestrial fauna
6	Focal bird species and overall	Migratory and resident waterbirds use the reservoir as a foraging/ nesting/ roosting ground and are utilising the natural resources there. These values have the potential to be impacted by loss of foraging	Foraging by focal bird populations to not significantly fall below average count number recorded during baseline surveys and control site(s) (if any). Refer to *Appendix 7.3* (ECD), *Table 6-1*	High	■ Nature conservation ■ Recreation (bird watching)

No.	Key Component / Process	LAC Justification	LAC Criteria (against which further investigation is recommended)	Confidence Level[a] (based on professional judgement)	Secondary Key Components / Processes or Services addressed through this LAC
	waterbird community	habitat, decreases in aquatic prey abundance, function, as well as the change of ecosystems/ habitats in the wider catchment.	for species-specific targets. This includes species of conservation concern and others representative of the bird community. Waterbird assemblage to not significantly fall below average number of species recorded during baseline surveys and control sites(s) (if any). The average number during baseline survey is 8 species.		
7	Focus Species of High Conservation Concern	Species dependent, or partly dependent, on the reservoir with a high (VU), very high (EN) or extremely high risk (CR) of extinction in Singapore (based on Singapore Red Data Book[c]). These species are likely to be affected by loss of foraging habitat, decreased prey abundance and changes within the wider catchment.	Continued presence of black-crowned night heron (nationally EN) roosts, detected on at least two occasions each year, 6 months apart. Continued sighting within Kranji Reservoir and/ or active use of nest by grey-headed fish eagle (nationally VU) at Sungei Kadut Forest during this species' breeding season. Continued foraging of smooth-coated otter (nationally EN) within Kranji Reservoir and immediately surrounding habitats.	High	■ Nature conservation ■ Recreation (bird/ wildlife watching)

Notes:

(a) For each LAC a confidence level is estimated using the following scale:
- High – Quantitative site-specific data; good understanding linking the indicator to the ecological character of the site; LAC is objectively measurable.
- Medium – Some site-specific data or strong evidence for similar systems elsewhere derived from the scientific literature; or informed expert opinion; LAC is objectively measurable.
- Low – no site-specific data or reliable evidence from the scientific literature or expert opinion, LAC may not be objectively measurable and/ or the importance of the indicator to the ecological character of the site is unknown.

(b) Based on assumed level of tolerance to change

(c) Singapore Red Data Book status of species as of 28 July 2023. This may be subject to change

7.7.2.4 Impact Assessment and Mitigation Measures

A summary of the assessment of impacts to biodiversity and proposed mitigation measures during Project's operation is provided in *Table 7-18*. General impact scoping and mitigation approaches were also taken from IUCN (2021) Mitigating Biodiversity Impacts Associated with Solar and Wind Energy Development.

Table 7-18: Impact Assessment for Biodiversity (Operation Phase)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
AQUATIC BIODIVERSITY					
O1	**Changes to the planktonic and/ or benthic communities**	■ **Nature**: Changes to the planktonic and/ or benthic communities is considered **negative** for aquatic biodiversity. ■ **Type**: **Indirect** impacts which may extend across the reservoir. ■ **Duration**: Impacts are **long-term** throughout the Project operational phase. Its effect on aquatic biodiversity is reversible should the Project's FPV be removed. ■ **Extent**: Impacts are limited **locally** within the reservoir only. ■ **Scale**: **Indirect** changes may extend throughout the reservoir. ■ **Frequency**: The change will be **continuous** throughout the Project operational phase. ■ **Sensitive Receptor(s)**: Aquatic habitats (planktonic and benthic) (Medium), Fish (Medium). A 40% reduction in solar radiation below the FPV panels is assumed (see *Appendix 6.1*). The total Kranji Reservoir surface area is 522 ha. Within the Reservoir Project Site of 201 ha, the unmitigated maximum FPV layout is assumed to occupy 113 ha (including areas for intra-island spacing between FPV islands required for maintenance vessel and firefighting access). As such the unmitigated maximum FPV layout coverage (i.e. 113 ha) is up to 21.6% of the total Kranji Reservoir surface area. This would reduce solar radiation entering the reservoir which would otherwise be available to primary producers (phytoplankton and submerged macrophytes). Scientific literature indicates that surface covers (FPVs, ice, cloth etc.) reduce solar irradiance and photosynthesis by a factor between 50%-88% depending on the waterbody type (Exley, 2021). Surface Water Quality modelling results show a decline in predicted chlorophyll-a values, that can be seen as a proxy for phytoplankton biomass, of 7-8 µg/L when FPVs are present compared to a non-FPV scenarios (see *Appendix 6.1*). The panels would also reduce heat absorption in the water column and shield the surface from wind, resulting in a reduction in the degree of mixing and mixing depth (see *Table 7-16*). Following the trimming of aquatic macrophyte vegetation within the top 1 m of the water column during the construction phase, nutrient availability will increase for phytoplankton and submerged	Impact Magnitude: **Medium** Receptor Sensitivity: **Medium** Impact Significance: **Moderate**	Mitigation measures presented in the Surface Water Quality *Section 6* will be applied, including DO, Chlorophyll-a, Total Nitrogen, Total Phosphorus, Ammonia (as N), etc. monitoring, to verify impacts and inform the need for adaptive management. In addition to: ■ Detailed design of FPV layout to optimise/ minimise FPV island footprint, where feasible. Monitoring and adaptive management measures including: ■ Establish operation phase biodiversity monitoring programme in agreement with relevant Government authorities prior to works commencement, to inform the Developer/ Owner on any potential disturbance to biodiversity from the works. - Biodiversity monitoring to include: plankton (zooplankton and phytoplankton) ■ Any notable deterioration of biodiversity observed should be investigated. Investigation should determine whether or not the observed deterioration can be attributed to the operation of the Project. If affirmative, the cause of adverse biodiversity events should be reviewed and targeted mitigation applied. The Developer/ Owner should liaise with NParks closely on monitoring results and investigation findings and seek agreement on management action(s), which may include potential layout changes, removal of the FPV etc, where appropriately agreed between responsible agencies and the Developer/ Owner. Where observations are not attributable to the Project, the Developer/ Owner will liaise with relevant Government Agencies responsible for managing the identified effect for their action. Although mitigation is proposed through detailed design development the residual impact magnitude and significance has been retained at pre-mitigation levels on a precautionary basis due to the (1) limited baseline data available, and (2) uncertainty of long term effects on plankton community. Establishment of extensive long-term monitoring, datasets and analysis (see *Section 12*) are to validate residual (post-mitigation) impact significance, and further support management of this impact and determination of deteriorating trends (if any).	Impact Magnitude: **Medium (retained on precautionary basis)** Impact Significance: **Moderate (retained on precautionary basis)**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		macrophyte production due to decreased competition. However, in the absence of sufficient sunlight with the FPV panels deployed the phytoplankton and macrophytes would not utilise all available nutrients. It is anticipated that benthic macroinvertebrate diversity in shallow areas would also reduce from an observed medium level to mirror the low levels of biodiversity found in existing deeper areas of the reservoir, where light levels are reduced. It is not expected light levels will be reduced to the extent that primary production is precluded all together. There may be a shift in the phytoplankton community to taxa better adapted to lower light intensities beneath the panels, as is likely to currently occur beneath floating matts of aquatic vegetation (water hyacinth). It is likely phytoplankton distribution will change but their relative abundances or distributions would not change. The FPV islands will increase the amount of edge habitat across the reservoir surface and provide stable (not moving) shelter and foraging opportunities for zooplankton. Conservatively, should there be a die-off in phytoplankton, submerged macrophytes and benthic macroinvertebrates would increase bacterial decomposition activity in the benthos and lower the pH and dissolved oxygen concentration. Potentially anoxic conditions may promote phosphate and ammonium release from the sediments due to a reduced photosynthesis/ respiration ratio. High Total Phosphorus and low Total Nitrogen/ Total Phosphorus ratios can lead to cyanobacteria blooms. Within the setback zones around the reservoir edge, oxygen levels would likely remain unchanged (due to exchange across the reservoir surface). Connector cables laid on the reservoir bed are not expected to impact aquatic communities significantly due to their electric isolation and the comparatively small area they occupy. They might provide additional habitat structures for the aquatic communities. Taken together, these impacts could affect a significant proportion of aquatic habitats within the Reservoir Project Site. However, Yang et al. (2022) found for the Tengeh reservoir FPV system, that processes away from the immediate area of FPV panels appear to be largely unaffected. Overall, the impact magnitude is expected to be ***Medium*** for the aquatic biodiversity, where impacts are expected to (i) affect part of the habitat but not threaten long-term habitat viability/ function, and/or (ii) cause a substantial change in abundance and/or the reduction in distribution of a population over one or more			

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		generations but does not threaten the long-term viability/ function of that population, or any population dependent on it, with embedded controls (e.g. optimising angle FPV panels to allow for some light to penetrate the water surface and reduce shading) for surface water quality and biodiversity; and considering that conservatively less than 21.6% of the total Kranji Reservoir area will be covered.			
O2	**Changes to the fish community**	■ **Nature**: Changes to the fish community is considered **negative** for aquatic biodiversity. ■ **Type**: **Indirect** impacts which may extend across the reservoir. ■ **Duration**: Impacts are **long-term** throughout the Project operational phase. Its effect on aquatic biodiversity is reversible should the Project's FPV be removed. ■ **Extent**: Impacts are limited **locally** within the reservoir only. ■ **Scale**: Indirect changes may extend throughout the reservoir. ■ **Frequency**: The change will be **continuous** throughout the Project operational phase. ■ **Sensitive Receptor(s)**: Fish (Medium). The drivers of the biomass and distribution of fish in reservoirs are light, temperature, the distribution of macrophytes and plankton (zooplankton and phytoplankton), and shelter for spawning or avoiding predation. Dissolved oxygen is also a limiting factor affecting the fish community. Following the changes described above for the planktonic and benthic communities, the fish community could be altered in terms of the biomass and distribution of species. However, all fish species recorded are generalists and none are strict planktivorous (feed on plankton). So, despite any changes to plankton community, the overall biomass and size of the fish population is unlikely to change. This includes the introduced but globally EN Asian arowana. Installation of the FPVs could potentially reduce eutrophication and improve conditions for native species. The FPV panels will increase surface edge habitat and might provide new stable (not moving) shelter and nursery grounds. Anchoring might serve as additional habitat structures for fish and macroinvertebrates. Overall, impact magnitude is expected to be ***Small*** for the fish community, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/ or (ii) not cause substantial change in species population or other species dependent on it, with embedded controls for surface water quality and biodiversity including no development of area south of the Reservoir Project Site where fish biomass is highest.	Impact Magnitude: **Small** Receptor Sensitivity: **Medium** (introduced globally EN Asian arowana) Impact Significance: **Minor**	Mitigation measures presented in the Surface Water Quality *Section 6* will be applied to inform need for adaptive management. In addition to: ■ Detailed design of FPV layout to optimise/ minimise FPV island footprint, where feasible. Monitoring and adaptive management measures including: ■ Establish operation phase biodiversity monitoring programme in agreement with relevant Government authorities prior to works commencement, to inform the Developer/ Owner on any potential deterioration of biodiversity from the works. - Biodiversity monitoring to include: fish biomass and size. ■ Should monitoring show a decline in fish biomass, the Developer/ Owner to consider opportunities, in consultation with relevant Government authorities, for additional nature based solutions, e.g. for fish habitat enhancement in the retained habitats areas within the reservoir, for example: - Patches of floating vegetation to be retained, where feasible, in the Reservoir Project Site, subject to FPV system and PUB's reservoir operational requirements. - If the fish population is observed to be significantly affected despite above adaptive measures then consider other adaptive management which may include, for example, potential layout changes, removal of FPV panels etc, where appropriately agreed between responsible agencies and the Developer/ Owner.	Impact Magnitude: **Negligible** Impact Significance: **Negligible**
TERRESTRIAL BIODIVERSITY					

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
O3	**Reduced foraging opportunities on reservoir surface for terrestrial fauna**	■ **Nature**: Reduced foraging opportunities on reservoir surface is considered **negative** for terrestrial fauna. Additional resting areas on, and increased surface edge habitat and aquatic nursery grounds under, FPV within the reservoir are considered positive for terrestrial fauna foraging. ■ **Type**: **Direct** impacts from permanent Project in-reservoir footprint (e.g. FPV islands, PCUs). **Indirect** impacts which may extend across the reservoir. ■ **Duration**: Impacts are **long-term** throughout the Project operational phase. Its effect on terrestrial fauna is reversible should the Project's FPV be removed. ■ **Extent**: Impacts are limited **locally** within the reservoir only. ■ **Scale**: Direct impacts within permanent Project in-reservoir footprint. Indirect changes may extend throughout the reservoir. ■ **Frequency**: The change will be **continuous** throughout the Project operational phase. ■ **Sensitive Receptor(s)**: Birds (Low to High), Reptiles (Low to Medium), Smooth-coated otter (Medium), Bats (Medium). See also item O1 and O2 above on aquatic biodiversity. The unmitigated maximum FPV layout includes a 25 m setback from the western reservoir shoreline to the FPV panels, corridors between large FPV islands, and PUB vessel corridors (50m wide) for reservoir operations, which can be used for fauna passage and foraging. The setback of the FPV infrastructure from the eastern shoreline is at least 50 m to allow for the required PUB vessel corridors (at a prescribed depth). In addition, as described in *Section 7.7.2.2*, the large FPV islands presented will be further broken down with 30-40m "intra-island corridors" in the final design by the Developer/ Owner to allow for Operation and Maintenance (O&M) and emergency vessel access. The unmitigated maximum FPV layout, the subject of this biodiversity impact assessment, within the Reservoir Project Site (201 ha) is shown *Figure 7-22 and Figure 7-24.* The unmitigated maximum FPV layout is assumed to occupy 113 ha, up to 21.6% of the total Kranji Reservoir surface area (522 ha). This means 409 ha or 78.3% of the Kranji Reservoir surface area will remain unoccupied by the Project's permanent in-reservoir structures under the unmitigated maximum FPV layout scenario. It is considered that the vessel corridors, and the intra-island corridors between the FPV islands will still provide access to the observed higher bird foraging habitat areas and allow in-reservoir fauna movements. The majority of feeding by bird species (e.g. herons, Rallidae) is concentrated along the shoreline edge of the reservoir and south of the Reservoir Project Site (avoided by the Project, as these areas are outside the Reservoir Project Site boundary) and on patches of floating vegetation. As indicated in *Section 7.5.2.10*, very low levels of foraging were recorded for all species in the Vantage Point (VP) survey area of Kranji Reservoir (35.4 foraging events per hour, equivalent to 0.1 foraging events per hectare per	Impact Magnitude: **Small** Receptor Sensitivity: **High** Impact Significance: **Moderate**	Mitigation measures presented in item O1 and O2 above on plankton, benthic and fish communities, including monitoring, will be applied to inform need for adaptive management. In addition to: ■ Detailed design of FPV layout to optimise/ minimise FPV island footprint, where feasible. ■ A mitigated biodiversity FPV layout is recommended under this EIA for approval: - (i) Reduce the FPV layout footprint in the observed higher bird foraging area within the Reservoir Project Site, in the central west edge (near VP3, adjacent to Kranji Marshes) (see *Figure 7-15*). - (ii) Establish a setback distance of 50 m from the FPV panels to the western shoreline of Kranji Reservoir, where relatively higher bird foraging was observed, as suggested by stakeholders, to give greater confidence in the ability of the mitigated biodiversity FPV layout to reduce impacts on biodiversity associated with disturbance and displacement along the western shoreline. ■ Based on bird baseline survey data analysis using foraging activity per 50x50m cell, a mitigated biodiversity FPV layout has been proposed, and is presented as the FPV layout in the EIA's Project Description for approval (*Section 2*, *Figure 2-3*). ■ The mitigated biodiversity FPV layout footprint will occupy approximately 112 ha or 21.5% of the total Kranji Reservoir surface area. This means 410 ha or 78.5% of the total Kranji Reservoir surface will remain unoccupied by the Project's permanent structures. ■ The (i) targeting of areas of higher foraging activity to adjust the mitigated layout, and (ii) increasing of the western shoreline setback to the FPV panels to 50 m; allows an overall 2 ha reduction in FPV cover to achieve an improvement of 31% fewer foraging events lost compared to the unmitigated maximum FPV layout; and 16% more observed foraging areas gained compared to the unmitigated maximum FPV layout. ■ See *Figure 7-24* comparing the unmitigated maximum FPV and mitigated biodiversity FPV layouts, *Table 7-20* comparing the observed baseline foraging events against the mitigated biodiversity FPV layout, and *Figure 7-25* and *Figure 7-26* indicating the FPV layouts against foraging events per hour for all species. Monitoring and adaptive management measures include: ■ Establish operation phase biodiversity monitoring programme in agreement with relevant Government authorities prior to operation, to inform the Developer/ Owner on any potential disturbance to biodiversity from the works. - Biodiversity monitoring to include: focal-/ waterbird species and smooth-coated otters. ■ Any notable deterioration of biodiversity observed should be investigated. Investigation should determine whether or not the observed deterioration can be attributed to the operation of the Project. If affirmative, the cause of adverse biodiversity events should be reviewed and targeted mitigation developed. The Developer/ Owner should liaise with NParks closely on monitoring results and investigation findings and seek agreement on management action(s), which may include potential layout changes, removal of the FPV etc, where appropriately agreed between responsible agencies and the Developer/ Owner. Where observations are not attributable to the Project, the Developer/ Owner will liaise with relevant Government Agencies responsible for managing the identified effect for their action.	Impact Magnitude: **Small (retained on precautionary basis)** Impact Significance: **Moderate (retained on precautionary basis)**

<table>
<tr><th>S/N</th><th>Impact</th><th>Impact Magnitude Description</th><th>Pre-Mitigation Impact Significance</th><th>Mitigation Measures and Monitoring</th><th>Residual (with mitigation) Impact Significance</th></tr>
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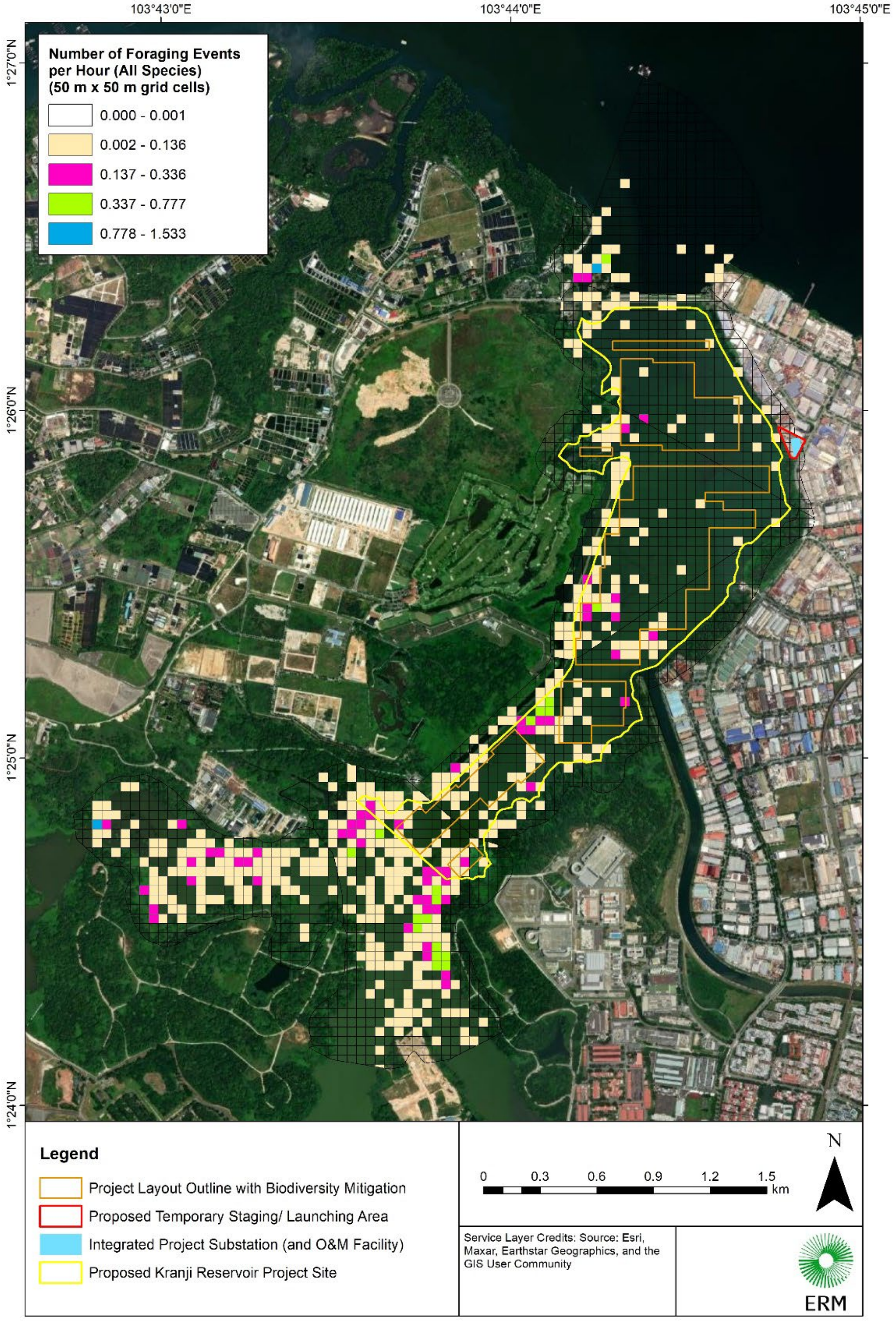
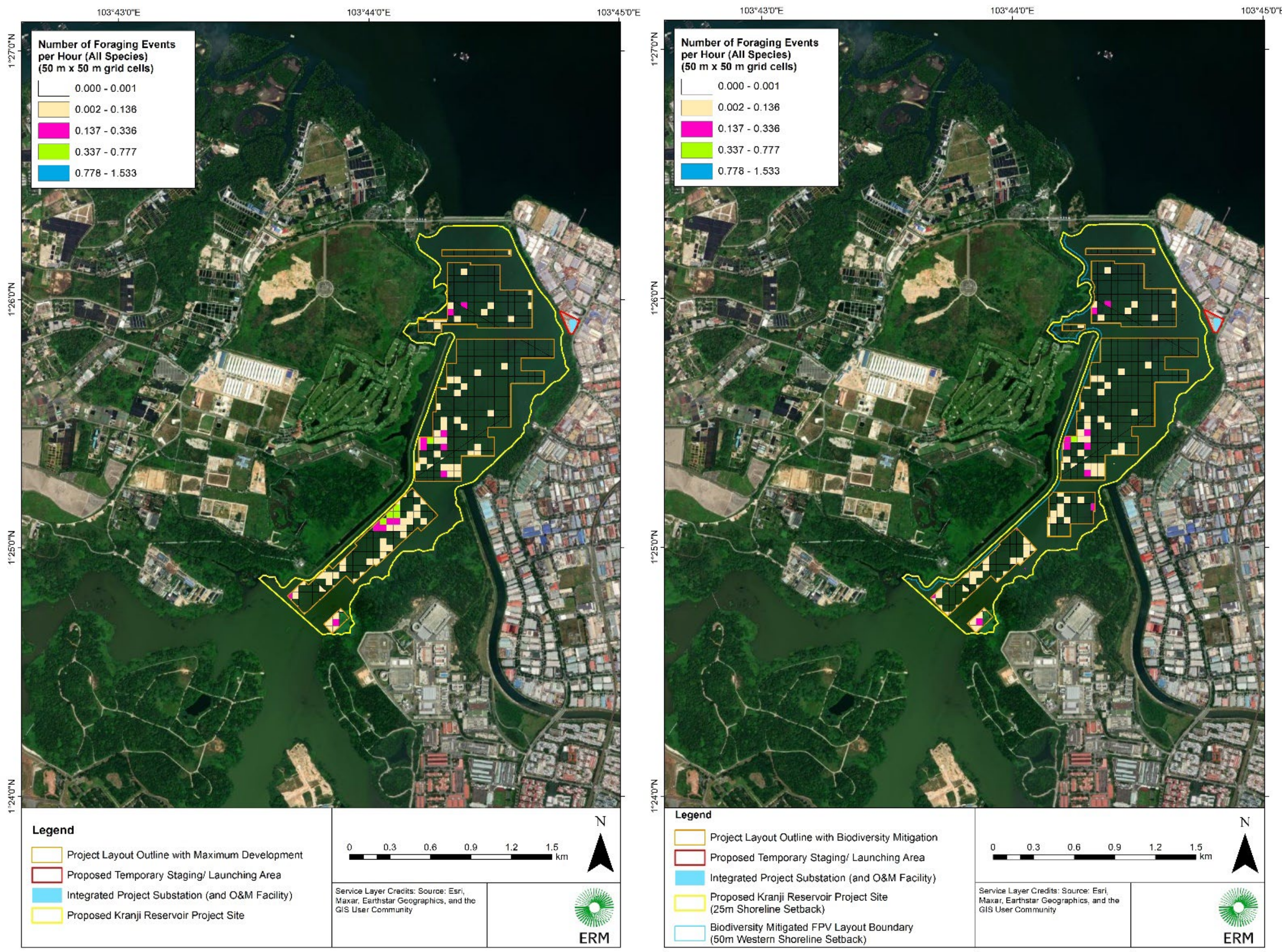
hour[6]). Further analysis indicates the majority of these foraging events were attributable to little tern (national EN) (22.9 foraging events per hour). Low foraging activity was recorded for white-bellied sea eagle, grey-headed fish eagle, purple heron, other ardeids and other terns in the VP survey area. Hence, given their relative numbers, foraging analysis focuses on little terns.
For little terns, records indicate the unmitigated maximum FPV layout coverage (113 ha) may result in 6.6 fewer foraging events per hour (7.8 fewer foraging events per hour for all species). The unmitigated maximum FPV layout covers an area of 15 ha observed to be used by little terns for foraging (i.e. 15 ha of foraging area will be lost due to the FPV coverage across the VP survey area).
Table 7-19: Comparison of Observed Foraging Events in VP Survey Area against Unmitigated Maximum FPV Layout (see Figure 7-26)
<table>
<tr><th></th><th>Foraging events per hour in VP study area: <u>without FPV</u></th><th>Foraging events per hour in VP study area: if <u>unmitigated maximum FPV layout</u></th><th>Difference: without FPV vs unmitigated maximum FPV layout</th></tr>
<tr><td>All species</td><td>■ 35.4</td><td>■ 27.6</td><td>■ - 7.8</td></tr>
<tr><td>Little Tern</td><td>■ 22.9</td><td>■ 16.3</td><td>■ - 6.6</td></tr>
</table>
The foraging range of the little terns is reported to range from 4 km for breeding birds (Parsons et al 2015) to 9-11 km (Thaxter et al. 2012). Given the absence of breeding little tern in the data recorded, their foraging habitat is expected to extend outside of the reservoir. Thus, the lost foraging habitat due to the unmitigated maximum FPV layout is considered to represent only a small fraction of the total foraging grounds of this species. The likelihood that little terns would not be able to compensate for this very small loss of foraging events by increasing feeding in areas unaffected by the FPV layout is extremely low. Furthermore, fish populations will continue to be able to sustain little terns (S/N O2 above). The impact magnitude is expected to be <u>Small</u> for the foraging by little terns, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/ or (ii) not cause substantial change in species population or other species dependent on it, with embedded controls for biodiversity. Noting the area south of the Reservoir Project Site is where fish biomass is highest, and little terns foraging was recorded to be concentrated, remains unaffected.
</td><td></td><td>


Figure 7-24: Unmitigated Maximum FPV Layout (left) and Mitigated Biodiversity FPV Layout (right)
Table 7-20: Comparison of Observed Foraging Events in VP Survey Area against Mitigated FPV Layout (see Figure 7-26)
<table>
<tr><th></th><th>Foraging events per hour in VP study area: <u>without FPV</u></th><th>Foraging events per hour in VP study area: if <u>mitigated biodiversity FPV layout</u></th><th>Difference: without FPV vs mitigated biodiversity FPV layout</th></tr>
<tr><td>All Species</td><td>■ 35.4</td><td>■ 30</td><td>■ - 5.4</td></tr>
<tr><td>Little Tern</td><td>■ 22.9</td><td>■ 18.4</td><td>■ - 4.5</td></tr>
</table>
</td><td></td></tr>
</table>

[6] The total number of foraging events recorded from each VP was mapped to a 50m x 50m cell and divided by the hours of observation at the VP to generate a map of foraging activity per hour.

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		Similarly, for other bird species, the home ranges of these species extend to foraging habitat outside of the reservoir, and fish populations will continue to be able to sustain these birds populations. Furthermore, it should be noted, that the piscivorous (fish feeding) raptors are efficient and spend relatively little time foraging, especially in food rich areas. The impact magnitude is expected to be ***Negligible*** for these other birds, where impacts are expected to be within normal range of natural variation for the habitat, or population of the species with embedded controls. Baseline surveys indicate birds tolerate boats within 5 - 25m before initiating flight response, and that birds use existing infrastructure within the reservoir for roosting and feeding. Information from Tengeh reservoir also indicates rapid habituation of some species to FPV's[7]. Insectivorous bats were recorded foraging mainly on the reservoir edge. The unmitigated 25 m western setback to FPV panels, and various vessel corridors within (subject to final design) and between the large FPV islands and PUB vessel corridors (50 m) will also still be able to provide foraging habitat. Insect populations will continue to be able to sustain bat populations. The impact magnitude is expected to be ***Small*** for insectivorous bats, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/or (ii) not cause substantial change in species population or other species dependent on it. Smooth-coated otters were recorded using the reservoir, particularly the banks. This species is expected to forage beyond Kranji Reservoir within nearby rivers to the south, mangroves and mudflats to the north, Kranji Marshes and storm drains. Fish populations will continue to be able to sustain the smooth-coated otter. The impact magnitude is expected to be ***Small*** for the foraging by the smooth-coated otter, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/or (ii) not cause substantial change in species population or other species dependent on it, with embedded controls. Aquatic herpetofauna (reptiles), such as the Asian soft-shelled turtle, Malayan box terrapin and red-tailed pipe-snake are also adapted to disturbed waterbodies with poor surface water quality. These species are less mobile than birds and the individuals in the reservoir may not be able to relocate as easily as birds to find other foraging habitat. With embedded controls, the impact magnitude is expected to be ***Small*** for the foraging by reptiles, where impacts are expected to (i) only affect a small area with no loss of habitat viability/ function, and/or (ii) not cause substantial change in species population or other species dependent on it.		 **Figure 7-25: All Species Foraging Events per Hour in VP Survey Area overlaid on Mitigated Biodiversity FPV layout**	

[7] Meet the Wildlife of Sembcorp Tengeh Floating Solar Farm https://www.youtube.com/watch?v=0jGWYTwHJeQ

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		Some incidental positive impact is possible by the FPVs providing stable (non-moving) shade and nursery habitats for fish and resting habitat for species such as birds, including little tern, herons and egrets, and non-flying (i.e. swimming) terrestrial fauna. Overall, conservatively the impact magnitude is expected to be ***Small*** for the foraging by the terrestrial fauna, where impacts are expected to (i) only affect a small area of the Kranji Reservoir with no loss of habitat viability/ function, and/ or (ii) not cause substantial change in species population or other species dependent on it, with embedded controls.		 **Figure 7-26: All Species Foraging Events per Hour recorded within Unmitigated Maximum FPV Layout (left) and Mitigated Biodiversity FPV Layout (right)** This "loss of foraging" analysis for the unmitigated and mitigated FPV layout scenarios is based on the conservative assumption birds will not compensate for the loss of foraging areas by changing their foraging behaviour, for example, by increasing: (i) the intensity of their foraging, (ii) the length of time foraging, or (iii) the area of foraging, to offset the effect of the FPV covering the reservoir surface. This is a highly precautionary approach. On the basis of the low number of foraging events lost to the FPV coverage and the high likelihood that birds could compensate; in addition to the mitigated FPV layout, and further open areas required for the 30-40m intra-island vessel corridors for O&M and emergency vessel use (embedded control to be incorporated in final design); the magnitude of the impact on foraging could be reduced from small (pre-mitigation) to negligible (residual). However, despite the proposed mitigation and refinement of the FPV layout, the residual impact magnitude and significance has been retained at pre-mitigation levels on a precautionary basis due to the uncertainty of bird responses to the FPV panels. Establishment of extensive long-term monitoring, datasets, and analysis (see *Section 12*) are to validate residual (post-mitigation) impact significance, and further support management of this impact and determination of deteriorating trends (if any). The EMMP will also specify adaptive management measures in the event limits of acceptable change could be exceeded.	
O4	**Bird and/ or bat collision**	▪ **Nature**: Bird and/ or bat collision with FPV panels is considered **negative**. ▪ **Type**: **Direct** impact from collision with FPV panels.	Impact Magnitude: **Negligible**	Mitigation measures presented in item O3 above on foraging by terrestrial fauna, including monitoring, will be applied to inform need for adaptive management. In addition to:	Impact Magnitude: **Negligible**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
	with FPV panels	■ **Duration**: Impacts are **long-term** throughout the Project operational phase. Its effect on terrestrial fauna is reversible should the Project's FPV be removed. ■ **Extent**: **Localised** to FPV layout footprint. ■ **Scale**: Specific to location of collision within the FPV layout footprint. ■ **Frequency**: **Incidental** during the operation phase. ■ **Sensitive Receptor(s)**: Birds (Low to High), Bats (Low to Medium). There is little scientific evidence to suggest that birds mistake PV panels for waterbodies (IUCN, 2021). Literature of comparable studies with similar surrounding environments to Kranji Reservoir are not available. To date there is no scientific proof that bats are attracted to FPV panels for insects, or that they collide with them. A comprehensive review of the risks associated with solar power was undertaken by Natural England, the national government conservation body (*Evidence review of the impact of solar farms on birds, bats and general ecology (NER012) 2017*), concluded that the risks of solar panel collision was low but not impossible and strongly recommended further research. A number of influential bird NGO's including Audubon society, Birdlife International and organisations such as the IUCN are supportive of solar power but stress the need for post-construction monitoring to help quantify effects. Monitoring forms a significant part of the EMMP (see *Section 12*) in part to address this. Low angling of panels and use of anti-reflective materials will reduce collision likelihood. Collisions are less likely given the panels are part of an existing waterbody, rather than the situation identified by some studies reported in the IUCN guidance on solar and wind energy development (2019), where such PV arrays were placed in desert conditions, thereby potentially attracting birds. This putative creation of a lake effect (or mirage) for birds in desert settings is unlikely to occur for FPVs in existing waterbodies. It is also understood that no bird and bat collisions have been reported to date from other FPV testbeds and utility scale FPV installations in Singapore. Also noting that collision risks are generally avoided by the fact that bird and bat usage of the open areas of the Kranji Reservoir surface is low overall, with the exception of little tern. With embedded controls, however, for little tern bird and bat species, the effects of any collisions, should they occur, the impact magnitude is expected to be ***Negligible***, where impacts are expected to be within normal range of natural variation for the habitat, or population of the species.	Receptor Sensitivity: **High** (Birds, particularly little tern) Impact Significance: **Negligible**	■ Establish a Wildlife Incident Response Plan and Reporting (including for birds, bats, snakes, crocodiles etc) to be enacted when a trapped/ injured/ dead/ dangerous animal is encountered around or within the Project Site(s), e.g. during the regular monitoring or maintenance activities.	Impact Significance: **Negligible**
O5	**Barrier effects/ habitat**	■ **Nature**: Barrier effects and habitat fragmentation across the reservoir surface and land-based integrated Project Substation site is considered **negative** for terrestrial fauna.	Impact Magnitude: **Negligible**	■ Detailed design to determine whether operational fencing is required at locations around the Reservoir Project Site, due to operational safety and security concerns, the Developer/ Owner should, in consultation with relevant Government authorities, establish wildlife-friendly fencing, crossings, access into the fencing design.	Impact Magnitude: **Negligible**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
	fragmentation across reservoir surface and integrated Project Substation site	■ **Type**: **Indirect** impacts from FPV layout footprint and integrated Project Substation site. ■ **Duration**: Impacts are **long-term** throughout the Project operational phase. Its effect on terrestrial fauna in-reservoir is reversible should the Project's FPV be removed. For the integrated Project Substation site the future surrounding land use is designated as Park. ■ **Extent**: **Localised** to FPV layout footprint and integrated Project Substation site. ■ **Scale**: **Indirect** changes may extend throughout the Project Site(s). ■ **Frequency**: The change will be **continuous** throughout the Project operational phase. ■ **Sensitive Receptor(s)**: Smooth-coated otter (High), Reptiles (Low to Medium). As terrestrial species, the mammals and herpetofauna (reptiles) recorded using the surface of the reservoir for foraging would be able to walk/ run over the FPVs. The fauna may also rest, or for herpetofauna bask, on the FPVs and the walkways and perimeter floats. The retained setback zone around the edge of the reservoir, also, corridors within/ between the large FPV islands, and PUB vessel corridors can still be used for passage and foraging. Wildlife will still be able to move around the FPVs without incurring significant additional energy expenditure or predation risk, etc. The 150 m shoreline adjacent to the integrated Project Substation will be re-planted to support continuity of habitat along the eastern shoreline. The future designated land use is Park. Minimal fragmentation is expected to terrestrial habitats for any fauna. There is no scientific evidence that flight paths of birds, including migratory birds, might be disrupted by increased light reflectance by solar panels. Since the FPV panels will be coated with anti-reflective materials to maximise light absorption and minimise glare as an embedded measure, no impact on the flight path of birds is expected. Overall, the impact magnitude is expected to be ***Negligible*** for the barrier effects/ fragmentation to terrestrial fauna, where impacts are expected to are expected to be within normal range of natural variation for the habitat, or population of the species with embedded controls.	Receptor Sensitivity: **High** Impact Significance: **Negligible**	Monitoring and adaptive management measures include: ■ Establish operation phase biodiversity monitoring programme in agreement with relevant Government authorities prior to operation, to inform the Developer/ Owner on any potential disturbance to biodiversity from the works. - Biodiversity monitoring to include: bird flight paths post-construction against pre-construction behaviour to identify if there are any significant changes in flight behaviour.	Impact Significance: **Negligible**
AQUATIC AND/OR TERRESTRIAL BIODIVERSITY					
O6	**Maintenance**	■ **Nature**: Maintenance activities could be considered **negative** for aquatic and thus terrestrial fauna. ■ **Type**: **Direct** impact from use on in-reservoir infrastructure. ■ **Duration**: Impacts may occur **long-term** throughout the Project operational phase, however impacts would be temporary. ■ **Extent**: **Localised** to in-reservoir infrastructure footprint.	Impact Magnitude: **Negligible** Receptor Sensitivity: **Medium**	No mitigation measures are required as embedded controls are considered to be adequate to manage impact significance to be ***Negligible.***	N/A (refer to Pre-Mitigation Impact Significance Column)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		■ **Scale**: **Indirect** changes may extend throughout the Reservoir Project Site. ■ **Frequency**: Occasional during the operation phase. ■ **Sensitive Receptor(s)**: Aquatic habitats (Medium, includes for secondary value to terrestrial fauna) See also Surface Water Quality *Section 6, Table 6-12,* item O2. Embedded controls include no detergent or soap allowed for FPV cleaning, where water (pressurised if needed) drawn from the reservoir directly is to be used. Overall, the impact magnitude is expected to be ***Negligible*** for maintenance impacts to terrestrial fauna, where impacts are expected to are expected to be within normal range of natural variation for the habitat, or population of the species with embedded controls.	Impact Significance: **Negligible**		
O7	**Introduction and spread of invasive alien species**	■ **Nature**: Introduction and spread of invasive alien species is considered **negative** for both aquatic and terrestrial biodiversity. ■ **Type**: Introduction will have a **direct** impact on aquatic and terrestrial biodiversity. ■ **Duration**: Impacts may occur **long-term** throughout the Project operational phase. ■ **Extent**: **Localised** around the Project site(s) and the immediate surroundings, and Kranji Reservoir. ■ **Scale**: Potentially localised patches across the reservoir and surrounding terrestrial habitats. ■ **Frequency**: **Intermittently** during the operational phase. ■ **Sensitive Receptor(s)**: Aquatic habitat (Medium), Surrounding terrestrial habitats (Low to High) The site has an existing significant issue with invasive non-native species. Regular management of aquatic vegetation within the Kranji Reservoir is already undertaken by PUB. Additional aquatic vegetation trimming and management and therefore also increased management of invasive plant species is expected to occur during operation period within the Reservoir Project Site. Therefore, the project might overall exert a positive impact regarding invasive species. Toxic blooming species of phytoplankton already occur in the reservoir. No invasive species have been identified on the land-based worksite. The impact magnitude is expected to be ***Negligible*** for invasive species, where impacts are expected to be within normal ranges of natural variation for habitats and populations of the species, given embedded controls and the existing baseline.	Impact Magnitude: **Negligible** Receptor Sensitivity: **Medium** (Aquatic - Kranji Reservoir) to **High** (Terrestrial, Sungei Kadut Forest) Impact Significance: **Negligible**	No mitigation measures are required as embedded controls are considered to be adequate to manage impact significance to be **Negligible**. However, mitigation measures presented in the Surface Water Quality (*Section 6)* will be applied, for example: ■ Establish an Aquatic Vegetation/ Invasive Species Management Plan (includes removal of aquatic vegetation). This plan should be prepared and submitted to PUB for agreement prior to commencement of the operations.	N/A (refer to Pre-Mitigation Impact Significance Column)
PROTECTED AREAS (SBNP NETWORK)					
O8	**Loss/ degradation of integrity of**	■ **Nature**: Loss/ degradation of integrity of Protected Areas is considered **negative**. ■ **Type**: **Indirect** impacts given the Protected Areas are outside the Project Site(s).	Impact Magnitude: **Negligible** to **Small**	All of the mitigation measures described above to control the impacts in relation to works in and around the reservoir will also generally avoid and minimise their magnitude on the Protected Areas.	Impact Magnitude: **Negligible**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
	Protected Areas	■ **Duration**: Impacts may occur **long-term** throughout the Project operational phase. ■ **Extent**: Impacts to Protected Areas surrounding the Project Site(s), potential regional extent. ■ **Scale**: Within SBNP Network. ■ **Frequency**: **Infrequent** during the operational phase. ■ **Sensitive Receptor(s)**: Protected areas (High) outside the Project Site(s). Although the conservation objectives for the Protected Areas within the SBNP Network are not publicly available, the integrity of these Areas likely depends on the maintenance of the following: ■ The extent and distribution of wetland habitats of the designating features. ■ The structure and function of those wetland habitats of the designating features. ■ The supporting processes on which the habitats of the designating features rely. ■ The population of each designating feature. ■ The distribution of designating features within those Areas. The designating features for each site are listed above in *Table 7-6*. Of the impacts addressed in this table only the following could potentially affect the integrity of the Protected Areas: ■ Maintenance – with reference to item O6 above, this has been assessed to have an impact magnitude of *Negligible*. ■ Introduction/ spread of invasive species – with reference to item O7 above, this has been assessed to have an impact magnitude of *Negligible*. ■ Unplanned events from fire/ explosion or spills – with reference to item U2 below, this has been assessed to have an impact magnitude of *Negligible* (land-based) to *Small* (in-reservoir). In all cases above, expected impact magnitudes for Protected Areas would not cause a (i) loss of habitat viability/ function, and/ or (ii) substantial change in species population or other species dependent on it, with embedded controls.	Receptor Sensitivity: **High** Impact Significance: **Minor to Moderate**	Taking these in account, no significant impacts are expected on the integrity of the Protected Areas.	Impact Significance: **Negligible**
UNPLANNED EVENTS					
U2	**Habitat degradation from unplanned event of fire/ explosion and environmental spills**	■ **Nature**: Habitat degradation from unplanned events is considered **negative** for aquatic and terrestrial biodiversity. ■ **Type**: Fire/ explosion or spills can **directly** or **indirectly** affect habitats and species, depending on the event location. ■ **Duration**: Impacts are **short term** and temporary, and biodiversity is expected to return to baseline in the **longer-term** after the event. ■ **Extent**: Impacts are **localised** at area around the fire/ explosion or spill, with potential to spread across further into surrounding habitats if uncontrolled. ■ **Scale**: Scale of impact depends on location and nature of the fire/ explosion or environmental spill. Effect of land-based event would likely be limited to the immediate vicinity and its	Impact Magnitude: **Negligible** (land-based) to **Small** (in-reservoir) Receptor Sensitivity: **High** (aquatic and terrestrial habitats, fauna and flora)	Likelihood Evaluation See likelihood evaluation in *Section 6* (Surface Water Quality). In summary, a spillage on land is unlikely, and in-reservoir is unlikely; a fire/ explosion on land is unlikely, and in-reservoir is unlikely. Mitigation Mitigation measures presented in the Surface Water Quality *Section 6* will be applied. The following measures would also be implemented to further mitigate the consequence of the unplanned event of fire and explosion, and environmental spills to biodiversity: ■ Spill Prevention and Emergency Response Plan to have inclusions for addressing wildlife and biodiversity concerns from events.	Pre-Likelihood Significance: **Negligible** (land-based) to **Moderate** (in-reservoir) Likelihood of Occurrence: **Unlikely** Post-Likelihood Impact Significance:

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		immediate surroundings habitat. Per the Surface Water Quality impact assessment (*Section 6*), an in-reservoir event could affect habitat up to a few hundred meters. ■ **Frequency**: Fire/ explosion and spill are unlikely to happen with embedded controls ■ **Sensitive Receptor(s)**: Protected areas (High), Aquatic habitats (Medium), Surrounding terrestrial habitats (Low to High), Aquatic plants (Low), Terrestrial Plants (Low to High), Fish (Low to Medium), Invertebrates (Low to High), Birds (Low to High), Reptiles (Low to Medium), Smooth-coated otter (High), Long-tailed macaque (Medium), Bats (Low to Medium). ■ **Likelihood**: Unlikely. Spills and leaks may occur accidentally during maintenance works, for example during fuelling of a boat engine or other maintenance equipment, as required. Any impact would be localised due to the small volume of any spill. Dilution effects in the reservoir are expected to be high. Embedded controls include establishing a Spill Prevention and Emergency Response Plan. Fire could spread to native vegetation. If the fire reached Sungei Kadut Forest this could be of large magnitude. Embedded controls include compliance with the Fire Safety Act and SCDF requirements, as well as establishing an Emergency Response Plan. Also, setting back the FPV's from shore prevents fires from spreading on terrestrial habitats; and spacing between FPV islands avoids fires spreading in the reservoir between FPV islands, and also enables firefighting access. In view of embedded controls implemented outlined in *Appendix 2.2* and Surface Water Quality impact assessment (*Section 6*) for land and in-reservoir fire/ explosion and spill events the impact magnitude is expected to be ***Negligible*** for land-based events on terrestrial habitats and species, and to conservatively be ***Small*** for the aquatic habitat and species of Kranji Reservoir.	Pre-Likelihood Significance: **Negligible** (land-based) to **Moderate** (in-reservoir)		**Negligible** (land-based) to **Minor** (in-reservoir)

7.7.2.5 Summary of Operational Impacts

Adoption of the abovementioned mitigation measures are expected to reduce the operational residual impact magnitudes of the described impacts on biodiversity. Potential operational residual impact significance for biodiversity are anticipated to be reduced to ***Negligible*** to ***Moderate***.

Taking a precautionary approach, significant (above minor) residual operational impacts to biodiversity are anticipated to remain for:

- Moderate (residual) = Changes to the planktonic and/ or benthic communities (O1) – retained on a precautionary basis
- Moderate (residual) = Reduced foraging opportunities on reservoir surface for terrestrial fauna (O3) – retained on a precautionary basis

For the plankton community (O1), although mitigation is proposed through detailed design development the residual impact magnitude and significance has been retained at pre-mitigation levels on a precautionary basis due to the (1) limited baseline data available, and (2) uncertainty of long-term effects on plankton community.

For bird foraging (O3), although the assessment is based on a conservative assumption that birds will not compensate for the loss of foraging by changing their foraging behaviours, and that mitigation is proposed through detailed design development and refinement of the FPV layout (i.e. biodiversity mitigation layout),the residual impact magnitude and significance has been retained at pre-mitigation levels due to the uncertainty of bird responses to the FPV panels.

Establishment of extensive long-term monitoring, datasets and analysis (see *Section 12*) are to validate residual (post-mitigation) impact significance, and further support management of this impact and determination of deteriorating trends (if any).

A programme of monitoring and adaptive management is proposed to verify and minimise impacts on biodiversity during operation, see *Section 7.7.3* and *Section 12* (EMMP) for further details.

It is noted that a positive impacts may result from FPVs providing stable (non-moving) shade and nursery habitats for fish and resting habitat for species such as birds, including little tern, herons and egrets, and non-flying (i.e. swimming) terrestrial fauna; positive impacts may also result from the management of non-native and invasive aquatic vegetation in the Reservoir Project Site.

Unplanned events for fire/ explosion and environmental spills during operation on biodiversity are considered unlikely to occur with embedded controls. The residual impact significance (considering their likelihood and mitigation measures) are anticipated to be ***Negligible*** (land-based) to ***Minor*** (in-reservoir) for unplanned events.

Should any of the design and/ or operational assumptions assessed in this Section change (i.e. be considered to be greater, or more impactful, than those assumed in this assessment) as a result of the Developer/ Owner’s detailed design and operations, the above impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein.

A summary of the impact assessment for the operation phase is presented in *Table 7-21* and operational unplanned events in *Table 7-22.*

Table 7-21: Impact Summary of Biodiversity during Operation

Impacts	Aquatic Biodiversity: ■ Changes to the planktonic and/ or benthic communities (O1) ■ Changes to the fish community (O2) Terrestrial Biodiversity: ■ Reduced foraging opportunities on reservoir surface for terrestrial fauna (O3) ■ Bird and/or bat collision with FPV panels (O4) ■ Barrier effects / habitat fragmentation across reservoir surface and integrated Project Substation site (O5) Aquatic and/or Terrestrial: ■ Maintenance (including use of Algicides) (O6) ■ Introduction and spread of invasive alien species (O7) Protected Areas (Sungei Buloh Nature Reserve Network): ■ Loss/ degradation of integrity of Protected Areas (O8)				
Impact Nature	**Negative**	**Positive**	Neutral		
	The FPVs coverage of the reservoir surface will have a negative effect on primary production and fish populations, although the existing communities may be sustained in littoral areas. These effects will reduce the use of the reservoir surface by terrestrial foraging species (including birds). A positive impact may result from FPVs providing stable (non-moving) shade and nursery habitats for fish and resting habitat for species such as birds, including little tern, herons and egrets, and non-flying (i.e. swimming) terrestrial fauna; positive impacts may also result from the management of non-native and invasive aquatic vegetation in the Reservoir Project Site.				
Impact Type	**Direct**	**Indirect**	Induced		
	Direct impacts from permanent Project footprint and immediate surroundings. Indirect impacts which may extend across the reservoir.				
Impact Duration	Temporary	Short-term	**Long-term**	**Permanent**	
	Impacts are long term throughout the Project operational phase. Its effect on most aquatic and terrestrial fauna is reversible should the Project's FPV be removed.				
Impact Extent	**Local**	**Regional**	Global		
	Typically, impacts are localised around the Project site(s) and the immediate surroundings, and Kranji Reservoir. Whereas indirect impacts may extend across the reservoir, potentially into nearby Protected Area (potential regional extent).				
Impact Scale	Direct impacts within permanent Project in-reservoir footprint. Indirect changes may extend throughout the reservoir.				
Impact Frequency	Typically, the change will be continuous throughout the Project operational phase.				
Impact Magnitude	Positive	**Negligible**	**Small**	**Medium**	Large

	Without mitigation the impact magnitude for impacts during construction ranges from **Negligible to Medium**. An impact magnitude of Medium is defined where impacts are expected to (i) affect part of the habitat but does not threaten the long-term viability/ function of the habitat, and/ or (ii) cause a substantial change in abundance and/ or the reduction in distribution of a population over one or more generations but does not threaten the long-term viability/ function of that population, or any population dependent on it.			
Receptor Sensitivity	**Low**	**Medium**	**High**	
	■ Protected Areas and Designated Sites (outside the Kranji Reservoir) (High) ■ Aquatic Habitats (all habitats i.e. littoral and pelagic / benthic and planktonic etc.) (Medium) ■ Surrounding Terrestrial habitats (Low to High) ■ Aquatic Plants/ Vegetation (Low) ■ Terrestrial Plants (Low to High) ■ Fish (Low to Medium) ■ Invertebrates (Low to High) ■ Birds (Low to High) ■ Reptiles (Low to Medium) ■ Non-flying mammals – smooth-coated otter (High), Long-tailed macaque (Medium) ■ Bats (Low to Medium)			
Key Embedded Controls (beyond legislation, regulations, standards and guidelines)	■ Environmental Manager to monitor, supervise and evaluate works that may impact on biodiversity, including providing training on Project's biodiversity commitments to site personnel ■ Shoreline setbacks and FPV spacing: - Minimum 25 m around the reservoir edges, including for boat access - Setback at least 100 m from the Kranji tidal gate and dam and thus SBWR and Mandai Mangroves and Mudflats to the north - 50 m vessel corridors at prescribed water depths for PUB operations – including north-south vessel corridor on eastern reservoir edge (depth requirements can only be accommodated along the eastern portion of the reservoir) – resulting in generally >50 m eastern shoreline setback to FPV infrastructure; and east-west vessel corridor to PUB intake channel (the channel on the western side of Kranji bund) - Spacing between large FPV islands and breaking up of large FPV islands (in subsequent detailed design by Developer/ Owner) required for maintenance vessel and firefighting access (required by SCDF) ■ No development of the area south of the Reservoir Project Site ■ Use directional lighting at night to avoid lighting directed at, and minimise light spill, especially to Kranji Marshes and Sungei Kadut Forest and reservoir edges ■ Speed limits of 5 knots for boats ■ Low angling of panels and use of anti-reflective materials ■ For cleaning of FPVs in reservoir, no detergent or soap would be allowed. Water (pressurised if needed) drawn from the reservoir directly would be used			
	Negligible	**Minor**	**Moderate**	Major

<table>
<tr><td>Significance (without mitigation)</td><td colspan="5">The impact significance is Negligible to Moderate without mitigation. Significant (above minor) impacts are:
■ Moderate (without mitigation):
- Changes to the planktonic and/ or benthic communities (O1)
- Reduced foraging opportunities on reservoir surface for terrestrial fauna (O3)
- Loss/ degradation of integrity of Protected Areas (O8)</td></tr>
<tr><td>Key Mitigation and Monitoring Measures</td><td colspan="5">■ Detailed design of FPV layout to optimise/ minimise FPV island footprint, where feasible.
■ Reduce the FPV layout footprint in the higher observed bird foraging areas within the Reservoir Project Site, in the central west edge (near VP3, adjacent to Kranji Marshes).
■ 50m setback from western shoreline to FPV layout (as suggested by stakeholders).
■ The recommended mitigated biodiversity FPV layout will occupy approximately 112 ha or 21.5% of the total Kranji Reservoir surface area (inclusive of all in-reservoir Project permanent infrastructure). This means 410 ha or 78.5% of the total Kranji Reservoir surface will remain unoccupied by the Project's permanent structures. Establish an Aquatic Vegetation/ Invasive Species Management Plan (includes removal of aquatic vegetation). This plan should be prepared and submitted to PUB for agreement prior to commencement of the operations.
■ Establish a Wildlife Incident Response Plan and Reporting.
■ If any operational fencing is required, consult with relevant Government authorities to establish wildlife-friendly fencing, crossings, access into the fencing design.
■ Monitoring and adaptive management including:
- Establish operation phase biodiversity monitoring programme in agreement with relevant Government authorities prior to operation. Biodiversity monitoring to include: plankton (zooplankton and phytoplankton), fish biomass and size, focal-/ waterbird species and smooth-coated otters. Also, monitoring of bird flight paths post-construction against pre-construction behaviour. Monitoring to support adaptive management, e.g. through the long-term monitoring of LACs.
- If notable deterioration of biodiversity observed, investigate cause (if from the Project, or otherwise). If from Project, review and identify further mitigation (including potential layout changes, and removal of the FPV), where appropriately agreed between responsible agencies and the Developer/ Owner.
- Should monitoring show a decline in fish biomass, the Developer/ Owner to consider opportunities, in consultation with relevant Government authorities, for additional nature-based solutions, e.g. for fish habitat enhancement in the retained habitats areas within the reservoir, for example:
▪ Patches of floating vegetation to be retained, where feasible, in the Reservoir Project Site, subject to the FPV system's and PUB's reservoir operational requirements.
▪ If the fish population is observed to be significantly affected despite above adaptive measures then consider other adaptive management which may include, for example, potential layout changes, removal of FPV panels, etc where appropriately agreed between responsible agencies and the Developer/ Owner.</td></tr>
<tr><td rowspan="2">Residual Impact Magnitude (with mitigation)</td><td>Positive</td><td>Negligible</td><td>Small</td><td>Medium</td><td>Large</td></tr>
<tr><td colspan="5">The residual impact magnitude is expected to be reduced with mitigation, however, the residual impact magnitude has been retained at pre-mitigation levels on a precautionary basis (for O1 and O3)</td></tr>
<tr><td></td><td>Negligible</td><td>Minor</td><td>Moderate</td><td colspan="2">Major</td></tr>
</table>

Residual Impact Significance (with mitigation)	The residual impact significance is expected to be reduced with mitigation, however, the residual impact magnitude and significance has been retained at pre-mitigation levels on a precautionary basis (for O1 and O3). Therefore, on a precautionary basis, residual impact significance with mitigation ranges from **Negligible** to **Moderate**. Significant (above minor) residual impacts are: ■ Moderate (precautionary, residual, with mitigation): - Changes to the planktonic and/ or benthic communities (O1) – retained on a precautionary basis - Reduced foraging opportunities on reservoir surface for terrestrial fauna (O3) – retained on a precautionary basis For the plankton community (O1), although mitigation is proposed through detailed design development the residual impact magnitude and significance has been retained at pre-mitigation levels on a precautionary basis due to the (1) limited baseline data available, and (2) uncertainty of long-term effects on plankton community. For bird foraging (O3), although the assessment is based on a conservative assumption that birds will not compensate for the loss of foraging by changing their foraging behaviours, and that mitigation is proposed through detailed design development and refinement of the FPV layout (i.e. biodiversity mitigation layout), the residual impact magnitude and significance has been retained at pre-mitigation levels due to the uncertainty of bird responses to the FPV panels. Establishment of extensive long-term monitoring, datasets and analysis (see Section 12) are to validate post-mitigation impact significance, and further support management of this impact and determination of deteriorating trends (if any). A programme of monitoring and adaptive management is proposed to verify and minimise impacts on biodiversity during operation, see *Section 7.7.3* and *Section 12* (EMMP) for further details. A positive impact may result from FPVs providing stable (non-moving) shade and nursery habitats for fish and resting habitat for species such as birds, including little tern, herons and egrets, and non-flying (i.e. swimming) terrestrial fauna; positive impacts may also result from the management of non-native and invasive aquatic vegetation in the Reservoir Project Site.

Table 7-22: Impact Summary of Biodiversity during Operation Unplanned Event

Impact	■ Habitat degradation from unplanned event of fire/ explosion and environmental spills (U2)				
Impact Nature	**Negative**	Positive	Neutral		
	The nature of the impacts would be negative.				
Impact Type	**Direct**	**Indirect**	Induced		
	Directly and indirectly affecting habitats and species, depending on the event location.				
Impact Duration	**Temporary**	**Short-term**	Long-term	Permanent	
	Impacts are short-term and temporary, and biodiversity is expected to return to baseline in the longer-term after the event.				
Impact Extent	**Local**	Regional	Global		
	Impacts are localised within the event areas and the immediate surroundings, with potential to spread across further into surrounding habitats if uncontrolled.				
Impact Scale	Effect of land-based event would likely be limited to the immediate vicinity and its immediate surroundings habitat. Surface Water Quality impact assessment (*Section 6*) considers an in-reservoir event could affect habitat up to a few hundred meters.				
Impact Frequency	Infrequent, with embedded controls.				
Impact Magnitude	Positive	**Negligible**	**Small**	Medium	Large
	Without mitigation impact magnitude for impacts during construction phase unplanned events is considered **Negligible** (land-based) to **Small** (in-reservoir).				
Receptor Sensitivity	**Low**	**Medium**	**High**		
	■ Protected Areas and Designated Sites (outside the Kranji Reservoir) (High) ■ Aquatic Habitats (all habitats i.e. littoral and pelagic/ benthic and planktonic etc.) (Medium) ■ Surrounding Terrestrial habitats (Low to High) ■ Aquatic Plants/ Vegetation (Low) ■ Terrestrial Plants (Low to High) ■ Fish (Low to Medium) ■ Invertebrates (Low to High) ■ Birds (Low to High) ■ Reptiles (Low to Medium) ■ Non-flying mammals - smooth-coated otter (High), Long-tailed macaque (Medium) ■ Bats (Low to Medium)				

<table>
<tr><td>Key Embedded Controls (beyond legislation, regulations, standards and guidelines)</td><td colspan="4">■ In addition to key embedded controls identified in Table 7-12.
■ Spill Prevention and Emergency Response Plan detailing how fires/ explosions will be managed and spillage, leakage or accidents involving hazardous materials will be dealt with will be prepared</td></tr>
<tr><td rowspan="2">Pre-likelihood Significance (without mitigation)</td><td>Negligible</td><td>Minor</td><td>Moderate</td><td>Major</td></tr>
<tr><td colspan="4">The pre-likelihood significance ranges from Negligible (land-based) to Moderate (in-reservoir). Significant (above minor) impacts are:
■ Moderate (without mitigation):
- Habitat degradation from unplanned event of fire/ explosion and environmental spills (U2)</td></tr>
<tr><td>Key Mitigation and Monitoring Measures</td><td colspan="4">In addition to key embedded controls identified in Table 7-12:
■ Spill Prevention and Emergency Response Plan to have inclusions for addressing wildlife and biodiversity concerns from events</td></tr>
<tr><td rowspan="2">Likelihood of Occurrence</td><td>Unlikely</td><td colspan="2">Possible</td><td>Likely</td></tr>
<tr><td colspan="4">Fire and explosions and environmental spills are considered unlikely to happen during operation phase with embedded controls.</td></tr>
<tr><td rowspan="2">Post-likelihood Residual Significance (with mitigation)</td><td>Negligible</td><td>Minor</td><td>Moderate</td><td>Major</td></tr>
<tr><td colspan="4">The post-likelihood residual significance with mitigation ranges from Negligible (land-based) to Minor (in-reservoir). No significant (above minor) residual impacts are anticipated.</td></tr>
</table>

7.7.3 Biodiversity Monitoring

As outlined in *Section 7.7.1.3* and *7.7.2.4* above, biodiversity monitoring is recommended to be carried during the pre-construction, construction and operational phases of the Project. The biodiversity (and surface water quality) monitoring programmes have been aligned with the ecosystem level approach considered in the EIA to support monitoring of the interactions between biotic (living, e.g. flora/ fauna) and abiotic (non-living, e.g. water quality) components and processes within Kranji Reservoir.

The Environmental Management and Monitoring Plan (EMMP) (*Section 12*) establishes further details of the proposed monitoring programmes for this Projects.

7.7.4 Potential Cumulative Impacts from Other Major Concurrent Developments

Consultation between URA and MND has been undertaken during the course of this study to identify other known concurrent projects in the immediate vicinity of the Project Sites for which works will occur at the same time as this Project, see *Section 4.3.1, Table 4-2*. The detailed schedules for such developments are not available at the time of writing. Cumulative impacts have therefore not been undertaken in this EIA due to the lack of available information. In the event that information on surrounding committed developments does become available, the Kranji FPV Project should be assessed under the cumulative impact assessments within the EIAs of these surrounding committed developments. Details of this Project, where appropriate, will be coordinated and provided to the EIA owners of surrounding developments to support their cumulative impact assessment.

8. AIR QUALITY

8.1 Overview

This Section of the EIA evaluates the potential air quality impacts associated with dust emissions from the land-based construction phase of the Project, i.e. proposed temporary Staging/ Launching Area and integrated Project Substation worksite. Where required, the mitigation hierarchy of avoidance, minimisation, reduction or compensation has been applied to potentially significant impacts to reduce impact levels to as low as reasonably practicable.

Relevant Technical Agencies have been consulted since the early phases of the Project (since January 2020) to understand air quality concerns and in preparing the air impact assessment for this Project. The discussions and recommendations from relevant Technical Agencies have been taken into account in the following assessment.

The scope of this air quality assessment focussed on construction dust where guidance from the UK's Institute of Air Quality Management (IAQM, 2018) on *Monitoring in the Vicinity of Demolition and Construction Sites* indicates that the most common impacts during construction are increased particulate matter and dust soiling. Studies from the IAQM (2014) on the *Assessment of Dust from Demolition and Construction* indicates that 85 – 90% of dust generated from construction activities ranges in size between 2.5 µm ($PM_{2.5}$) and 10 µm (PM_{10}). For the purpose of this assessment, dust will therefore be assessed in terms on PM_{10} (which includes $PM_{2.5}$).

Regarding emissions from construction equipment and vehicles, the use of diesel-powered construction equipment and vehicles will result in the emission of air pollutants from combustions, such as oxides of nitrogen (NO_X), carbon monoxide (CO), sulphur dioxide (SO_2), particulate matter (PM) and volatile organic compounds (VOCs). In Singapore, these equipment and vehicles are required to comply with the vehicle emissions and fuel standards in *Environmental Protection and Management (EPMA) (Vehicular Emissions) Regulations (Amendment), 2023* and *EPMA (Off-Road Diesel Engine Emissions) Regulations, 2012* (see *Section 8.2*). These standards require vehicles to comply with Euro 6 standards, JPN2009 or JPN2018, which limit the sulphur content to ultralow-sulphur fuels. Furthermore, guidance from IAQM (2017) on *Land Use & Development Control: Planning for Air Quality Guidelines* indicates that a change (i.e. increase) of light duty vehicles flows of more than 500 Annual Average Daily Traffic (AADT), or a change of heavy dusty vehicle flows of 100 AADT, will only then have potential significant impacts to ambient air quality. For this Project, a total of up to approximately 300 diesel operated vehicles are anticipated to be used over the approximately 3 year construction period. Thus, based on construction equipment and vehicles' compliance with the standard, as well as the guidelines above, the estimated vehicle flows are not significant, air quality assessment for air emissions generated from the vehicles has been scoped out from this assessment.

Dust and emissions from construction equipment and vessels used (in various phases) during the construction period in the reservoir is anticipated to be minimal (i.e. up to 8 work boats, barges, and up to 6 piling workstations). Thus, construction dust and emissions from in-reservoir activities is not anticipated to be significant and have also been scoped out from this assessment.

Operational impacts from the Project (FPV System and integrated Project Substation) are not anticipated to be significant (e.g. for dust emissions, and air pollutants from diesel-powered O&M vehicles, including up to 4 work boats) given the minimal O&M traffic generation, and are thus scoped out from this assessment. In addition, as described in *Section 1*, operation from the Project will have a ***positive*** impact on Singapore's air quality by contributing to the reduction of Singapore's Greenhouse Gas emissions through the use of renewable energy, as well as reducing fossil fuel usage.

Unplanned fire and explosion events due to release of ash or smoke from fires are assessed for both the construction and operation phase.

8.2 Regulatory Framework

The legislation, standards, and guidelines applicable to governing air quality at construction sites in Singapore relevant to this Project are listed in *Table 8-1*. These provide requirements and guidance for the impacts from air quality on nearby sensitive receptors due to construction activities. These legislation and guidelines also serve to scope out any non-significant impacts in this assessment, see *Section 8.1*.

Table 8-1: Summary of Legislative Requirements and Guidelines to Protect Air Quality

Legislation/ Standard/ Guideline	Relevance to Air Quality for this EIA
Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021	This Act provides for the control of air, water and noise pollution, for the safe management of hazardous waste and for the protection and management of the environment and resource conservation.
Environmental Protection and Management (Vehicular Emissions) Regulations (Amendment), 2023	All motor vehicles being driven in Singapore, when using diesel or petrol, must only use Euro V diesel or petrol that conforms with the standard of using Ultra Low Sulphur Diesel (ULSD) Fuel with a maximum sulphur concentration of 10 parts per million (ppm) (0.001%) or lower to minimise SO_2 emissions.
Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations, 2012	Vehicles and off-road diesel engines used on site must be in compliance with emissions standards stipulated in the relevant regulations.
Environmental Public Health Act (EPHA), (Amendment), 2022	Control measures shall put in place to minimise dust nuisances arising from construction works.
NEA Singapore Ambient Air Quality Targets (AAQTs), 2020	Recommends air quality targets, sulfur dioxide emission inventory, and industrial and vehicle emission standards for Singapore.
NEA Code of Practice for Environmental Control Officers for Construction Sites, 2021	Provides recommended guidelines on practice measures to reduce dust arising from construction. Open burning of construction and other wastes are not allowed at the worksite. Effective measures such as water sprinklers/ spray, shielding, netting, covers/ hoarding for aggregate and sand storage should be taken to minimise dust pollution caused by construction or demolition works. The netting or barriers on the scaffolding of the construction site shall be of suitable height for effective containment of dust and debris. All construction debris should be properly stored and removed for disposal quickly. They should not be left to accumulate at the site. All construction equipment and machinery must be well maintained and should not emit dark smoke. Generators should be sited at locations that minimise the smell and noise nuisance affecting nearby sensitive receptors.
Guidance on Monitoring in the Vicinity of Demolition and Construction Sites (IAQM), 2018	Provides recommendations for the method of monitoring of concentrations of particulate matter and dust deposition in the vicinity of demolition and construction sites.
Guidance on the Assessment of Dust from Demolition and Construction (Institute of Air Quality Management, IAQM), 2014	Provides guidance on the assessment of dust arising from the construction and air quality impact magnitude and air receptor sensitivity criteria. Provides guidelines on good practice measures to reduce dust arising from construction.
Land Use & Development Control: Planning for Air Quality Guidelines, IAQM (2017)	Guidance to ensure that air quality is adequately considered in the land-use planning and development control processes.
World Health Organisation Air Quality Guidelines (WHO AGS), 2021	Recommends levels for air quality guidelines and interim targets for common air pollutants: PM, O_3, NO_2 and SO_2.

Legislation/ Standard/ Guideline	Relevance to Air Quality for this EIA
Fire Safety Act (Amendment), 2022	Petroleum or flammable materials will be stored in compliance with requirements under the relevant storage licence. All practical steps will be taken to prevent the occurrence of an accident through fire, explosion, leakage or ignition of any petroleum or flammable material or vapours. Firefighting equipment and other emergency response equipment will be provided at all worksites. Workers will be trained in the use of available firefighting and emergency response equipment. A SCDF Plan will need to be submitted to and approved by SCDF during the final design stage.

8.2.1 Ambient Air Quality

Singapore has adopted AAQTs for 2020 and Long-Term Targets, which are largely based on the *World Health Organization Air Quality Guidelines* (WHO AGS) as presented in *Table 8-2.*

Table 8-2: Singapore's Ambient Air Quality Targets

Parameter	Averaging Time	Unit	Singapore AAQTs by 2020*	Long-Term Targets*
Sulphur Dioxide (SO_2)	24 hour	µg/m^3	50 (WHO Interim Target)	- 20 (WHO Final)
Particulate Matter (PM_{10})	Annual 24 hour	µg/m^3	20 50 (WHO Final)	- -
Particulate Matter ($PM_{2.5}$)	Annual 24 hour	µg/m^3	12 37.5 (WHO Interim Target)	10 25 (WHO Final)
Ozone	8 hour	µg/m^3	100 (WHO Final)	-
Nitrogen Dioxide (NO_2)	Annual 1 hour	µg/m^3	40 200 (WHO Final)	- -
Carbon Monoxide (CO)	8 hour 1 hour	mg/m^3	10 30 (WHO Final)	- -
Note: * - Singapore ambient air quality targets are derived from WHO (2005) Final Air Quality Guidelines.				

Source: NEA (n.d.)

At the time of writing, there has been no guidance regarding the applicability of Singapore 2020 AAQTs after 2020. Both the AAQTs for 2020 and Long-Term Targets are therefore considered to be applicable to the Project.

8.3 Assessment Criteria

The magnitude of potential construction dust impacts on ambient air quality have been assessed in accordance with the agreed targets presented in *Table 8-2.*

Considering the type of construction activities that will be undertaken, criteria for "earthworks" and "construction" published in the *Guidance on the Assessment of Dust from Demolition and Construction* (IAQM, 2014) will be adopted and are outlined in *Table 8-3.* No demolition works are anticipated for this Project.

Table 8-3: Magnitude Criteria for Assessment of Dust Impacts

Magnitude of Impacts	Definitions
Negligible	No building construction works; or Earthworks: - Total site area < 500 m^2; - Soil type with large grain size (e.g. sand); and - Total material moved < 5,000 tonnes.

Magnitude of Impacts	Definitions
Small	Construction: - Total building volume < 25,000 m^3; and/ or - Construction material with low potential for dust release, e.g. metal cladding, timber. Earthworks: - Total site area 500 to 2,500 m^2; - Soil type with large grain size (e.g. sand); and - Total material moved 5,000 to 20,000 tonnes.
Medium	Construction: - Total building volume 25,000 to 100,000 m^3; - Potentially dusty construction material e.g. concrete; and/ or - On site concrete batching. Earthworks: - Total site area 2,500 to 10,000 m^2; - Moderately dusty soil type (e.g. silt); and - Total material moved 20,000 to 100,000 tonnes.
Large	Construction: - Total building volume > 100,000 m^3; - Potentially dusty construction material e.g. concrete; and/ or - On site concrete batching and sandblasting. Earthworks: - Total site area > 10,000 m^2; - Potentially dusty soil type (e.g. clay, which will be prone to suspension when dry due to small particle size); and - Total material moved > 100,000 tonnes.

The sensitivity of human receptors to the health effects of dust follows the *Guidance on the Assessment of Dust from Demolition and Construction* (IAQM, 2014) criteria for PM_{10}. The agreed sensitivity criteria adopted for this assessment are presented in *Table 8-4*.

Table 8-4: Determination of Receptor Sensitivity

Sensitivity	Description
Low	Locations where human exposure is transient such as recreational areas, public open spaces and shopping areas.
Medium	Locations where the people exposed are workers, and exposure is over a time period relevant to the air quality objective for PM_{10} (in the case of the 24-hour objectives, a relevant location would be one where individuals may be exposed for eight hours or more in a day). Example of areas include industrial and agricultural areas.
High	Locations where members of the public are exposed over a time period relevant to the air quality objective for PM_{10} (in the case of the 24-hour objectives, a relevant location would be one where individuals may be exposed for eight hours or more in a day). Example of areas include hospitals, schools, residential and sensitive commercial land uses.

8.4 Baseline Conditions

8.4.1 Climate

In general, Singapore experiences an equatorial monsoonal tropical climate with warm, humid conditions throughout the year. Singapore has two main monsoon seasons, which include the Northeast Monsoon season from December to March, and the Southwest Monsoon season from June to September. The Northeast Monsoon features rapid development of early afternoon and evening showers, as well as monsoon surges leading to continuous moderate to heavy rains. Towards the end of this season, conditions are windy and relatively dry. The Southwest Monsoon season features showers and thunderstorm activity between pre-dawn and midday, which can be intense (< 30 minutes).

Sumatra squalls (i.e. thunderstorm lines that can bring about one to two hours of thunder and showers) are also common *(Meteorological Service Singapore (MSS)[a], n.d).*

Separating the two monsoon seasons are the Inter-monsoon periods from April to May, and October to November respectively. Thunderstorms, at times scattered or severe, can occur during these periods in the afternoon or early evenings. At other times, the weather is dry.

8.4.2 Wind

Surface wind conditions in Singapore generally follow the prevailing monsoon flows (i.e. Northeast Monsoon season from December to March (wind blows from north or northeast), and the Southwest Monsoon season from June to September (wind blows from the south or southeast). Winds during Inter-monsoon periods are usually light and tend to vary in direction on a daily basis. Mean monthly surface wind speeds range from 2.5 to 10 km/h, with maximum wind gusts of up to 80 km/h during the passage of Sumatra squalls *(MSS [a], n.d).*

8.4.3 Temperature and Humidity

Typical temperatures in Singapore reach a high of 31°C to 33°C during the day and a low of 23°C to 25°C during the night. The relative humidity in Singapore is high, with humidity levels rising to more than 90% during the morning just before sunrise and falling to about 60% in the afternoon on days when there is no rain. During periods of rain relative humidity frequently reaches 100%. The mean annual relative humidity is 83.9% *(MSS [a], n.d.).*

8.4.4 Rainfall

There is no distinct wet or dry season in Singapore. Rain falls every month of the year; however, the peak rainfall occurs from November to January during the wet phase of the Northeast Monsoon, while the driest month is February during the dry phase of the Northeast Monsoon. On average, there are about 167 rainy days a year.

Over the 31-year period from 1991 to 2021, the long-term mean annual rainfall total was 2,554.8 mm. The highest monthly total rainfall occurs in December *(MSS[b], n.d).*

8.4.5 Long-term Baseline Air Quality Monitoring (Island Wide NEA Monitoring)

The NEA carries out routine monitoring of ambient air quality through the Telemetric Air Quality Monitoring and Management System (TAQMMS).

The TAQMMS comprises of twenty-two (22) remote monitoring stations located around Singapore (*Figure 8-1*) which are linked to a Central Control System (CCS). Eighteen (18) of the stations monitor ambient air quality while four (4) measure the quality of roadside air.

Source: NEA, 2018

Figure 8-1: Telemetric Air Quality Monitoring and Management System (TAQMMS) Monitoring Station Locations

At the air monitoring stations, automatic analysers continuously monitor the common urban air pollutants such as SO_2, NO_X, CO, ozone, and particulate matter (PM_{10} and $PM_{2.5}$). At selected stations, meteorological parameters such as wind speed and direction, temperature and relative humility are also measured. *Table 8-5* presents the overall ambient air quality data for the range of parameters measured at these monitoring stations as well as those parameters anticipated to be emitted during construction (i.e. PM_{10}), for the latest available year of data.

Table 8-5: Island-wide Ambient Air Quality

Parameter	Averaging Time	Unit	Singapore 2020 AAQTs	Long-Term Targets	2021 Averaged Ambient Air Quality[(c)]
CO	8-hour [(a)]	mg/m³	10	-	1.2
	1-hour [(a)]		30	-	1.3
SO_2	Annual	µg/m³	15	-	-
	24-hour [(a)]		50	20	**89**
NO_2	Annual	µg/m³	40	-	25
	1-hour [(a)]		200	-	123
Ozone	8-hour[(a)]	µg/m³	100	-	**176**
PM_{10}	Annual	µg/m³	20	-	**28**
	24-hour [(b)]		50	-	**51**
$PM_{2.5}$	Annual	µg/m³	12	10	**12**
	24-hour [(b)]		37.5	25	**28**

Notes:

(a) Maximum 24-hr, 8-h or 1-hr
(b) 99th percentile
*(c) Value highlighted in **bold** denotes an exceedance of Singapore Ambient Air Quality Target (AAQT) or Long-Term Targets*

Source: MEWR, 2022

As shown above, there are several exceedances against the 2020 Singapore Ambient Air Quality Targets (AAQTs) reported including 24-hour SO_2, 8-hr ozone, and both annual and 24-hour of PM_{10}. Besides this, 24-hour SO_2 and both annual and 24-hour of $PM_{2.5}$, exceeded the Long-Term Targets. According to the historical NEA Environmental Protection Division's (EPD) 2018 annual report, the exceedances could be due to industrial and man-made sources of emissions such as petroleum refining processes and motor vehicles (NEA, 2018).

In order to establish the baseline for ambient particulate matter (PM) levels, the following long-term data were retrieved and collated from desktop research.

- Annual mean $PM_{2.5}$ and PM_{10} levels; and
- 24-hour mean (99th percentile) $PM_{2.5}$ and PM_{10} levels.

Table 8-6 provides a summary of overall Singapore average data of ambient PM levels between 2017 – 2021. From the summary, both annual and 24-hour PM_{10} exceeded Singapore 2020 AAQT between the years 2017 to 2021 except 24-hour PM_{10} in 2020. Annual $PM_{2.5}$ exceeded the Singapore 2020 AAQT between the years 2017 to 2019; whilst only 2019 exceeded the Singapore 2020 AAQT for 24-hour $PM_{2.5}$.

Table 8-6: Ambient Particulate Matter Level (Overall Singapore Average) – 2017 to 2021

Parameter	Averaging Time	Unit	Singapore 2020 AAQTs	Overall Singapore				
				2017	2018	2019	2020	2021
PM_{10}	Annual	µg/m^3	20	**25**	**29**	**30**	**25**	**28**
	24-hour (a)		50	**57**	**59**	**90**	43	**51**
$PM_{2.5}$	Annual	µg/m^3	12	**14**	**15**	**16**	11	12
	24-hour (b)		37.5	34	32	**62**	24	28

Notes:
(a) 99th percentile
*(b) Value highlighted in **bold** denotes an exceedance of Singapore Ambient Air Quality Target (AAQT) by 2020*

8.4.6 Short-term Baseline Air Quality Monitoring Results

Short-term ambient air quality monitoring for $PM_{2.5}$, Total Suspended Particulate (TSP) and PM_{10} were carried out at 2 locations for this Project, identified as AQ01 and AQ02 (*Figure 8-2*). This was to establish the existing baseline concentrations around the Project Sites.

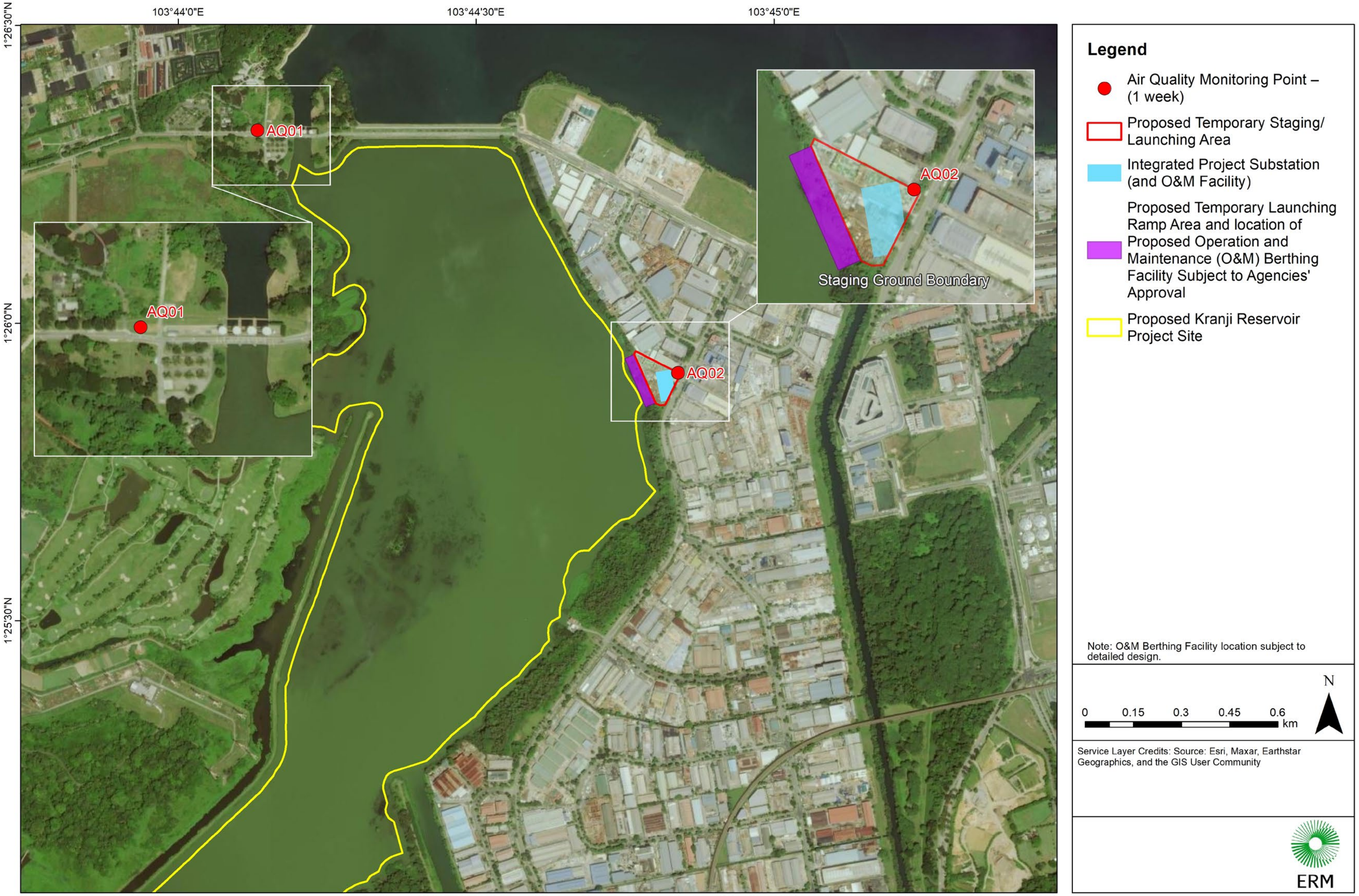


Figure 8-2: Baseline Ambient Air Quality Monitoring Locations

The parameters monitored, and methods used, for the air quality sampling are summarised in *Table 8-7.* The rationale for selecting these sampling locations and the sampling periods are provided in *Table 8-8* and the results against 24-hour AAQTs are show in *Table 8-9*. The baseline ambient air quality survey results are provided in *Appendix 8.3.*

Table 8-7: Baseline Air Quality Sampling Parameters and Methods

Parameter	Method	Duration
$PM_{2.5}$ & PM_{10}	TSI Environmental DustTrak Monitoring System	1 week
Total Suspended Particulate (TSP)	Dust Deposition Gauge	1 week

Table 8-8: Baseline Air Quality Sampling Location Rationale & Sample Period

Monitoring Location	Rationale	Sampling Period
AQ01 – Open space near Sungei Buloh Wetland Reserve Visitor Centre and PUB Office	Represents closest sensitive receptors in the north-west of the Reservoir	26 October to 2 November 2021
AQ02 – Entrance of Star Sin Trading along 12 Sungei Kadut Drive	Represents sensitive receptors for the nearby Sungei Kadut Industrial Estate at the proposed temporary Staging/ Launching Area and integrated Project Substation worksite	5 April to 12 April 2022

Based on *Table 8-9,* there are exceedances at AQ02 against Singapore's 2020 AAQTs and Long Term Targets for $PM_{2.5}$. These exceedances are anticipated to be due to the high volume of vehicles on the road adjacent to the sampling point AQ02 in Sungei Kadut Industrial Estate.

Table 8-9: Baseline Air Quality Sampling Results

Sampling ID	Monitoring Results for PM_{10} ($\mu g/m^3$)	Monitoring Results for $PM_{2.5}$ ($\mu g/m^3$)	Monitoring Results for TSP ($g/m^2/mth^1$)[(d)]
AQ01	11.7 – 18.0	8.14 – 13.8	7.6
AQ02	15.3 – 39.3	7.82 – 28.9[(c)]	16.2
Ambient Air Quality Targets (24-hour)	50[(a)]	37.5[(a)] 25[(b)]	Currently, there is no established limit for Total Suspended Particulates

Note:
- *(a) Singapore 2020 Ambient Air Quality Targets is derived based on WHO (2005) Final Air Quality Guidelines.*
- *(b) Singapore Ambient Air Quality Long Term Targets is derived based on WHO (2005) Final Air Quality Guidelines.*
- *(c) Exceedances due to high volume of vehicles on the road.*
- *(d) Calculated based on the total concentration recorded over the entire sampling duration.*

8.5 Sensitive Receptors

Dust from construction activities is typically re-deposited within 350 m of the source (IAQM, 2014), thus this impact assessment focuses on predicting the scale of impacts to Air Sensitive Receptors (ASRs) within 350 m of the land-based proposed temporary Staging/ Launching Area and integrated Project Substation construction worksite. Given the assessment of unplanned fire and explosion events from both land- and reservoir-based sites during construction and operation, ASRs within 350 m of the Reservoir Project Site were also identified. *Table 8-10* presents a summary of the Air Sensitive Receptors (ASRs) identified for the Project based on the nearest distances from the Project Sites (*Figure 8-3*). See *Appendix 8.2* for a detailed list of ASRs and their sensitivity.

Table 8-10: Summary of Air Sensitive Receptors (ASRs)

Project worksites	Type of Nearby Receptor	Sensitivity	Number of ASRs within 350 m
Proposed temporary Staging/ Launching Area and integrated Project Substation	Industrial	Medium	12
	Transportation	Medium	1
Reservoir Project Site	Park (Future)	Low	5
	Industrial	Medium	29
	Sports and Recreation	Medium	1
	Dormitories	High	1

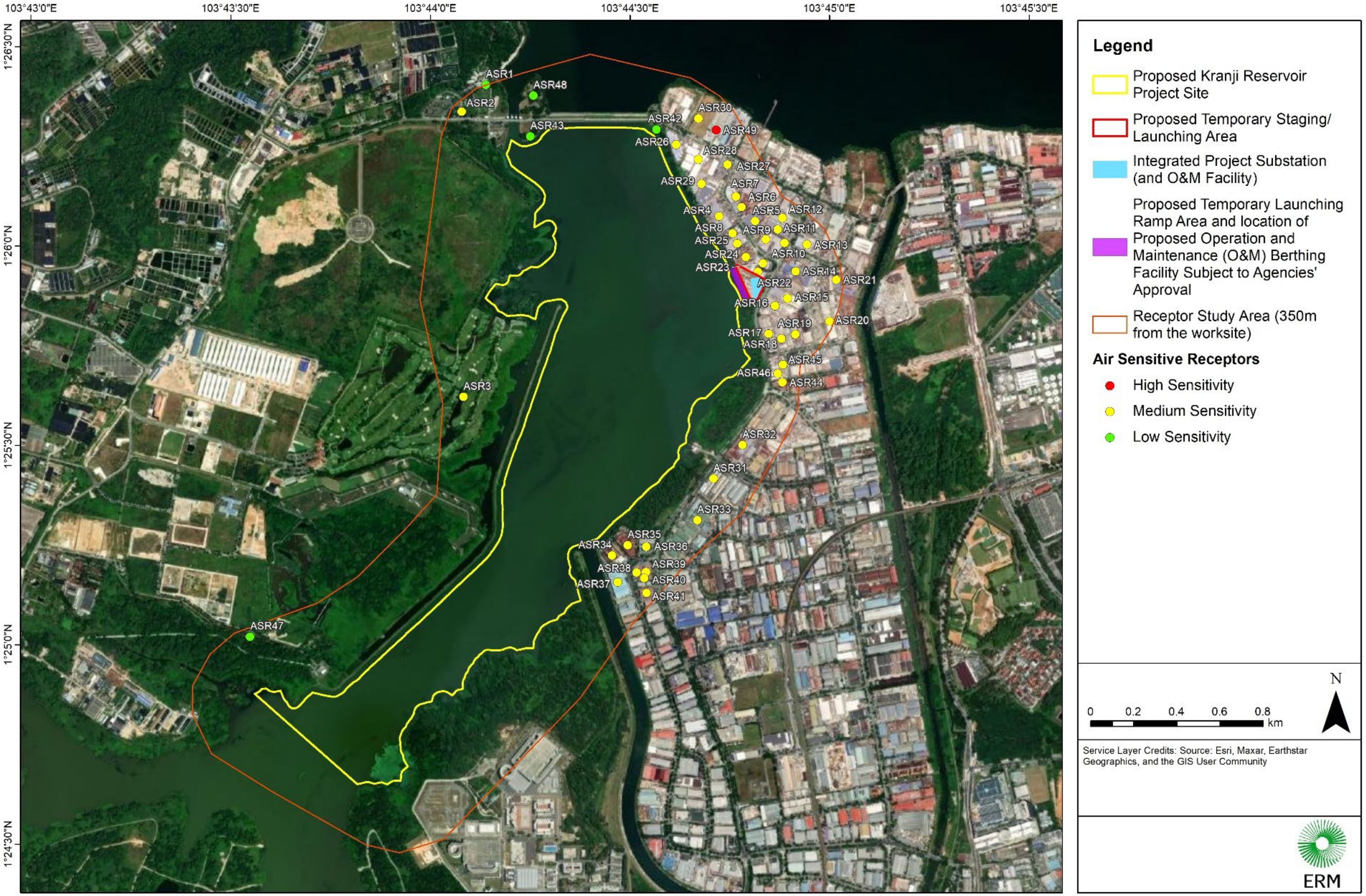


Figure 8-3: Air Sensitive Receptor (ASR) Locations

8.6 Impact Assessment – Construction & Unplanned Events

8.6.1 Construction Phase and Unplanned Events

8.6.1.1 Potential Sources of Impact

Dust emissions are anticipated to arise from land-based construction activities undertaken at the proposed temporary Staging/ Launching Area and integrated Project Substation worksite. Depending on the nature of the activities, dust impacts may arise from:

- Earthworks, e.g. site preparation, excavation and backfilling;
- Civil works e.g. concreting works;
- Construction of new aboveground structures such as the proposed temporary Staging/ Launching area facilities and permanent integrated Project Substation;
- Vehicle movements on unpaved roadways resulting in material being tracked out from the site and deposited on paved roads, where particulates may be re-suspended by passing vehicles; and
- Wind erosion at earthwork areas, exposed soil areas, and construction materials stockpiles.

Specific activities within this area which may result in impacts to ambient air quality include the following:

Proposed temporary Staging/ Launching Area & Integrated Project Substation – Construction Works on Land

- Geotechnical/site investigation at the proposed temporary Staging/Launching Area and integrated Project Substation site;
- Preparation of the proposed temporary Staging/Launching Area, including ramp into reservoir; and
- Construction of the integrated Project Substation and land-based connector cable.

Unplanned Events (on water or land)

- Fire and Explosion.

The impacts that may arise due to the above activities/ events that are considered in *Section 8.6.1.3* include:

- Generation of dust due to land-based construction activity; and
- Release of ash or smoke from fires from unplanned event of fire and explosion during construction and operation phase.

8.6.1.2 Embedded Controls

Embedded controls are measures (physical or procedural) that are planned to be put in place as part of the Project design, construction and operation from the outset. These actions are to manage the Project's compliance with relevant legislation, regulations and guidelines in relation to development and air quality. The below are further to the embedded controls outlined for Surface Water Quality (*Section 6*), Biodiversity (*Section 7*), Airborne Noise and Vibration (*Section 9*), Soil and Groundwater (*Section 10*) and Vectors (*Section 11*).

As described above in *Section 8.1,* construction works will be required to meet the requirements of the *Environmental Protection and Management Act (EPMA)* and related vehicles emission and fuel standards. Embedded controls beyond those identified in *Section 8.2* include good practice to be implemented such as:

- All temporary stockpiles of spoil or backfill that have not been used for more than 3 days shall be covered with canvas sheeting or erosion control blankets;

- Vehicular access to worksites will be paved using suitable materials such as concrete, mill waste or hardcore;
- All cement mixer trucks must have a containment system, or a flap installed to prevent spillage of cement;
- Provide and maintain a truck wash bay for washing vehicles leaving the worksite onto a roadway at each vehicular egress point to minimise resuspension of dust due to trackout of dirt on roadways before commencement of works on site. As part of the Earth Control Measures (ECM) Plan, obtain approval from PUB for the design of each truck wash bay;
- Speed limits will be applied within the construction worksite;
- All asphalt roads, pavements and public footpaths will be kept clear of dust, silt and debris;
- Switch off machinery when not in use;
- Ensure construction machinery used complies with the USEPA Tier 4 emission standards for NO_x and PM_{10};
- Maintaining all equipment and machinery, including excavators and gen-sets regularly, to minimise smoke and dust exhaust emissions; and
- To use Ultra Low Sulphur Diesel Fuel with a maximum sulphur concentration of 10 parts per million for diesel run construction equipment.

8.6.1.3 Impact Assessment and Mitigation Measures

A summary of the assessment of impacts to air quality and proposed mitigation measures during Project construction is provided in *Table 8-11*.

Table 8-11: Impact Assessment for Air Quality (Construction Phase & Unplanned Events)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
C1	**Generation of dust from land-based construction at the proposed temporary Staging/ Launching Areas and integrated Project Substation worksite**	■ **Nature**: Increased dust pollution is considered **negative**. ■ **Type**: **Direct and indirect** impact to receptors near to land-based worksite. ■ **Duration**: The worksite will be active throughout construction (3 years) which is considered relatively **long term** for air quality, and is reversible upon completion of the construction. ■ **Extent**: Impacts are **localised** within the land-based worksite and the immediate surroundings. ■ **Scale**: Per Guidelines, receptors within 350 m may be affected. ■ **Frequency**: Activities will happen **daily/ intermittently** during the specified period of construction phase, with most dust emissions likely in the initial few months related to land clearance, site levelling and site establishment for the proposed temporary Staging/ Launching Area, and then for the integrated Project Substation construction period. The following approximate areas and material volumes are assumed for this assessment, and are subject to detailed design: Worksite area: 11,000 m^2 (1.1 ha) occupied by the proposed temporary Staging / Launching area, within which 4,400 m^2 (0.44 ha) is allocated for permanent integrated Project Substation area Building area: approximately 3,160 m^2 for permanent integrated Project Substation (with O&M facility) Building volume: approximately 23,520 m^3 (including 3.5 m cable chamber basement) Site levelling: Minor grading, limited to smoothing of soil Waste volume: 1,800 m^3 Excavation/ backfill: 10,000 m^3 (3,500 tonnes) During land clearance, excavation or backfill activities, track out of soil may occur when heavy duty vehicles leave the construction sites with dusty material which may then spill onto the road, and/or when heavy duty vehicles transfer dust and dirt onto the road having travelled over muddy ground on site. It is assumed that at the peak there will be approximately 4 to 5 trucks moving in and out the proposed temporary Staging/ Launching Area and integrated Project Substation worksite per day. It is noted this worksite is adjacent to Sungei Kadut Forest - see *Section 7* (Biodiversity) regarding assessment of potential dust impacts to this ecological receptor. Typical good practice embedded control measures discussed in *Section 8.6.1.2* above will be implemented. Impact magnitude is expected to be ***Small*** for dust, when considering (i) the permanent building volume is under 25,000m^3, (ii) earthwork material moved is < 20,000 tonnes (only 3,500 tonnes), (iii) the existing industrial nature of the nearby Sungei Kadut Industrial Estate, (iv) the limited dusty activities during FPV assembly activities after initial proposed temporary Staging/ Launching Area establishment, as well as (v) the embedded controls.	Impact Magnitude: **Small** Receptor Sensitivity: **Medium** Impact Significance: **Minor**	Detailed design and construction methodology and scheduling to minimise extent and duration of dusty activities, where feasible. No significant (above minor) residual impacts are anticipated related to air quality, as such specific air quality monitoring is not considered necessary. However, it is recommended to conduct regular environmental site inspections, i.e. on a weekly basis, see the *Section 12* (EMMP).	Impact Magnitude: **Negligible** Impact Significance: **Negligible**
U1	**Release of ash or smoke from burning due to fire and explosion (unplanned event) during the construction and operational phase**	■ **Nature**: Ash and smoke in the air are considered to be **negative**. ■ **Type**: **Indirect** impact to surrounding receptors. ■ **Duration**: These impacts will be present temporarily for a **short period** of time during the unplanned event. ■ **Extent**: Impacts could **spread into immediate surroundings** if uncontrolled. ■ **Scale**: Scale of impact depends on location and nature of fire and explosion. Effect would likely be limited to the surrounding area of the fire. ■ **Frequency**: **Infrequent**, due to the unlikely event of fire and explosion with embedded controls.	Impact Magnitude: **Negligible** Receptor Sensitivity: **Low** (Future Park) **to High** (dormitories east of the reservoir) Pre-Likelihood Significance: **Negligible**	<u>Likelihood Evaluation</u> See likelihood evaluation in *Appendix 4.2*. In summary, a fire/ explosion on land and in-reservoir is unlikely during construction and operation. <u>Mitigation</u> The following measures would also be implemented to further mitigate the consequence of the unplanned event of fire and explosion: Train workers in implementation of the Spill Prevention and Emergency Response Plan.	Pre-Likelihood Significance: **Negligible** Likelihood of Occurrence: **Unlikely** Post-Likelihood Impact Significance: **Negligible**

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
		■ **Likelihood**: **Unlikely**. Spacing between islands of FPV, setbacks from reservoir edge etc, will control/ slow down the spread of fire and the associated impact. Design, construction and operation of the FPV and integrated Project Substation will align with the Fire Safety Act and the SCDF's requirements as well as relevant Singapore and international standards. A Spill Prevention and Emergency Response Plan detailing how fires/ explosions will be managed will be prepared and agreed with SCDF for construction and operation, including response arrangements. Workers onsite will be properly trained to operate vessels and machinery. The implementation of the Spill Prevention and Emergency Response Plan would minimise the air quality impacts from any fire or explosion incident. Air quality impacts to surrounding receptors during construction and operational phases will depend on the (i) wind direction, and (ii) time taken to put out the fire. As indicated in *Section 8.4.2*, wind can be from the north/ northeast (smoke moving south/ southwest), or from south/ southeast (smoke moving north/ northwest) depending on the time of year. With embedded controls during construction and operation to minimise and limit the extent of fires, and SCDF response times, FPV island spacing, shut off systems, spacing around FPV islands providing firefighting access etc it is anticipated that fires will be under control and put out within a few hours or less. As such, the impact magnitude is expected to be ***Negligible*** during construction and operation.		Joint exercises/ drills for spillage and fire will be conducted each year by the Developer/ Owner with SCDF to ensure preparedness fire preventing and fighting among site staff.	

8.6.1.4 Summary of Construction and Unplanned Event Impacts

Adoption of the abovementioned mitigation measures are expected to reduce the construction and unplanned event residual impact magnitudes of the described impacts on air quality. Potential construction and unplanned event residual impact significance for air quality are anticipated to be reduced to ***Negligible***.

No significant (above minor) residual construction impacts to air quality are anticipated.

It is noted that operation of the Project will have a positive impact on Singapore’s air quality by contributing to the reduction of Singapore’s Greenhouse Gas emissions through usage of renewable energy and reduction of fossil fuel usage.

Unplanned events for fire/ explosion during construction and operation on air quality are considered unlikely to occur with embedded controls. The residual impact significance (considering their likelihood and mitigation measures) are anticipated to be ***Negligible*** for land-based and in-reservoir unplanned fire/ explosion events.

Should any of the design, construction and/or unplanned event assumptions assessed in this Section change (i.e. be considered to be greater, or more impactful, than those assumed in this assessment) as a result of the Developer/ Owner’s detailed design, construction methodology and operations, the above impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein.

A summary of the impact assessment for the construction phase is presented in *Table 8-12* and construction and operational unplanned events in *Table 8-13.*

Table 8-12: Impact Summary of Air Quality during Land-Based Construction

Impact	Generation of dust from land-based construction at the proposed temporary Staging/ Launching Areas and integrated Project Substation worksite (C1)				
Impact Nature	**Negative**	Positive	Neutral		
	Increased dust pollutants are considered negative. Note: a positive impact on Singapore's air quality is anticipated through the reduction of Singapore's Greenhouse Gas emissions through the use of renewable energy, as well as reduced fossil fuel usage.				
Impact Type	**Direct**	**Indirect**	Induced		
	Direct and indirect impact to receptors near to land-based worksite.				
Impact Duration	Temporary	Short-term	**Long-term**	Permanent	
	The worksite will be active throughout construction (3 years) which is considered relatively long term for air quality, and is reversible upon removal of the Project.				
Impact Extent	**Local**	Regional	Global		
	Impacts are localised within the land-based worksite and the immediate surroundings.				
Impact Scale	Typically, 350 m from the proposed temporary Staging/ Launching Areas and integrated Project Substation worksite.				
Impact Frequency	Activities will happen daily/ intermittently during the specified period of construction phase, with most dust emissions likely in the initial few months related to land clearance, site levelling and site establishment for the proposed temporary Staging/ Launching Area, and then for the integrated Project Substation construction period.				
Impact Magnitude	Positive	Negligible	**Small**	Medium	Large
	Without mitigation impact magnitude for impacts during construction is **Small**, considering the building volume, earthwork material, the site and surroundings, and limited dusty construction activities.				
Receptor Sensitivity	Low	**Medium**	High		
	Within 350 m of the proposed temporary Staging/ Launching Areas and integrated Project Substation worksite: Industrial and transportation receptors (**Medium**)				
Key Embedded Controls (beyond legislation, regulations, standards and guidelines)	■ All temporary stockpiles not being used for > 3 days shall be covered with canvas sheeting or erosion control blankets ■ Vehicular access to worksites will be paved ■ Truck wash bay for washing vehicles leaving the worksite onto a roadway at each vehicular egress point ■ Machinery to comply with the USEPA Tier 4 emission standards for NOx and PM_{10} ■ Maintaining all equipment and machinery regularly				
Significance	**Negligible**	**Minor**	Moderate	Major	

(without mitigation)	The significance is **Minor** without mitigation. No significant (above minor) impacts are anticipated.				
Key Mitigation and Monitoring Measures	Detailed design and construction methodology and scheduling to minimise extent and duration of dusty activities, where feasible.				
Residual Impact Magnitude (with mitigation)	Positive	**Negligible**	Small	Medium	Large
	The residual impact magnitude is expected to be reduced to **Negligible** with mitigation.				
Residual Impact Significance (with mitigation)	**Negligible**	Minor	Moderate	Major	
	The residual impact significance with mitigation is **Negligible**. No significant (above minor) residual impacts are anticipated. Regular environmental site inspections, i.e. on a weekly basis, at the land-based worksite during construction are recommended, see *Section 8.6.3* and *Section 12* (EMMP) for further details. A positive impact on Singapore's air quality is anticipated through the reduction of Singapore's Greenhouse Gas emissions through the use of renewable energy, as well as reduced fossil fuel usage.				

Table 8-13: Impact Summary of Air Quality during Construction and Operation Unplanned Event

Impact	Release of ash or smoke from burning due to fire and explosion (unplanned event) during the construction and operational phase (U1).				
Impact Nature	**Negative**	Positive	Neutral		
	Ash and smoke in the air are considered **Negative**.				
Impact Type	Direct	**Indirect**	Induced		
	Indirect impact to surrounding receptors.				
Impact Duration	Temporary	**Short-term**	Long-term	Permanent	
	These impacts will be present temporarily for a short period of time after the unplanned event.				
Impact Extent	**Local**	Regional	Global		
	Impacts could spread into immediate surroundings if uncontrolled.				
Impact Scale	Scale of impact depends on location and nature of fire and explosion. Effect would likely be limited to the surrounding area of the fire.				
Impact Frequency	Infrequent, with embedded controls.				
Impact Magnitude	Positive	**Negligible**	Small	Medium	Large
	With embedded controls impact magnitude for impacts during construction and operation phase unplanned events is considered **Negligible**.				
Receptor Sensitivity	**Low**	**Medium**	**High**		
	Within 350 m of the proposed temporary Staging/ Launching Areas and integrated Project Substation worksite, and the Reservoir Project Site: ■ Industrial and transportation receptors (**Medium**) ■ Future Park (**Low**) ■ Sports and Recreation (**Medium**) ■ Dormitories (**High**)				
Key Embedded Controls (beyond legislation, regulations, standards, and guidelines)	In addition to embedded controls identified in *Table 8-13*: ■ Emergency Response Plan detailing how fires/explosions and response arrangements will be managed ■ Train workers in use of equipment and machinery and vessels				
Pre-likelihood Significance (without mitigation)	**Negligible**	Minor	Moderate	Major	
	The pre-likelihood significance is **Negligible** (land-based and in-reservoir) for construction and operation. No significant (above minor) impacts are anticipated.				

<table>
<tr><td>Key Mitigation and Monitoring Measures</td><td colspan="5">In addition to mitigation and monitoring identified in Table 8-13:
■ Train workers in implementation of Emergency Response Plans
■ Joint exercises/ drills for spillage and fire will be conducted each year by the Developer/ Owner with SCDF to ensure preparedness fire preventing and fighting among site staff.</td></tr>
<tr><td rowspan="2">Likelihood of Occurrence</td><td colspan="2">Unlikely</td><td colspan="2">Possible</td><td>Likely</td></tr>
<tr><td colspan="5">Fire and explosions are considered unlikely to happen during the construction and operation phase with embedded controls.</td></tr>
<tr><td rowspan="2">Post-likelihood Residual Significance (with mitigation)</td><td>Negligible</td><td colspan="2">Minor</td><td>Moderate</td><td>Major</td></tr>
<tr><td colspan="5">The post-likelihood residual significance with mitigation is Negligible (land-based and in-reservoir) for construction and operation. No significant (above minor) residual impacts are anticipated.</td></tr>
</table>

8.6.2 Air Quality Monitoring

As outlined in *Section 8.6.1.3* above, no significant (above minor) residual impacts are anticipated related to air quality, as such specific air quality monitoring is not considered necessary.

However, it is recommended to conduct regular environmental site inspections, i.e. on a weekly basis, at the proposed temporary Staging/ Launching Area and integrated Project Substation worksite during construction to check the implementation of the embedded controls and mitigation measures, see the Environmental Management and Monitoring Plan (EMMP) in *Section 12*.

8.6.3 Potential Cumulative Impacts from Other Major Concurrent Developments

Consultation between URA and MND has been undertaken during the course of this study to identify other known concurrent projects in the immediate vicinity of the Project Sites for which works will occur at the same time as this Project, see *Section 4.3.1, Table 4-2*. The detailed schedules for such developments are not available at the time of writing. Cumulative impacts have therefore not been undertaken in this EIA due to the lack of available information. In the event that information on surrounding committed developments does become available, the Kranji FPV Project should be assessed under the cumulative impact assessments within the EIAs of these surrounding committed developments. Details of this Project, where appropriate, will be coordinated and provided to the EIA owners of surrounding developments to support their cumulative impact assessment.

9. AIRBORNE NOISE AND VIBRATION

9.1 Overview

This Section of the EIA evaluates the potential airborne noise and vibration impacts to human receptors associated with the land-based and in-reservoir construction and land-based operation phases of the Project. Where required, the mitigation hierarchy of avoidance, minimisation, reduction or compensation has been applied to potentially significant impacts to reduce impact levels to as low as reasonably practicable. Monitoring recommendations for airborne noise during the construction phase of the Project are also referenced, where applicable.

Relevant Technical Agencies have been consulted since the early phases of the Project (since January 2020) to understand airborne noise and vibration concerns and in preparing the airborne noise and vibration impact assessment for this Project. The discussions and recommendations from relevant Technical Agencies have been taken into account in the following assessment.

Airborne noise and vibration impacts from construction piling within the reservoir (assuming a conservative case of using piling rather than anchor blocks for the anchoring system), and construction activities in the proposed temporary Staging/ Launching Area and integrated Project Substation worksite, have been assessed quantitatively.

During construction, there may be a possibility of utilising a helicopter to transfer the approximate 18 to 36 Power Converter Units (PCU) into position on their piled decks within the reservoir in the eastern portion of the reservoir. However, since this activity will be short-term (i.e. each of these mobilisations will be less than an hour over the reservoir, and a one-off irregular event), the airborne noise and vibration impacts are not anticipated to be significant for human receptors (it is worth noting military aircraft already frequently operate over Kranji Reservoir), and have been scoped out from this assessment.

During the operation of the integrated Project Substation (including O&M Facility) the transformers normally operate without cooling fans. During emergency scenarios the transformers use cooling fans, however such emergency scenarios are only expected to occur for up to 10 hours a year. Given that the likelihood of occurrence is considered to be low, and for a very limited duration, the airborne noise and vibration impact assessment for the emergency scenario has been scoped out from this assessment. In addition, there are no vibratory equipment in the operating integrated Project Substation thus operational vibration has been scoped out from this assessment. Therefore, only the airborne noise impacts from the normal operation phase of the integrated Project Substation are quantitatively assessed.

Within the reservoir, the main sources of noise during the operation phase of the Project would include the use of 2 to 4 small work boats to conduct maintenance of the FPV and PCUs. Currently, PUB is using work boats and barges with excavators on a daily basis within the reservoir. The frequency and number of maintenance efforts for the FPV and PCUs is expected to be low as the equipment have minimal moving parts, and such limited maintenance activities will be carried out during any one day. Additionally, there are no sources of vibration during the operation of the Project within the reservoir. As such, the impact assessment for airborne noise and vibration for the operation phase of the Project within the reservoir has been scoped out from this assessment.

Airborne noise and vibration impacts from potential unplanned events (e.g. fire/ explosion) would only last for a short period of time (i.e. less than a few seconds) and hence would not be significant. In addition, based on a review of the surrounding sensitive receptors, there are no sensitive receptors (hospitals, schools, institution etc) or residential areas within 150 m of the construction and operation Project Sites. Thus, unplanned events are not anticipated to produce significant impacts with regards to airborne noise and vibration, and have been scoped out from this assessment.

Impacts to ecological/ biodiversity receptors as a result of the Project construction noise are assessed in *Section 7* (Biodiversity).

9.2 Regulatory Framework

The legislation, standards and/ or guidelines applicable to governing airborne noise and vibration levels at construction sites and operations of a “factory premise” (in this case a substation) in Singapore relevant to this Project include those listed in *Table 9-1.*

Table 9-1: Summary of Legislative Requirements and Guidelines to Control Airborne Noise and Vibration

Legislation/ Standard/ Guideline	Relevance to Airborne Noise and Vibration for this EIA
Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021	■ This Act provides for the control of air, water and noise pollution, for the safe management of hazardous waste and for the protection and management of the environment and resource conservation.
Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2011	■ Airborne noise during construction works shall comply with the limits in the legislation based on various classifications of surrounding noise sensitive receptors. ■ No work to be carried out during the prohibited periods (i.e. 10 pm on Saturday or eve of a Public Holiday, to 7 am on the following Monday or day after the Public Holiday) for construction work at any worksite located less than 150 m away from residential and noise-sensitive premises. If work is required to be carried out during the prohibited periods, permission shall be requested from the authority (i.e. NEA).
Environmental Protection and Management (Boundary Noise Limits for Factory Premises) Regulations, 2008	■ Airborne noise during Project operation shall comply with the limits in the legislation based on the type of affected premises along the boundaries of the factory premise.
Environmental Protection and Management (Vehicular Emissions) Regulations, 2008	■ Motor vehicles used onsite will be in compliance with noise emissions stipulated in the legislation.
Environmental Public Health Act (EPHA), (Amendment), 2022	■ Noise control measures should be put in place to minimise noise nuisance arising from construction works to the noise sensitive receptors.
NEA's Code of Practice for Environmental Control Officers for Construction Sites, 2021	■ Provides recommended guidelines on practice measures to manage noise on construction sites. ■ Generators should be sited at locations that minimise the smell and noise nuisance affecting nearby sensitive receptors.
Singapore Standards SS602:2014 Code of Practice for Noise Control on Construction and Demolition Sites, 2014	■ Recommends methods of monitoring, estimation of construction equipment noise levels, noise control techniques and selection of quieter construction equipment and methods.
Singapore Standards SS593: 2013 Code of Practice for Pollution Control (COPPC)	■ Recommends noise pollution control requirements and good practices to safeguard the noise sensitive receptors.
British Standard 5228:2009+A1:2014 and Code of Practice for Noise and Vibration Control on Construction and Open Sites	■ Recommends basic methods of vibration and noise control relating to construction and open sites where work activities/ operations generate significant vibration or noise levels.
British Standard 6472-1:2008 - Part 1: Vibration sources other than blasting	■ Provides guidelines to evaluate human exposure to vibration in buildings
International Organisation for Standardisation (ISO), (1996); International Standard 9613-2: Acoustics – Attenuation of Sound During Propagation Outdoors	■ Provides method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level (as described in ISO 1996) under meteorological conditions.
Fundamental of Acoustics, Fourth edition (2000)	■ Provides physical and mathematical concepts related to the generation, transmission and reception of acoustic waves.

9.2.1 Noise Limits for Construction

Noise limits for a construction site in Singapore are specified under the *Environmental Protection and Management (Control of Noise at Construction Sites) Regulations 2011*. This regulation stipulates noise level limits to be complied with based on various classifications of surrounding noise sensitive receptors. The adjacent premises that might be potentially affected by the noise levels from the Project's construction worksites are predominantly industrial and recreational areas (see *Figure 9-1*). There are no sensitive receptors (hospitals, schools, institution etc) or residential areas within 150 m of the Project Sites. As such, the relevant affected premises fall under the category of *"All other buildings"* as defined in the Regulations. The applicable limits are summarised in *Table 9-2*.

Table 9-2: Applicable Construction Noise Limits

Type of Affected Building	Worksite Operational Hours		
	Day (0700 – 1900)	Evening (1900 – 2200)	Night (2200 – 0700)
Hospital, School, University, Aged Care Facility	60 dB $L_{Aeq,12hours}$	50 dB $L_{Aeq,12hours}$	
	75 dB $L_{Aeq,5mins}$	55 dB $L_{Aeq,5mins}$	
Residential (within 150 meters of construction site)	75 dB $L_{Aeq,12hours}$	65 dB $L_{Aeq,1hour}$	55 dB $L_{Aeq,1hour}$
	Mondays to Saturdays 90 dB $L_{Aeq,5mins}$ Sundays and Public Holidays 90 dB $L_{Aeq,5mins}$	Mondays to Saturdays 70 dB $L_{Aeq,5mins}$ Sundays and Public Holidays 55 dB $L_{Aeq,5mins}$	Mondays to Sundays, and Public Holidays 55 dB $L_{Aeq,5mins}$
All other buildings	**75 dB $L_{Aeq,12hours}$**	**65 dB $L_{Aeq,12hours}$**	
	90 dB $L_{Aeq,5mins}$	**70 dB $L_{Aeq,5mins}$**	

Notes: ***Bold*** *items are applicable to this Project*

(a) The Fourth Schedule of the Regulation states that all works are prohibited from 10 pm every Saturday to 7 am the following Monday, and from 10 pm on the eve of a public holiday to 7 am the following day.

(b) "$L_{Aeq,5mins}$" is the average sound level measured over 5 minutes; "$L_{Aeq, 12hour}$" is the average sound level measured over 12 hours.

Source: Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2011

According to the NEA, under the *Environmental Protection and Management (Control of Noise at Construction Sites) Regulations 2011*, construction sites at the architectural/ project completion stage are allowed to carry out quieter forms of work (see list of permitted quieter works in ePortal) on specific Sundays and public holidays. Contractors shall submit a permit application via ePortal to NEA for such works, and will be subject to compliance with stringent conditions specified in the application form and any other conditions imposed by NEA.

9.2.2 Noise Limits for Operation

Noise limits for factory premises in Singapore are specified under the *Environmental Protection and Management (Boundary Noise Limits for Factory Premises) Regulations 2008*. This regulation stipulates noise level limits to be complied with based on type of affected premises along the boundaries of the factory premise. The adjacent premises that might be potentially affected by the noise levels from the operation of the integrated Project Substation (& O&M Facility) are predominantly industrial (see *Figure 9-1). T*here are no noise sensitive receptors (hospitals, schools, institution etc), residential areas or commercial premises along the boundaries of the integrated Project Substation. As such, the relevant affected premises fall under the category of *"Factory"* as defined in the Regulations. The applicable limits are summarised in *Table 9-3*.

Table 9-3: Applicable Operation Noise Limits

Type of Affected Building [(a)]	Worksite Operational Hours		
	Day (0700 – 1900)	Evening (1900 – 2300)	Night (2300 – 0700)
Noise sensitive	60	55	50
Residential	65	60	55
Commercial	70	65	60
Factory	**75**	**70**	**65**

*Notes: **Bold** items are applicable to this Project*

(a) "Factory premises" means any premises used for any industrial or manufacturing purposes and includes any repair or processing workshop, and warehouse, but does not include any construction site within the meaning of the Environmental Protection and Management (Control of Noise at Construction Sites) Regulations (Rg 2); "Commercial premises" means any premises used for the purposes of trade, business or commerce and includes any shopping complex, financial institution and hotel but does not include any factory premises; "Noise sensitive premises" means any premises used for purposes that require peace and quiet and includes any recreational area, nature park, hospital, home for the aged sick, educational institution, place of worship, library and court of law; "Residential premises" means any premises used for human habitation.

(b) The Fourth Schedule of the Regulation states that all works are prohibited from 10 pm every Saturday to 7 am the following Monday, and from 10 pm on the eve of a public holiday to 7 am the following day.

Source: Environmental Protection and Management (Boundary Noise Limits for Factory Premises) Regulations, 2008

9.2.3 Correction Factors for Noise Limits

The regulations for construction sites and operation of a "factory premise" also allow for corrections to be applied to these permissible noise limits to account for the existing background noise levels (i.e. higher noise limits are acceptable if existing background noise levels are high) (see *Section 9.4.3* for detailed information of the correction factor application for this Project). According to NEA's directive, the maximum permissible noise levels for the Project's operation shall be adjusted by the addition of a correction factor to the higher of either the permissible noise level or the measured background noise level, to account for the existing background noise levels in the area. The correction factors correspond to the difference between the applicable permissible levels, the background noise levels, and are presented in *Table 9-4* below.

Table 9-4: Correction Factors for Noise Limits

Difference between Permissible and Background Noise Levels dB(A)	Correction Factor dB(A)
Below 2	3
2 to less than 4	2
4 to less than 10	1
10 and above	0

9.2.4 Vibration

There is no legislation or guidelines in Singapore that stipulates vibration limits for the avoidance of disturbance to humans. International standards such as the *British Standard 5228:2009+A1:2014* have therefore been reviewed to identify the vibration limits applicable for this study, see *Section 9.3* below.

9.3 Assessment Criteria

The evaluation of impact significance for airborne noise and vibration impacts involves an assessment of the magnitude of the airborne noise and vibration levels generated against the relevant limits (see *Section 9.2*). These limits have been established through empirical studies and implicitly take into account the sensitivity of the receptors to airborne noise and vibration.

The impact magnitude criteria for airborne noise during construction and operation are presented in *Table 9-5* and *Table 9-7* respectively. They are assessed differently as the applicable construction noise limits from the *Environmental Protection and Management (Control of Noise at Construction Sites) Regulations 2011,* considers the impact of increases in the audibility of noise levels to the nearest noise receptors surrounding the Project worksites; while the applicable operation noise limits from the *Environmental Protection and Management (Boundary Noise Limits for Factories Premises) Regulations 2008* assess the exceedances of maximum permissible noise limits at the Project Site boundaries.

9.3.1 Airborne Noise Impact Criteria for Construction

The maximum permissible noise levels applicable for this Project during the construction phase are provided in *Section 9.2.1*. The proposed impact criteria for the Project's construction is based on whether there is any predicted exceedance of the maximum permissible noise levels and how audible the increase in noise levels are predicted to be for the receptors.

The magnitude of potential construction noise impacts on airborne noise have been assessed in accordance with the agreed criteria presented in *Table 9-5*.

Table 9-5: Impact Magnitude Criteria for Airborne Noise Impacts during Construction

Impact Magnitude	Criteria Exceedance	Audibility of Increase
Negligible	0 – 2 dB(A)	Not Noticeable
Small	3 – 5 dB(A)	Noticeable
Medium	6 – 9 dB(A)	Clearly Noticeable
Large	10 dB(A) or greater	Subjective Doubling

According to the *Fundamentals of Acoustics* published by the World Health Organisation, an increase in noise levels of 3 dB(A) represents a doubling of sound power and is just perceptible to the human ear, while a difference of more than 5 dB(A) is clearly noticeable. Based on this, it is assumed that a noise level increment of 6 dB(A) but not more than 9 dB(A) above the criteria will be clearly noticeable to receptors and is therefore classified as having a Medium impact magnitude, while any increase in noise levels of 10 dB(A) and above the standards can cause impacts of Large magnitude to receptors.

The impact significance criteria also considers the duration of exposure to the increase in noise levels at each receptor location. A timeframe of greater than 1-month exposure has been taken as a reasonable definition of 'long-term' exposure. For each impact magnitude, the impact significance for long-term exposure is one grade higher than the impact significance for short-term exposure. The only exception for this would be for impact magnitude classified as 'Negligible', wherein by its definition, increase in noise levels will not have any significant impacts on receptors.

A summary of the significance criteria to be used for construction noise is provided in *Table 9-6* below.

Table 9-6: Impact Significance Criteria for Noise Airborne Noise Impacts during Construction

Impact Magnitude	Corresponding Impact Significance	
	Short-term (Up to 1 month exposure)	Long-term (Greater than 1 month exposure)
Negligible	Negligible	Negligible
Small	Negligible	Minor
Medium	Minor	Moderate
Large	Moderate	Major

9.3.2 *Airborne Noise Impact Criteria for Operation*

The maximum permissible noise levels applicable for this Project during the operation phase are provided in *Section 9.2.2*. The proposed impact criteria for the Project operation are based on the whether there is any predicted exceedance of the maximum permissible noise levels.

The magnitude of potential operational noise impacts on airborne noise (assumed to be long-term exposure) have been assessed in accordance with the agreed the criteria presented in *Table 9-7*.

Table 9-7: Impact Significance (and Magnitude) Criteria for Airborne Noise Impacts during Operation

Impact Significance (Magnitude)	Definition
Negligible (Negligible)	Boundary noise levels are at or below maximum permissible noise levels.
Minor (Small)	Boundary noise levels are up to 3 dB(A) above maximum permissible noise levels.
Moderate (Medium)	Boundary noise levels are between 3 dB(A) and 10 dB(A) above maximum permissible noise levels.
Major (Large)	Boundary noise levels are more than 10 dB(A) above maximum permissible noise levels.

9.3.3 *Vibration Impact Criteria for Construction – Human Comfort*

Based on desktop research of the nature of operations of surrounding premises, there are no vibration sensitive facilities within the vicinity of the Project construction sites. In addition, the nature of the activities during the construction of the Project are not likely to cause damage to nearby buildings. Thus, the vibration assessment focuses on the disturbance to humans from land-based and in-reservoir construction.

There is no legislation or guidelines in Singapore that stipulates vibration limits for construction works for the avoidance of disturbance to humans. The *British Standard 5228-2:2009+A1:2014*, and those referenced therein, have been reviewed to identify the vibration limits applicable for this Project. BS5228-2 provides criteria in terms of the overall peak particle velocity (PPV) of the vibration source (measured in millimetres per second, mm/s). PPV is a parameter that only considers the overall level of the vibration source and does not account for the duration of the impacts. Accordingly, the PPV criteria are only proposed to be used at the screening analysis to determine likely locations of impacts. The magnitude of potential construction vibration impacts have been assessed based on the agreed criteria presented in *Table 9-8*.

Table 9-8: Impact Magnitude Criteria for Vibration Impacts on Humans

Impact Magnitude	Vibration Magnitude [PPV[(a)(b)(c)]]	Effect
Negligible	Less than 0.14 mm/s	Vibration is barely perceptible in the most sensitive situations for most vibration frequencies associated with construction. At lower frequencies, people are less sensitive to vibration.
Small	Greater than or equal to 0.14 mm/s and less than 1 mm/s	Vibration might be just perceptible in residential environments but complaints may not occur.
Medium	Greater than or equal to 1 mm/s and less than 10 mm/s	It is likely that vibration of this level in residential environments will cause complaint but can be tolerated if prior warning and explanation has been given to residents.
Large	Greater than or equal to 10 mm/s	Vibration is likely to be intolerable for any more than a very brief exposure to this level in most building environments[(d)].

Notes:

(a) *The guidance values are applicable in the context of human response to vibration within buildings. There is a lack of guidance on levels triggering a response from human receptors located outdoors. These guidance values will therefore be adopted for such receptors in line with this study's precautionary approach.*

(b) *The magnitudes of the values presented apply to a measurement position that is representative of the point of entry into the receptor.*

(c) *A transfer function (which relates an external level to an internal level) needs to be applied if only external measurements are available.*

(d) *Single or infrequent occurrences of these levels do not necessarily correspond to the stated effect in every case. The values are provided to give an initial indication of potential effects, and where these values are not routinely measured or expected then magnitude would be less than shown.*

As the vibration criteria specified in *Table 9-8* implicitly take into account the sensitivity of the receptor, separate criteria for receptor sensitivity are not applicable and are therefore not presented. The corresponding impact significance rating is outlined in *Table 9-9* which also accounts for the duration of exposure.

Table 9-9: Impact Significance Criteria for Vibration Impacts on Humans

Impact Magnitude[(a)]	Duration	
	Short-term (Up to 1 month exposure)	Long-term (Greater than 1 month exposure)
Negligible	Negligible	Negligible
Small	Negligible	Minor
Medium	Minor	Moderate
Large	Moderate	Major

Notes:

(a) *Minor impact significance can be retained for activities with duration < 1 month for an impact magnitude up to Medium, to take into consideration that the 1 mm/s threshold 'can be tolerated if prior warning and explanation has been given to residents'. In addition, construction activities that may give rise to significant vibration are generally short-term in duration in terms of exposure to receptors, e.g. < 1 month for exposure to piling works. It is considered reasonable to upgrade the significance to Moderate for activities that might be longer in duration, i.e. 1 month or more, and which give rise to vibration levels > 1 mm/s i.e. Medium magnitude.*

9.4 Baseline Conditions

9.4.1 Methodology

9.4.1.1 Baseline Noise Monitoring

Long-term baseline noise monitoring was completed at three (3) monitoring locations over a period of one week between October – November 2021 and March – April 2022. The purpose for conducting the baseline noise monitoring is to understand the dominant sources of noise in the vicinity of the Project worksites as well as to facilitate the accounting for any correction factors, if applicable, as presented in *Table 9-4.*

Based on the NSRs identified in *Section 9.5*, *Table 9-14,* continuous long-term noise measurements were carried out at representative locations N01 – N03 (as seen in *Figure 9-1*) using unmanned noise loggers deployed over a period of one week. The noise loggers were set up at an elevation of 1.5 meters above the ground and at least 3 meters away from a façade or any reflective surface. The baseline noise monitoring locations were also selected away from local noise sources such as mechanical plant, pumps or regular community activity. The parameters monitored were the following:

- $L_{Aeq,\ 5mins}$ is the equivalent continuous sound pressure level over a 5-minute measurement period;
- $L_{Aeq,\ 1hour}$ is the equivalent continuous sound pressure level over a 1-hour measurement period; and
- $L_{Aeq,12hours}$ is the equivalent continuous sound pressure level over a 12-hour measurement period.

The rationale for selecting each monitoring location is provided in *Table 9-10* below.

Table 9-10: Rationale for Selection of Noise Monitoring Locations

Monitoring Location	Rationale
N01 - NRSCC Kranji Sanctuary Golf Course	To establish the baseline noise levels for recreational users within NRSCC Kranji Sanctuary Golf Course along the western shoreline of Kranji Reservoir.
N02 - Entrance of 12B Sungei Kadut Drive	To establish the baseline noise levels immediately adjacent to the 12B Sungei Kadut Drive and the Project's proposed temporary Staging/ Launching Area and integrated Project Substation worksite
N03 - Along the forest strip in vicinity of the eastern reservoir shoreline at 12A Sungei Kadut Drive	To establish the baseline noise levels at the shoreline forest patch at 12A Sungei Kadut Drive and the Project's proposed temporary Staging/ Launching Area.

Baseline noise monitoring was not conducted at the vicinity of NSR/ VSR 6 (FMB Trading and Engineering Pte Ltd) as conservatively the noise levels at N03 would be representative of the baseline levels at NSR/ VSR 6 since both locations are situated close to the reservoir shoreline (noting both are also within Sungei Kadut Industrial Estate).

In addition to the long-term baseline noise monitoring survey, short-term 15-minute traffic counts were conducted at N02 to quantify the effect of existing traffic flows on the measured noise monitoring levels.

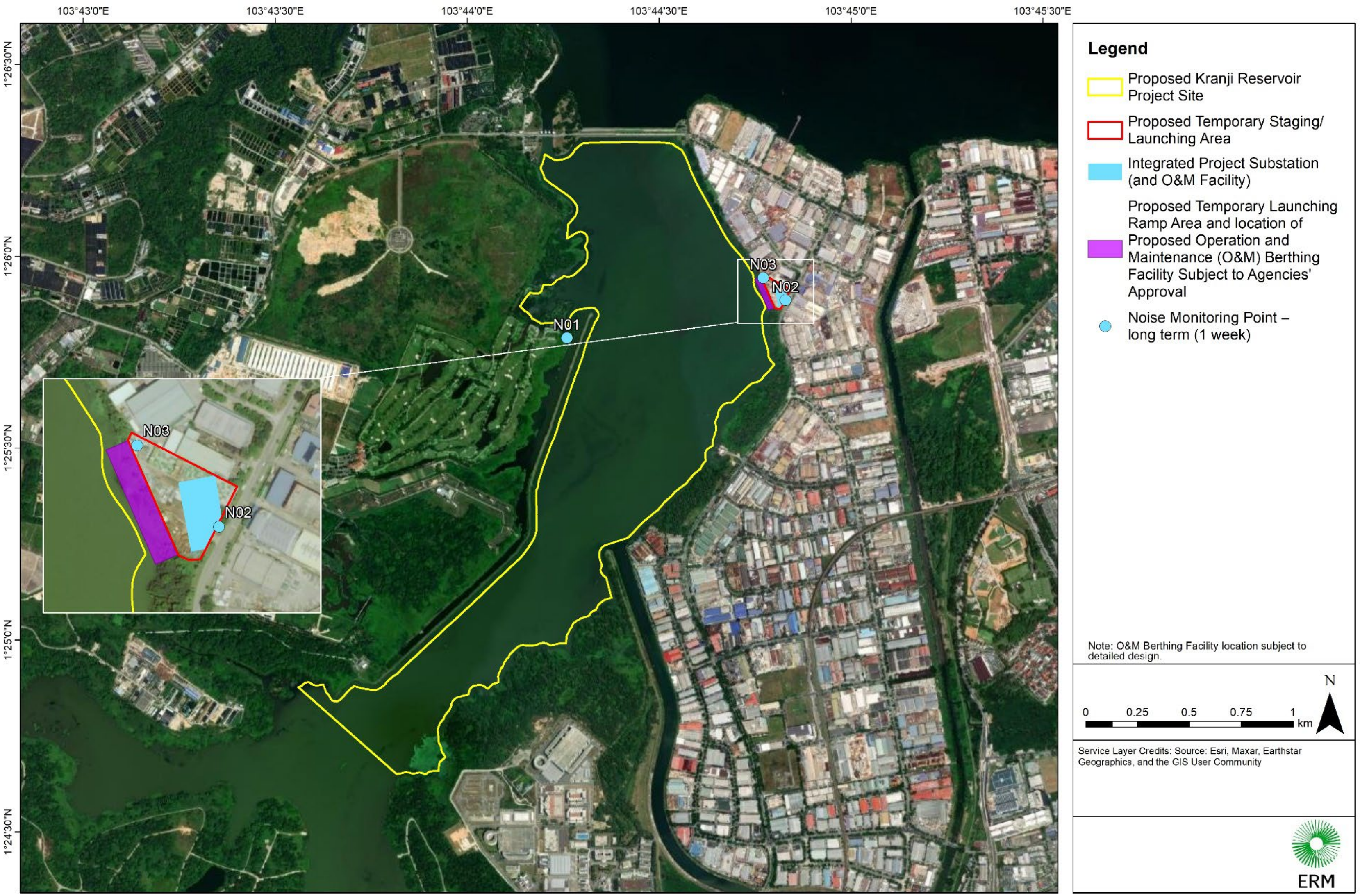


Figure 9-1: Baseline Noise Monitoring Locations

9.4.2 Findings

9.4.2.1 Baseline Noise Monitoring Results

The baseline noise monitoring measurements are summarised in *Table 9-11*. Based on the monitoring results, the dominant sources of baseline noise were observed to be vehicular traffic, (military) aircraft passing overhead, animal vocalisations and grass cutting, all of which were localised sources of noise unique to each monitoring location due to surrounding land uses. The surrounding land uses are predominantly industrial and recreational in nature.

Table 9-11: Summary of Long-Term Baseline Noise Monitoring Measurement Results

Survey Locations[a]	Baseline Measurements (dB(A)) [b]				
	$L_{Aeq,12hours}$[c]		$L_{Aeq,5mins}$[c]		
	Day (7am - 7pm)	Night (7pm - 7am)	Day (7am - 7pm)	Evening (7pm - 10pm)	Night (10pm - 7am)
N01 – NRSCC Kranji Sanctuary Golf Course	57 – 67	45 – 61	37 – 86	43 - 79	39 - 78
N02 - Entrance of 12B Sungei Kadut Drive	72 – 74	65 – 68	64 – 87	65 – 79	51 – 72
N03 - Along the forest strip in vicinity of the eastern reservoir shoreline at 12A Sungei Kadut Drive	57 – 72	45 – 61	39 – 89	37 – 79	31 – 64

Notes:

- *(a) Measurements were undertaken over one week in October – November 2021 and March – April 2022.*
- *(b) Time slices definition of Day, Evening and Night Periods are based on definitions in the Environmental Protection and Management (Control of Noise at Construction Sites) Regulations 2011.*
- *(c) Measurements are shown in LA_{eq} Min – Max.*

As for the short-term traffic count surveys conducted, the results are presented in *Table 9-12* below. The results indicate that the light and heavy vehicles passing by the N02 monitoring location is likely to have contributed to the baseline noise levels as sources and hence resulted in higher noise levels being recorded at this location.

Full details and reports from the noise monitoring measurements are provided in *Appendix 9.1.*

Table 9-12: Recorded Vehicular Traffic Volume

Survey Locations	Traffic Count			Recorded Noise Level, $L_{Aeq,5mins}$, dB(A)
	Light Vehicles	Heavy Vehicles	Motorbikes	
N02 - Entrance of 12B Sungei Kadut Drive	89	150	7	74.1

Notes:

- *(a) The traffic count was conducted on a weekday and for a period of 15 minutes.*
- *(b) Heavy vehicles consist of trucks, vans, lorries, and buses (involved in business). Light vehicles comprised family cars and small vehicles which are non-commercial.*

9.4.3 Applicability of Correction Factors

It is noted that, at the time of writing this report, the baseline noise monitoring results at N02 and N03 may no longer be representative of the existing noise levels within these area due to changes in the surrounding land uses at the two monitoring locations, i.e. tenants of the 12A and 12B Sungei Kadut

Drive locations (at the proposed temporary Staging/ Launching Area and integrated Project Substation site) have vacated the site (as of September 2022) and the site was reinstated to vacant (grass) land[1]. Therefore, the baseline noise results for N02 and N03 presented in *Table 9-11* will not be used to apply any correction factors to applicable maximum permissible noise limits during the construction and operation phases (i.e. the more stringent limits will be applied, and thus a conservative scenario is assessed).

Applicability of correction factors was only reviewed for the N01 monitoring results, as there are no changes to the surrounding land uses at the monitoring location at the time of writing the report, and hence it is still representative of the baseline noise levels.

Based on the results in *Appendix 9.1*, the average $L_{Aeq,12hours}$ and $L_{Aeq, 5mins}$ for N01 was calculated to understand the applicability of correction factors to the maximum permissible noise levels for construction within the reservoir (which N01 is representative of). However, it was determined that no correction factors could be applied to the maximum permissible noise levels for the day, evening and night periods. This is because, with reference to *Table 9-4*, the difference between the baseline ambient noise levels and the maximum permissible noise levels is more than 10 dB(A). The values for the average $L_{Aeq,12hours}$ and $L_{Aeq,5mins}$ for N01 as well as the final maximum permissible noise levels are presented in *Table 9-13* below.

Table 9-13: Adjusted Maximum Permissible Noise Levels

Survey Locations	Baseline Noise Monitoring Results, dB(A)[a]				
	Average $L_{Aeq,12hours}$		Average $L_{Aeq,5mins}$		
	Day (7am - 7pm)	Night (7pm - 7am)	Day (7am - 7pm)	Evening (7pm - 10pm)	Night (10pm - 7am)
	62	52	62	51	51
	Applicable Construction Noise Limits for "All other buildings", dB(A)				
	Day (7am - 7pm)	Night (7pm - 7am)	Day (7am - 7pm)	Evening (7pm - 10pm)	Night (10pm - 7am)
N01 – NRSCC Kranji Sanctuary Golf Course	75	65	90	70	
	Adjusted Maximum Permissible Noise Levels, dB(A)				
	$L_{Aeq,12hours}$		$L_{Aeq,5mins}$		
	Day (7am - 7pm)	Night (7pm - 7am)	Day (7am - 7pm)	Evening (7pm - 10pm)	Night (10pm - 7am)
	75	65	90	70	70

Notes:
(a) Time slices definition of Day, Evening and Night Periods are based on the definitions in the Environmental Protection and Management (Control of Noise at Construction Sites) Regulations 2011.

9.5 Sensitive Receptors

9.5.1 Noise Sensitive Receptors (NSRs) and Vibration Sensitive Receptors (VSRs)

Table 9-14 below refers to the nearest human receptors for airborne noise and vibration located adjacent to the Project Sites. Based on a review of the surrounding receptors, there are no sensitive receptors (hospitals, schools, institutions, etc.) or residential areas within 150 m of the Project Sites.

[1] Northern half of the proposed Project worksite (12A Sungei Kadut Drive) was occupied for machinery storage, and the southern half of the proposed Project worksite (12B Sungei Kadut Drive) was occupied for the storage of boring tools and welding works.

Only the nearest receptors located adjacent to the Project Site were considered in the impact assessment.

Receptors that are not directly facing the proposed temporary Staging/ Launching Area and integrated Project Substation worksites, i.e. other various industries, were not considered in the impact assessment as the noise levels propagated to those receptors would have reduced due to the shielding effect of the buildings closer to the Project Site.

To represent a conservative scenario for the noise impact assessment at the reservoir, i.e. from construction piling, only the receptors located closest to the FPV layout (*Figure 9-2*) were considered in the impact assessment (i.e. NSR/ VSR 5 & 6, see *Table 9-14*). Other human receptors present at Sungei Buloh Wetland Reserve, Kranji Marshes, Kranji Fishing Ground A and B and various industrial premises along the reservoir shorelines, were excluded as the noise levels propagated to those receptors would have reduced due to the increasing distances from the piling source.

Table 9-14 lists the representative human NSRs and VSRs considered for the noise impact assessment for each Project Site.

Table 9-14: Representative Human Airborne Noise and Vibration Sensitive Receptors

Project Site	ID	Sensitive Receptors	Approximate distance to nearest Project Worksite (metres)	Assumed Operating Hours
Proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M Facility)	NSR/ VSR 1	Star Sin Trading Pte Ltd	3.5	Weekday: 8am – 5.30pm Saturday: 8am – 1pm
	NSR/ VSR 2	Ley Choon Group Holding	50	Operating daily: 24 hours
	NSR/ VSR 3	Eng Hua Furniture Manufacturing Pte Ltd	42	Monday – Saturday: 8.30am – 5.30pm
	NSR/ VSR 4	Eng Seng Cement Products Pte Ltd	42	Monday – Saturday: 9am – 5pm
Reservoir Project Site	NSR/ VSR 5	NRSCC Kranji Sanctuary Golf Course	107	Operating daily: 7am – 5pm
	NSR/ VSR 6	FMB Trading and Engineering Pte Ltd	92	Weekday: 8.30am – 7pm Saturday: 8.30am – 12.30pm

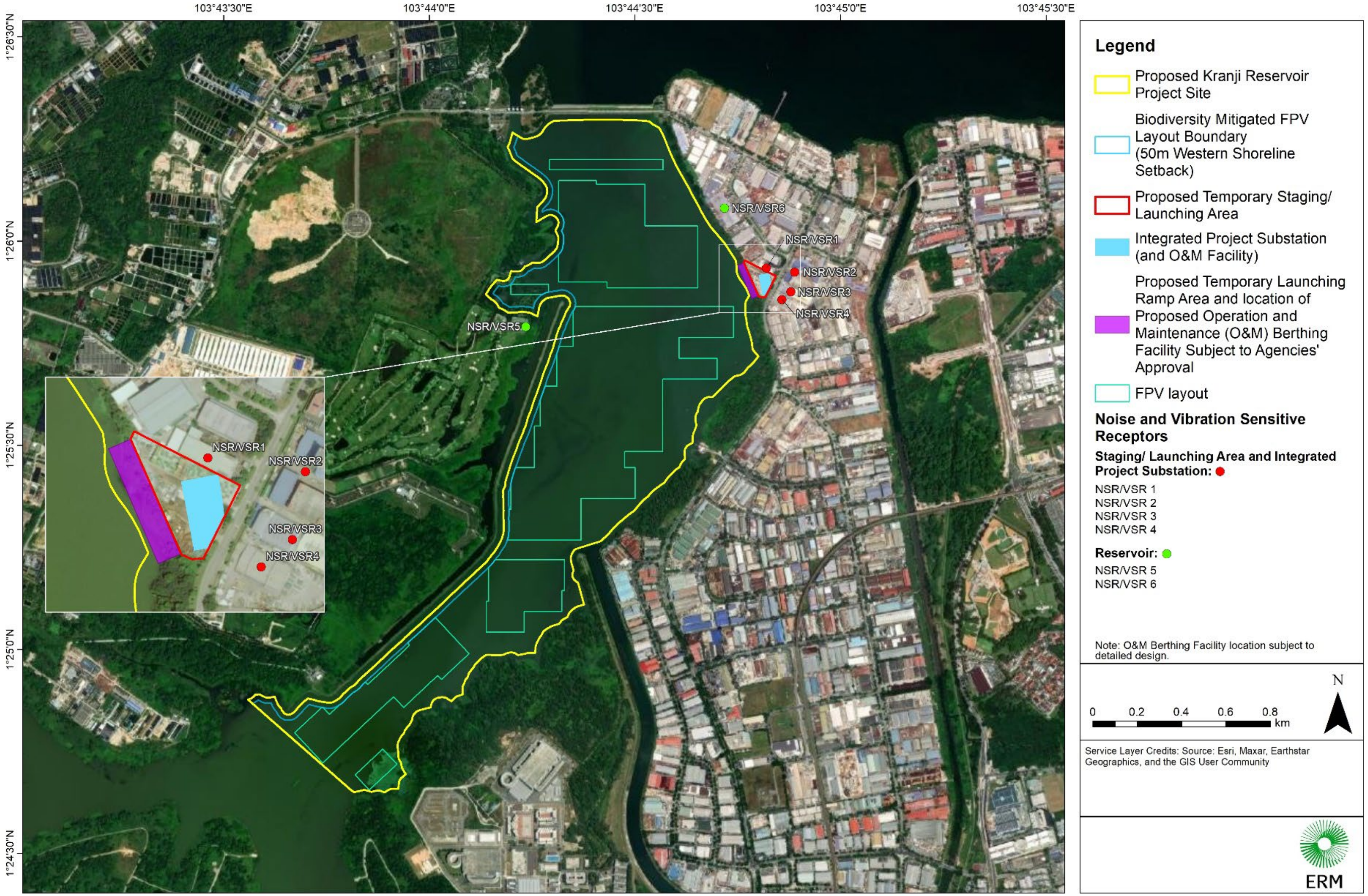


Figure 9-2: Representative Human Airborne Noise and Vibration Sensitive Receptors Locations

9.6 Prediction Methodology

9.6.1 Noise Prediction Approach

The noise prediction and impact assessment for construction at the proposed temporary Staging/ Launching Area and integrated Project Substation worksite and Reservoir Project Site; and the integrated Project Substation operation were assessed quantitatively through noise modelling. The SoundPLAN noise prediction software, version 8.2 was used to predict noise generated from the equipment anticipated to be used during the Project's construction and operation activities. The software implements the widely used international standard ISO 9613-2.

With regards to the construction noise impact assessment, the purpose of the modelling was to determine an indicative noise level at the off-site human noise sensitive receptors surrounding the proposed temporary Staging/ Launching Area and integrated Project Substation worksite and Reservoir Project Site due to the equipment likely to be used during the construction phase. For the operational noise impact assessment, the modelling was used to determine the indicative noise levels at the operational integrated Project Substation (with O&M Facility) boundary. The modelling establishes an understanding of potential noise impacts and considers potential mitigation recommendations. The noise modelling methodology and assumptions used are further described in the sections below.

9.6.1.1 Model Assumptions

The assumptions made for the noise prediction methods are described below:

- General assumptions:
  - Since the Project is currently at the feasibility stage, detailed information on the equipment specifications were not available. As a result, modelled equipment noise data are referenced from the British Standard 5228-1:2009+A1:2014, where relevant; and
  - The model assumes that the ground surfaces and water within the reservoir are acoustically reflective surfaces.
- Conservative assumptions used for construction noise modelling at land-based worksite:
  - The construction scenario modelled was selected based on the noisiest construction stage of the proposed temporary Staging/ Launching Area and integrated Project Substation construction phase. This was determined based on the construction schedule indicated in *Section 2.5*. Further details on the type and number of equipment assumed for each construction activity for the conservative construction noise scenario are presented below in *Table 9-16;*
  - Noise generating equipment were assumed to be moving around the whole proposed temporary Staging/ Launching Area and integrated Project Substation worksite. Therefore, noise sources in the model were represented as area sources;
  - All the construction equipment were assumed to be operating continuously, hence the predicted noise levels at the receptors will be the same for $L_{Aeq,5mins}$ and $L_{Aeq,12hours}$. In reality, not all the construction equipment will be running concurrently and the actual noise levels are expected to be lower; and
  - 24 hour construction activities are assumed at the worksite.
- Conservative assumptions used for construction noise modelling at Reservoir Project Site:
  - The potential anchoring system option (see *Appendix 2.1*) of driven piling activity (114dB(A)) (rather than low-noise piling or anchor block methods) was identified as the main activity contributing to potentially high noise levels throughout the construction period on the reservoir. The following was assumed as a conservative case: in the western portion of the reservoir, 4 piles will be driven simultaneously at the same location, resulting in a cumulative sound power level (SWL) of 120 dB(A); in the eastern

portion of the reservoir, 2 piles will be driven simultaneously at the same location, resulting in a cumulative SWL of 117 dB(A); thus having a highly conservative impact on potential receptors. In reality, it is highly unlikely that the piling impacts will happen at the same time and location, hence the actual noise levels are expected to be lower; and

  - 24 hour construction activities are assumed in the reservoir worksite (noting works within the reservoir will be limited to daylight hours only due to health and safety concerns).

- Conservative assumptions used for operational noise modelling at land-based integrated Project Substation site:
  - The transformers for the integrated Project Substation (with O&M Facility) are located within the building. Noise breakout from the building louvres located on the external façade of the building were modelled to predict the noise levels at the integrated Project Substation (with O&M facility) site boundaries;
  - The volume and finishes of the integrated Project Substation (with O&M Facility) building were considered during the calculation of the noise breakout from the building louvres;
  - Details on the number and sound power levels of the transformers included in the modelled operation scenario are presented in *Table 9-17*;
  - The transformers within the integrated Project Substation (with O&M Facility) were assumed to be operating continuously; and
  - The modelled louvres were orientated to face the public roads to the east, i.e. Sungei Kadut Drive, as an embedded control to minimise noise to the Kranji Reservoir and future park to the west of the integrated Project Substation (i.e. Future Kranji Reservoir Eastern Park).

In conducting this assessment, it should be noted that there are inevitably a number of uncertainties due to the preliminary nature of construction information, and the inherent uncertainties around different prediction methods and how they reflect real life features in detail (e.g. the degree to which a predictive model includes a predicted façade correction to account for reflections of sound from buildings). In order to take these uncertainties into account, generally, likely conservative case assumptions have been taken into account, particularly by assuming the highest likely size and number of construction equipment and the likely closest distances to receptors, which are anticipated to be the most significant factors for higher noise generation.

9.6.1.2 Main Construction Activities Considered

Based on a review of the construction schedule as well as the anticipated activities undertaken throughout the construction period, the noisiest construction period that had the highest cumulative noise levels, at the proposed temporary Staging/ Launching Area and integrated Project Substation worksite was identified and modelled as the conservative construction noise scenario. Such scenario is anticipated to occur in Year 2 Q2 – Q4 of the construction period.

Within the Reservoir Project Site, the main activity contributing to potentially high noise levels are conservatively considered to be the driven piling which are to be undertaken throughout the construction period of Year 1, Q4 to Year 2, Q4 As such, the model predicts the noise levels from the driven piling activity to the nearest off-site human NSRs to the FPV layout (*Figure 9-2)*. *Table 9-15* summarises the main noisy construction activities included in the model for each Project Site. *Table 9-16* shows the main construction equipment taken into consideration for the model.

Table 9-15: Assumed Main Noisy Construction Activities at each Project Site

Project Site	Project Period	Main Noisy Construction Activities
Proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M Facility)	Year 2, Q2 – Q4	Materials/ equipment storage, assembly, and deployment of FPV components, including medium excavator/ large rotary piling, on-site generators and compressor.
Reservoir Project Site	Year 1, Q4 – Year 2, Q4	Driven piling activities.

Table 9-16: Main Construction Equipment and Sound Power Levels at each Project Worksite

Project Site	Main Construction Equipment	Quantities	Sound Power Level (dB(A)) for Each Individual Equipment
Proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M Facility)	Skid Steer	2	95
	Telehandler	9	107
	Small Excavator	2	101
	Medium Excavator/ Large Rotary Piling	3	111
	Rough Terrain Crane	5	98
	Utility Vehicle	12	108
	Medium Duty Hauler	9	107
	Heavy Duty Hauler	14	108
	Boom Truck	4	105
	Concrete Mixer	6	112
	Compressor	5	107
	Generator	6	102
	Backhoe Loader	1	95
	Compactor	1	109
	Dozer	1	106
Reservoir Project Site	Pile Driving Rig	4 – in Western Reservoir 2 – in Eastern Reservoir	114

9.6.1.3 Main Operating Equipment Considered during Project's Normal Operation

Assumed SWLs of the equipment used during normal operation of the integrated Project Substation (with O&M Facility) are presented in *Table 9-17*.

Table 9-17: Noise Generating Equipment during Normal Operation

Operating Equipment	Quantities	Sound Power Level, dB(A)
Transformer	2	72

9.6.2 Vibration Prediction Approach

Within the proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M Facility), the only activity contributing to potentially high vibration levels are conservatively assumed to be rotary bored piling (augering) activities undertaken throughout the construction period. Based on *British Standard 5228-2:2009+A1:2014*, Table D.6 (C106), the vibration level for this type of piling activity is 0.54 mm/s (Peak Particle Velocity – PPV).

Within the Reservoir Project Site, the only activity contributing to potentially high vibration levels are conservatively assumed to be the pile driving rig (driven pile) activities undertaken throughout the construction period. Based on *British Standard 5228-2:2009+A1:2014*[11], Table D.2 (C24), the vibration level for this type of piling activity is 6.1 mm/s (Peak Particle Velocity – PPV). As a conservative approach, it was assumed that 4 piles and 2 piles will be driven simultaneously in the western and eastern portion of the reservoir, respectively.

The abovementioned values obtained from the *British Standard 5228-2:2009+A1:2014* are the PPV. PPV is defined as a maximum absolute value of vibration experienced at any one instant in time. In reality, it is unlikely that the piling impacts from multiple piling activities across the Project Sites will occur at precisely the same time, and hence the vibration levels are not likely to be additive. Therefore, for this vibration impact assessment, it is appropriate to consider only one piling activity representing the highest likely PPVs for both proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M Facility) and Reservoir Project Site when comparing predicted PPV values with the criteria.

9.7 Impact Assessment – Construction and Operation

9.7.1 Construction Phase – Airborne Noise and Vibration

9.7.1.1 Potential Sources of Impact

Land-based construction activities for the proposed temporary Staging/ Launching Area and integrated Project Substation worksite will take place near to receptors within Sungei Kadut Industrial Estate. In-reservoir driven piling construction works may affect the nearest off-site receptors on the eastern and western shorelines. Specific Project activities which may result in construction impacts to airborne noise and vibration include the following:

Proposed temporary Staging/ Launching Area & Integrated Project Substation – Construction Works on Land

- Preparation of the proposed temporary Staging/ Launching Area, including ramp into reservoir;
- Assembly of the FPV system; and
- Construction of integrated Project Substation and land-based connector cable.

FPV – Construction Works on/ in Reservoir

- Deployment of anchors/ ballasted foundations/ piles and mooring lines – specifically piling (assumed to be driven piles as a conservative case).

The impacts that may arise due to the above activities/ events that are considered in *Section 9.7.1.3* include:

<u>Airborne Noise:</u>

- Generation of noise during the land-based construction at the proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M facility) worksite; and
- Generation of piling noise at Reservoir Project Site.

Vibration:

- Generation of vibration during the land-based construction at the proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M facility) worksite; and
- Generation of vibration at Reservoir Project Site.

9.7.1.2 Embedded Controls

Embedded controls are measures (physical or procedural) that are planned to be put in place as part of the Project design, construction and operation from the outset. These actions are to manage the Project's compliance with relevant legislation, regulations and guidelines. There are no additional design-related embedded controls to be considered for airborne noise and vibration for the construction phase beyond those identified in *Section 9.2* and *Section 9.6*, see also a list of the embedded controls are presented in *Appendix 2.2*.

9.7.1.3 Impact Assessment and Mitigation Measures

A summary of the assessment of impacts to airborne noise and vibration and proposed mitigation measures during Project construction is provided in *Table 9-18*.

Unmitigated and mitigated noise contour plots, as required, from the noise model for the relevant impact assessments in *Table 9-18*, are provided in *Figure 9-3 to Figure 9-5.*

Table 9-18: Impact Assessment for Airborne Noise and Vibration (Construction Phase)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
C1	**Generation of noise during the land-based construction at the proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M facility) worksite**	■ **Nature**: Increased airborne noise levels are considered **negative**. ■ **Type**: **Direct** impact to human noise sensitive receptors near to land-based worksite. ■ **Duration**: The worksite will be active throughout construction (3 years) which is considered relatively **long-term** for airborne noise (greater than 1-month exposure), and is reversible upon completion of the construction. ■ **Extent**: Impacts are **localised** within the land-based worksite and the immediate surroundings. ■ **Scale**: Nearest human receptors are industrial premises located immediately adjacent to the land-based worksite. ■ **Frequency**: Activities will happen **daily/ intermittently** during the specified period of construction phase. Unmitigated noise levels predicted at the nearest off-site noise sensitive human receptors surrounding the proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M facility) worksite against the applicable criteria limits, as well as noise exceedances, corresponding impact magnitude and significance are provided in *Appendix 9.2 (Table 1)*. The results are also illustrated in *Figure 9-3* below. The nearest affected NSRs are Eng Hua Furniture Manufacturing (NSR 3), Eng Seng Cement Products Pte Ltd (NSR 4), Ley Choon Group Holding (NSR 2) and Star Sin Trading Pte Ltd (NSR 1). For $L_{Aeq,5mins}$ results: ■ Impact magnitude during the daytime period (7am – 7pm) would be ***Negligible*** (0 – 2 dB(A) exceedance) at NSRs 1 to 4; ■ Impact magnitude during the evening (7pm – 10pm) ranges from ***Small to Large*** (3 – >10 dB(A) exceedance) at NSRs 1 to 4; and ■ Impact magnitude during the night (10pm – 7am) ranges from ***Small to Large*** (3 – >10 dB(A) exceedance) at NSRs 1 to 4. For $L_{Aeq,12hours}$ results: ■ Impact magnitude during the daytime period (7am-7pm) ranges from ***Negligible to Large*** (0 – >10 dB(A) exceedance) at NSRs 1 to 4; and ■ Impact magnitude during the night (7pm – 7am) ranges from ***Medium to Large*** (6 - >10 dB(A) exceedance) at NSRs 1 to 4. Overall, taking into account that the duration of the construction for the proposed temporary Staging/ Launching Area and integrated Project Substation is greater than 1 month, the impact significance for all the nearest human NSRs (1 – 4) ranges from ***Negligible to Major*** for $L_{Aeq,5mins}$ and $L_{Aeq,12hours}$ for all periods – day, evening and night, see *Appendix 9.2 (Table 1)*.	Impact Magnitude: **Negligible to Large** Receptor Sensitivity: The impact magnitude criteria have already taken into account the receptor sensitivities. Impact Significance: **Negligible to Major**	Recommended mitigation measures include: ■ Installation of temporary 4 meter-high noise barrier along the northern, eastern and southern boundaries (see illustration in *Figure 9-4* below) throughout the construction phase; ■ The temporary noise barriers shall have a minimum surface density of 20kg/m^2 or a minimum sound transmission loss of 20 dB, e.g. steel with a 22-gauge with thickness of 0.79 mm, surface density of 6.1 kg/m^2 and sound transmission loss of 20 dB. Additionally, there shall be no gaps at the bottom of the noise barriers or in between the panels, as far as reasonably practicable. Any gaps must be sealed with rubber gasketing to minimise noise propagation to the nearest off-site receptors; ■ If required, access ways along the barriers should be minimised as much as possible as well; ■ Such materials and principals described above shall be applied to the worksite access gates, which should remain closed as far as reasonably practicable throughout the construction period; and ■ Detailed design and construction methodology and scheduling to minimise extent and duration of noisy activities (e.g. reduce continuously operating equipment and simultaneous equipment operation etc), where feasible. With the abovementioned noise barriers, the mitigated predicted noise levels at NSRs 1 to 4 (impact magnitude and significance) would be reduced. See *Appendix 9.2* (*Table 2*) and *Figure 9-4* below for further details. No significant (above minor) residual impacts are anticipated related to airborne noise, however, it is recommended to conduct noise monitoring during construction to verify the impacts assessed herein, see *Section 12* (EMMP).	Impact Magnitude: **Negligible to Small** Impact Significance: **Negligible to Minor**
C2	**Generation of piling noise at Reservoir Project Site**	■ **Nature**: Increased airborne noise levels are considered **negative**. ■ **Type**: **Direct** impact to human noise sensitive receptors near to reservoir worksite. ■ **Duration**: Depending on the final design of anchoring to be adopted, the installation of in-reservoir (driven) piles could take up to 56 weeks (see *Appendix 2.1*), which is considered to be relatively **long-term** for airborne noise (greater than 1-month exposure) and is reversible upon completion of the construction.	Impact Magnitude: **Negligible to Small** Receptor Sensitivity: The impact magnitude criteria have already taken into account the	Mitigation measures presented in the *Section 7* (Biodiversity) related to minimising in-reservoir piling noise to biodiversity will be applied, therefore also reducing the impacts for human receptors.	Impact Magnitude: **Negligible** Impact Significance: **Negligible**

<table>
<tr><th>S/N</th><th>Impact</th><th>Impact Magnitude Description</th><th>Pre-Mitigation Impact Significance</th><th>Mitigation Measures and Monitoring</th><th>Residual (with mitigation) Impact Significance</th></tr>
<tr><td></td><td></td><td>

Extent: Impacts are localised within the reservoir worksite and the immediate surroundings.
Scale: Nearest human receptors are industrial premises and sports and recreation areas that are located in the vicinity of the piling activity at the FPV footprint.
Frequency: Activities will happen daily/ intermittently during the specified period of construction phase.

The main activity contributing to high sound power levels (SWL) of 114 dB(A) in the reservoir is conservatively assumed to be the driven piling option for the FPV and PCU anchoring systems.
As a conservative case: in the western portion of the reservoir, 4 piles will be driven simultaneously at the same location, resulting in a cumulative sound power level (SWL) of 120 dB(A); in the eastern portion of the reservoir, 2 piles will be driven simultaneously at the same location, resulting in a cumulative SWL of 117 dB(A).
Unmitigated noise levels predicted at the nearest off-site noise sensitive human receptors to the FPV layout on the west and east portion of the reservoir against the applicable criteria limits, as well as noise exceedances, corresponding impact magnitude and significance are provided in Appendix 9.2 (Table 3). The results are also presented illustrated in Figure 9-5 below.
The nearest affected NSRs are NRSCC Kranji Sanctuary Golf Course (NSR 5) from the western shoreline of the reservoir, and FMB Trading and Engineering Ptd Ltd (NSR 6) from the eastern shoreline of the reservoir.
For $L_{Aeq,5mins}$ results:

Impact magnitude during the daytime period (7am – 7pm), evening (7pm – 10pm) and night (10pm – 7am) would be Negligible (0 – 2 dB(A) exceedance) at NSRs 5 and 6.

For $L_{Aeq,12hours}$ results:

Impact magnitude during the daytime period (7am – 7pm) results show the impact magnitude would be Negligible at NSRs 5 and 6; and
Impact magnitude during the night (7pm – 7am) would be Small (3 – 5 dB(A) exceedance) at NSRs 5 and 6.

Overall, taking into account that the duration of the construction for the driven piling activities in the Reservoir Project Site is greater than 1 month, the impact significance for the nearest human NSRs (5 - 6) along both the western and eastern shorelines ranges from Negligible to Minor for $L_{Aeq,5mins}$ and $L_{Aeq,12hours}$ for all periods – day, evening and night, see Appendix 9.2 (Table 3).
</td><td>receptor sensitivities.

Impact Significance: Negligible to Minor</td><td>No significant (above minor) residual impacts are anticipated related to airborne noise, however, it is recommended to conduct noise monitoring during construction to verify the impacts assessed herein, see Section 12 (EMMP).</td><td></td></tr>
<tr><td>C3</td><td>Generation of vibration during the land-based construction at the proposed temporary Staging/ Launching Area and integrated Project Substation</td><td>

Nature: Increased vibration levels are considered negative.
Type: Direct impact to human vibration sensitive receptors near to land-based worksite.
Duration: The rotary piling activity at the worksite is anticipated to be 6 - 8 weeks. Whilst this is greater than 1-month exposure, this is considered relatively short to long-term for vibration, and is reversible upon completion of the construction.
Extent: Impacts are localised within the land-based worksite and the immediate surroundings.
Scale: Nearest receptors are industrial premises located immediately adjacent to the land-based worksite.
Frequency: Activities will happen daily/intermittently during the specified period of construction phase.

At the proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M facility) worksite, the main vibration source will be the rotary bored pilling activity for concrete foundation work for the integrated Project Substation (with O&M Facility).
</td><td>Impact Magnitude: Medium at 2m distance.

Receptor Sensitivity: The impact magnitude criteria have already taken into account the receptor sensitivities.

Impact Significance: Moderate</td><td>It is calculated that rotary piling activities at a distance of 4 m from the nearest human VSR will result in a small (0.14 mm/s – 1 mm/s) impact magnitude (and thus minor significance).

Detailed design and construction methodology and scheduling to minimise extent, duration and distance (for example, minimum 4 m) to VSRs of vibration activities, where feasible.
</td><td>Impact Magnitude: Small

Impact Significance: Minor</td></tr>
</table>

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
	(with O&M facility) worksite	The vibration magnitude at the nearest receptor was predicted using empirical equations developed for vibratory piling, as presented in *British Standard 5228-2:2009+A1:2014*, Table D.6 (C106). Data obtained for Rotary Bored Piling (Augering) gave rise to 0.54 mm/s (Peak Particle Velocity – PPV)[2] at a 5 m distance from the sources. Vibration level propagation was calculated using the empirical equations as stated in the *British Standard 5228-2:2009+A1:2014*, Table E.1. A conservative scenario was selected to estimate the vibration levels at 2 m distance from the nearest human vibration sensitive receptors at the worksite (i.e. Star Sin Trading Pte Ltd, VSR 1, see *Figure 9-2*). The estimated level of vibration would be approximately 1.9 mm/s. Hence, a ***Medium*** (1 mm/s – 10 mm/s) impact magnitude is anticipated. Overall, taking into account that the duration of the construction for the rotary piling activities in the proposed temporary Staging/Launching Area and integrated Project Substation site is greater than 1 month, the impact significance for the nearest human VSR 1 is ***Moderate***.			
C4	**Generation of vibration at Reservoir Project Site**	■ **Nature**: Increased vibration levels are considered **Negative**. ■ **Type**: Vibration sensitive receptors are **directly** impacted by increased vibration levels. ■ **Duration**: Depending on the final design of anchoring to be adopted, the installation of in-reservoir (driven) piles could take up to 56 weeks (see *Appendix 2.1*), which is considered to be relatively **long-term** for airborne noise (greater than 1-month exposure), and is reversible upon completion of the construction. ■ **Extent**: Impacts are **localised** within the reservoir worksite and the immediate surroundings. ■ **Scale**: Nearest human receptors are industrial premises and sports and recreation areas that are located in the vicinity of the piling activity at the FPV footprint. ■ **Frequency**: Activities will happen **daily**/ **intermittently** during the specified period of construction phase. At the Reservoir Project Site, the main vibration source is conservatively assumed to be the driven pilling option for the FPV and PCU anchoring system. Data obtained from *British Standard 5228-2:2009+A1:2014*, Table D.2 (C24) for Driven Cast-in-place Piling (Drop hammer) gave rise to 6.1 mm/s (PPV) at a 8.5 m distance from the source. Vibration level propagation was calculated using the empirical equations as stated in the *British Standard 5228-2:2009+A1:2014*, Table E.1. A conservative scenario was selected to estimate the vibration levels at 100 meter distance from the nearest human vibration sensitive receptors to the FPV layout on the west and east portion of the reservoir, i.e. NRSCC Kranji Sanctuary Golf Course (NSR 5) from the western shoreline of the reservoir, and FMB Trading and Engineering Ptd Ltd (NSR 6) from the eastern shoreline of the reservoir (see *Figure 9-2*). The estimated level of vibration would be approximately 0.5 mm/s. Hence, a ***Small*** (0.14 mm/s – 1 mm/s) impact magnitude is anticipated. Overall, taking into account that the duration of the construction for the driven piling activities in the Reservoir Project Site is greater than 1 month, the impact significance for the nearest human VSRs (5 - 6) along both the western and eastern shorelines is ***Minor***.	Impact Magnitude: **Small** Receptor Sensitivity: The impact magnitude criteria has already taken into account the receptor sensitivities. Impact Significance: **Minor**	No mitigation measures are required as embedded controls are considered to be adequate to manage impact significance to be ***Minor***.	N/A. (refer to Pre-Mitigation Impact Significance Column)

[2] The vibration levels obtained from Code of Practice for Noise and Vibration control on Construction and Open Sites: BS 5228-2:2009+A1:2014 are measured outside of buildings. Note 3 in *Table 9-8* also refers to a transfer function (which relates to conversion of an external level to an internal level) which needs to be applied if only external measurements are available. In this case no transfer function has been applied which is likely to be a conservative case for most buildings.

Figure 9-3: Unmitigated Noise Contours for the Proposed Temporary Staging Ground/ Launching Area and Integrated Project Substation (with O&M Facility)

Figure 9-4: Mitigated Noise Contour for the Proposed Temporary Staging/ Launching Area and Integrated Project Substation (with O&M Facility)

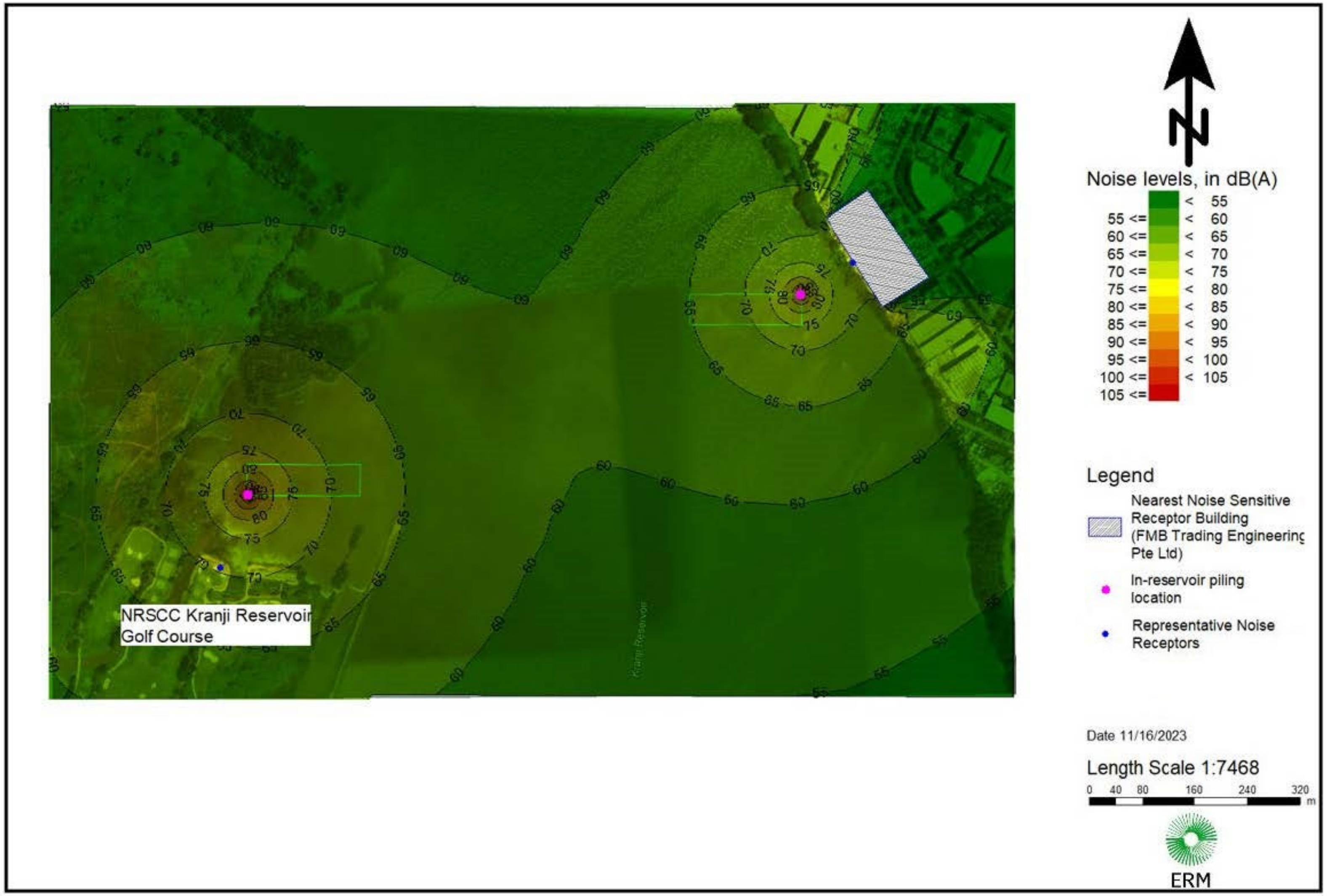


Figure 9-5: Unmitigated Noise Contours for In-reservoir Piling at Nearest Western and Eastern Shoreline Receptors

9.7.1.4 Summary of Construction Impacts

Adoption of the abovementioned mitigation measures are expected to reduce the construction residual impact magnitudes of the described impacts on airborne noise and vibration. Potential construction residual impact significance for airborne noise and vibration are anticipated to be reduced to ***Negligible to Minor***.

No significant (above minor) residual construction impacts to airborne noise and vibration are anticipated.

A programme of monitoring and adaptive management is proposed to verify and minimise impacts on airborne noise during construction, see *Section 9.7.3* and *Section 12* (EMMP) for further details.

Should any of the design and construction assumptions assessed in this Section change (i.e. be considered to be greater, or more impactful, than those assumed in this assessment) as a result of the Final Developer/ Owner's detailed design and construction methodology, the above impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein.

A summary of the impact assessment for the construction phase is presented in *Table 9-19.*

Table 9-19: Impact Summary of Airborne Noise and Vibration during Construction

Impact	■ Generation of noise during the land-based construction at the proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M facility) worksite (C1) ■ Generation of piling noise at Reservoir Project Site (C2) ■ Generation of vibration during the land-based construction at the proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M facility) worksite (C3) ■ Generation of vibration at Reservoir Project Site (C4)				
Impact Nature	**Negative**	Positive		Neutral	
	Increased airborne noise and vibration are considered negative.				
Impact Type	**Direct**	Indirect		Induced	
	Direct impacts to human airborne noise and vibration sensitive receptors.				
Impact Duration	Temporary	Short-term	**Long-term**	Permanent	
	The land-based worksite will be active for 3 years, with rotary piling activity for 6-8 weeks. In-reservoir (driven) piling could take up to 56 weeks. These are considered relatively long term for airborne noise and vibration and are reversible upon completion of the construction.				
Impact Extent	**Local**	Regional		Global	
	Impacts are localised within the land-based and reservoir worksites and the immediate surroundings.				
Impact Scale	For the land-based worksite the nearest human receptors are immediately adjacent. The in-reservoir (driven) piling areas (within the FPV layout footprint) are located nearest at the NRSCC Kranji Sanctuary Golf Course (NSR 5) on the western shoreline of the reservoir, and FMB Trading and Engineering Ptd Ltd on the eastern shoreline.				
Impact Frequency	Activities will happen daily / intermittently during the specified period of construction phase.				
Impact Magnitude	Positive	**Negligible**	**Small**	**Medium**	**Large**
	Without mitigation impact magnitude for impacts during construction is **Negligible to Large** for airborne noise, and **Negligible to Medium** for vibration.				
Receptor Sensitivity	■ Noise sensitive receptors = industrial premises to the north and east of proposed temporary Staging/ Launching Area and integrated Project Substation worksite. Sports and recreation areas on the western reservoir shoreline and industrial premises on the eastern reservoir shoreline. ■ Vibration sensitive receptors = industrial premises to the north and east of the proposed temporary Staging/ Launching Area and integrated Project Substation. ■ The impact magnitude under the airborne noise and vibration assessment criteria has already taken into account the receptor sensitivities.				

<table>
<tr><td>Key Embedded Controls (beyond legislation, regulations, standards and guidelines)</td><td colspan="6">No additional design-related embedded controls were considered beyond those identified in Section 9.2 and Section 9.6.</td></tr>
<tr><td rowspan="2">Significance (without mitigation)</td><td>Negligible</td><td colspan="2">Minor</td><td colspan="2">Moderate</td><td>Major</td></tr>
<tr><td colspan="6">The significance ranges from Negligible to Major without mitigation. Significant (above minor) impacts are:
■ Major:
- Generation of noise during the land-based construction at Staging/ Launching Area and integrated Project Substation worksite (with O&M facility) (C1).
■ Moderate:
- Generation of vibration during the land-based construction at the proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M facility) worksite (C3).</td></tr>
<tr><td>Key Mitigation and Monitoring Measures</td><td colspan="6">■ Detailed design and construction methodology and scheduling to minimise extent and duration of noisy activities; and distance to vibration sensitive activities (e.g. minimum 4 m), where feasible.
■ Installation of temporary 4 meter-high noise barrier along the northern, eastern and southern boundaries of the proposed temporary Staging/ Launching Area and integrated Project Substation worksite (with O&M facility).
■ The temporary noise barriers shall have a minimum surface density of 20 kg/m^2 or a minimum sound transmission loss of 20 dB.
■ No gaps at the bottom of the noise barriers or in between the panels, as far as reasonably practicable.
■ Access ways along the barriers should be minimised as much as possible.
■ Worksite access gates, which should remain closed as far as reasonably practicable throughout the construction period.
■ Conduct noise monitoring during construction to verify impacts.</td></tr>
<tr><td rowspan="2">Residual Impact Magnitude (with mitigation)</td><td>Positive</td><td>Negligible</td><td colspan="2">Small</td><td>Medium</td><td>Large</td></tr>
<tr><td colspan="6">The residual impact magnitude is expected to be reduced to Negligible to Small.</td></tr>
<tr><td rowspan="2">Residual Impact Significance (with mitigation)</td><td>Negligible</td><td colspan="2">Minor</td><td colspan="2">Moderate</td><td>Major</td></tr>
<tr><td colspan="6">The residual impact significance with mitigation ranges from Negligible to Minor. No significant (above minor) residual impacts are anticipated.
A programme of monitoring and regular environmental site inspections, i.e. on a weekly basis, of in-reservoir and land-based worksites is proposed to verify and minimise impacts on airborne noise during construction, see Section 9.7.3 and Section 12 (EMMP) for further details.</td></tr>
</table>

9.7.2 Operation Phase – Airborne Noise

9.7.2.1 Potential Sources of Impact

Specific Project activities which may result in operational impacts to airborne noise include the following:

Integrated Project Substation – Operation on land

- Operation of integrated Project Substation (with O&M facilities) on land.

The impacts that may arise due to the above activities/ events that are considered in *Section 9.7.2.3* include:

Airborne Noise:

- Generation of noise from operation of integrated Project Substation (with O&M facility).

9.7.2.2 Embedded Controls

The main noise avoidance measure embedded within the design to avoid impacts on airborne noise during operation is:

- Louvres for the integrated Project Substation are orientated to face the public roads to the east, i.e. Sungei Kadut Drive, to minimise noise to the Kranji Reservoir and future park to the west.

The above are further to the operational embedded controls outlined for Surface Water Quality (*Section 6*), Biodiversity (*Section 7*), Air Quality (*Section 8*), Soil and Groundwater (*Section 10*) and Vectors (*Section 11*).

9.7.2.3 Impact Assessment and Mitigation Measures

A summary of the assessment of impacts to airborne noise and proposed mitigation measures during Project operation is provided in *Table 9-20.*

A noise contour plot from the noise model for the relevant impact assessment in *Table 9-20* is provided in *Figure 9-6.*

Table 9-20: Impact Assessment for Airborne Noise (Operation Phase)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
O1	**Generation of noise from operation of integrated Project Substation (with O&M Facility)**	■ **Nature**: Increased airborne noise levels are considered **negative**. ■ **Type**: **Direct** impact to human noise sensitive receptors near to land-based worksite. ■ **Duration**: Impacts are throughout the Project operational phase. Its effect on human noise sensitive receptors is **reversible** should the Project's integrated Project Substation be removed. For integrated Project Substation site the future sensitive adjacent land use is designated as future park. ■ **Extent**: Impacts are **localised** within the integrated Project Substation (with O&M facility) site and the immediate surroundings. ■ **Scale**: Nearest human receptors are industrial premises located immediately adjacent north and east of the site, and future park to the immediate west. ■ **Frequency**: **Continuous** throughout the Project operational phase (25 years). Unmitigated noise levels predicted at the nearest off-site noise sensitive human receptors surrounding the integrated Project Substation (with O&M facility) site against the applicable criteria limits, as well as noise exceedances, corresponding impact magnitude and significance are provided in *Appendix 9.2 (Table 4).* The results are also presented illustrated in *Figure 9-6* below. The embedded control of orientating the louvres to face the public roads to the east (instead of the future park to the west) is included in the operational noise modelling. Based on the regulations, noise levels at the boundary of the Project Site (north, south, east, west) are assessed (instead of at the nearest human sensitive receptors). $L_{Aeq,5mins}$ during the daytime period (7am – 7pm), evening (7pm – 11pm) and night (11pm – 7am) results show the impact magnitude would be ***Negligible*** (0 – 2 dB(A) exceedance) at all boundaries. Overall, the impact significance at the boundary of the integrated Project Substation (with O&M facility) site is ***Negligible*** for $L_{Aeq,5mins}$ for all periods – day, evening and night, see *Appendix 9.2 (Table 4)*.	Impact Magnitude: **Negligible** Receptor Sensitivity: The impact magnitude criteria have already taken into account the receptor sensitivities. Impact Significance: **Negligible**	No mitigation measures are required as embedded controls are considered to be adequate to manage impact significance to be **Negligible**.	N/A. (refer to Pre-Mitigation Impact Significance Column)

Figure 9-6: Unmitigated Noise Contour during Integrated Project Substation (with O&M Facility) Operation

9.7.2.4 Summary of Operational Impacts

With embedded controls (i.e. orientating the integrated Project Substation louvres to the east) the operational residual impact magnitudes and significance for airborne noise are anticipated to be ***Negligible***.

No significant (above minor) residual construction impacts to airborne noise and vibration are anticipated.

Should any of the design and/ or operational assumptions assessed in this Section change (i.e. be considered to be greater, or more impactful, than those assumed in this assessment) as a result of the Developer/ Owner’s detailed design and operations, the above impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein.

A summary of the impact assessment for the operation phase is presented in *Table 9-21*.

Table 9-21: Impact Summary of Airborne Noise during Operation

Impact	■ Generation of noise from operation of integrated Project Substation (with O&M Facility) (O1)				
Impact Nature	**Negative**	Positive		Neutral	
	Increased airborne noise are considered negative.				
Impact Type	**Direct**	Indirect		Induced	
	Direct impacts to human noise sensitive receptors near to integrated Project Substation.				
Impact Duration	Temporary	Short-term	**Long-term**	Permanent	
	These impacts will be present throughout the operational phase (25 years). For integrated Project Substation site the future sensitive adjacent land use is designated as future park.				
Impact Extent	**Local**	Regional		Global	
	Impacts are localised within the integrated Project Substation (with O&M facility) site and the immediate surroundings.				
Impact Scale	Nearest human receptors are industrial premises located immediately adjacent north and east of the site, and future park to the immediate west.				
Impact Frequency	Continuous throughout the operational phase.				
Impact Magnitude	Positive	**Negligible**	Small	Medium	Large
	Without mitigation impact magnitude for airborne noise during operation is **Negligible**.				
Receptor Sensitivity	■ Noise sensitive receptors = industrial premises to the north and east, and future park to the west. The impact magnitude under the airborne noise assessment criteria has already taken into account the receptor sensitivities.				
Key Embedded Controls (beyond legislation, regulations, standards and guidelines)	■ Louvres for the integrated Project Substation are orientated to face the public roads to the east to minimise noise to the Kranji Reservoir and future park to the west.				
Significance (without mitigation)	**Negligible**	Minor	Moderate	Major	
	The impact significance without mitigation is **Negligible**. Therefore, no further mitigation measures are considered necessary. Thus no evaluation of residual impact significance is required, i.e. no significant (above minor) residual impacts are anticipated.				

9.7.3 Airborne Noise and Vibration Monitoring

As outlined in *Section 9.7.1.3* and *9.7.2.3* above, airborne noise monitoring is recommended to be carried out during construction for driven piling activities with the Reservoir Project Site, and construction activities in the proposed temporary Staging/ Launching Area and integrated Project Substation worksite to verify the impacts assessed herein.

The Environmental Management and Monitoring Plan (EMMP) (*Section 12*) establishes further details of the proposed monitoring programmes for this Project.

In addition, it is recommended to conduct regular environmental site inspections, i.e. on a weekly basis, at the Reservoir Project Site works areas, and the proposed temporary Staging/ Launching Area and integrated Project Substation worksite during construction to check the implementation of the embedded controls, mitigation measures and monitoring programmes.

9.7.4 Potential Cumulative Impacts from Other Major Concurrent Developments

Consultation between URA and MND has been undertaken during the course of this study to identify other known concurrent projects in the immediate vicinity of the Project Sites for which works will occur at the same time as this Project, see *Section 4.3.1, Table 4-2*. The detailed schedules for such developments are not available at the time of writing. Cumulative impacts have therefore not been undertaken in this EIA due to the lack of available information. In the event that information on surrounding committed developments does become available, the Kranji FPV Project should be assessed under the cumulative impact assessments within the EIAs of these surrounding committed developments. Details of this Project, where appropriate, will be coordinated and provided to the EIA owners of surrounding developments to support their cumulative impact assessment.

10. SOIL AND GROUNDWATER

10.1 Overview

This Section of the EIA reviews the potential soil and groundwater impacts associated with any contamination to the ground from the land-based construction phase of the Project, i.e. proposed temporary Staging/ Launching Area and integrated Project Substation worksite. Where required, the mitigation hierarchy of avoidance, minimisation, reduction or compensation has been applied to potentially significant impacts to reduce impact levels to as low as reasonably practicable.

Relevant Government agencies have been consulted since the early phases of the Project (since January 2020) to understand soil and groundwater concerns and in preparing the soil and groundwater impact assessment for this Project. The discussions and recommendations from relevant Government agencies have been taken into account in the following assessment.

Given the regulations and guidelines on managing contamination to soil and groundwater (which are considered to be embedded controls established at the outset of Project); soil and groundwater impacts from unplanned, accidental spills or leaks from the proposed temporary Staging/ Launching Area and integrated Project Substation worksite have been assessed qualitatively. Impacts from unplanned events from environmental spills to Surface Water Quality are considered to be assessed under *Section 6, Table 6-8, item S/N U2*).

Operational impacts related to soil and groundwater from the in-reservoir FPV system and land-based integrated Project Substation operations are not anticipated to be significant and have been scoped out from this assessment.

Potential impacts associated with reservoir sediment quality are covered under *Section 6* (Surface Water Quality).

10.2 Regulatory Framework

The legislation, standards and/or guidelines applicable to governing soil and groundwater quality at construction sites in Singapore relevant to this Project include those listed in *Table 10-1.*

Table 10-1: Summary of Legislative Requirements and Guidelines to Protect Soil & Groundwater Quality

Legislation/ Standard/ Guideline	Relevance to Soil and Groundwater Quality for this EIA
Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021	■ This Act provides for the control of air, water and noise pollution, for the safe management of hazardous waste and for the protection and management of the environment and resource conservation. ■ Provides measures related to pollution control regarding the discharge of toxic substances or hazardous substances deemed to cause pollution of the environment including groundwater.
Environmental Protection and Management (Hazardous Substances) Regulations (Amendment), 2021	■ A record indicating the quantity of hazardous substances shall be kept. ■ Employ required practices such as proper labelling and placement of containers storing hazardous substances. ■ Ensure potentially contaminated runoff discharged to any land or watercourse complies with statutory limits and will not contain substances stipulated within the regulations. ■ Workers will be adequately trained to handle toxic wastes stored on site, and to implement emergency action plans to deal with spills and leaks of toxic waste. ■ Ensure that workers have received adequate instruction and training to handle any accident or emergency involving any toxic industrial waste stored or transported within the construction site.
Environmental Protection and Management (Trade Effluent) Regulations, 2008	■ Only trade effluent that are treated and compliant with the discharge standards for watercourses and controlled watercourses, and which do not contain prohibited materials such as pesticides, refuse, petroleum etc., will be discharged from the Project worksites.

Legislation/ Standard/ Guideline	Relevance to Soil and Groundwater Quality for this EIA
	■ Treat all trade effluent before it is discharged into any watercourse or land, unless an exemption is specifically granted by the Director-General of the NEA. ■ Install sampling test points, inspection chambers, flow-meters, and recording and other apparatuses for trade effluent discharged into any watercourse or land. ■ Analyse potentially contaminated runoff discharged into any watercourse or land in accordance with the latest edition of "Standard Methods for the Examination of Water and Wastewater" published jointly by the American Public Health Association, the American Water Works Association and the Water Pollution Control Federation of the United States. ■ Prohibit discharge of any trade effluent, oil, chemical, sewerage or other polluting matters into any drain or land, without a license from the Director-General of the NEA. ■ Prohibit discharge of trade effluent that contains: - pesticides, fungicide, herbicide, insecticide, rodenticide or fumigant; - refuse, garbage, sawdust, timber, human or animal waste or solid matter; - petroleum or other inflammable solvent; and - any reactive substance that may give rise to hazardous fumes or odour.
Environmental Public Health Act (EPHA) (Amendment), 2022	■ Ensure proper storage and disposal of Toxic Industrial Waste (TIW). ■ Prevent excessive production of TIW. ■ Provide adequate sanitary facilities for workers.
Environmental Public Health (Toxic Industrial Waste) Regulations (Amendment), 2022	■ Keep a register of type, quantity and manner of disposal of TIW generated on site, date and quantity sold to TIW Collectors, and quantity held in stock and update it on a weekly basis. ■ Prepare and keep up to date an emergency action plan detailing how spillage, leakage or accidents which may arise from the storage of TIW will be dealt with and ensure that workers on site have received adequate training and instruction to enable them to implement the emergency action plan in the event of an emergency. ■ TIW such as contaminated soil from construction works must be disposed by a licensed toxic waste collector. ■ Ensure that TIW is stored in accordance with the approved code of practice. ■ Ensure that the TIW is not mixed with non-toxic waste, unless it is an approved process of treatment, use or disposal. ■ Emergency response kits will be provided at all worksites.
Environmental Public Health (General Waste Collection) Regulations (Amendment), 2019	■ Only licensed general waste collectors shall be contracted to collect, transport, and dispose of general waste generated from the Project Site.
Fire Safety (Petroleum and Flammable Materials – Exemption) Order (Amendment), 2020	■ In the event that storage of petroleum and/or flammable materials in quantities exceeding that specified in the First Schedule of the Fire Safety (Petroleum and Flammable Materials – Exemption) Order, 2008, is required at the Project worksite, Contractors shall obtain a Petroleum & Flammable Materials Storage License from the Singapore Civil Defence Force (SCDF).
Fire Safety (Petroleum and Flammable Materials) Regulations (Amendment), 2022	■ Contractors holding a Petroleum and Flammable Materials Storage License shall implement the controls listed in the regulations for the storage of petroleum and/or flammable materials on site. ■ Keep and maintain a register of petroleum and flammable materials stored for a period of 2 years. ■ Take all practicable steps to prevent the occurrence of an accident through fire, explosion, leakage or ignition of any petroleum or flammable material or vapours. ■ Ensure that security measures are undertaken to prohibit access to the licensed storage premises by untrained personnel. ■ Provide adequate fire-fighting material and other emergency response equipment e.g. spill kits at the storage site.

Legislation/ Standard/ Guideline	Relevance to Soil and Groundwater Quality for this EIA
	■ Ensure that chemical handlers are trained to handle available equipment and are aware of the actions to be taken in the event of any fire, explosion, leakage or other similar emergencies. ■ Provide and keep updated an Emergency Response Plan to deal with any spillage, leakage, accidental discharge or emergency which may result from the storage of petroleum or flammable material stored at the premises. ■ Ensure that appropriate emergency information panels or warning labels as prescribed in the code of labelling (SS 286) are installed at the approved storage area. ■ In the event of any loss, theft, fire, explosion, leakage, accident or accidental discharge of any petroleum and flammable material at the worksite, take immediate action to control and contain the leakage or discharge, and inform the Commissioner of the SCDF.
Sewerage and Drainage Act (Surface Water Drainage) Regulations, 2007	■ Prohibit the discharge of silt or debris directly or indirectly into stormwater drainage systems. ■ Must not cause any obstruction to the flow of any stormwater drainage system. ■ Prohibit works that will affect any storm water drainage system, drain or drainage reserve, directly or indirectly, without obtaining in respect of those works, a clearance certificate or approval of the PUB.
Singapore Standard SS593: 2013 Code of practice for pollution control (COPPC)	■ Ensure that only containers constructed and inspected in accordance with internationally acceptable standards are used for the storage of hazardous substances and affixed with approved labels. ■ Ensure that storage areas are equipped with containment as well as disposal facilities to deal with any accidental release of hazardous substances. ■ Immediate mitigation measures shall be taken to control and contain the release, leakage or spillage of any hazardous substance and to clean up any lands affected by the release, leakage or spillage. All wastes generated shall be treated and disposed of safely. ■ A full containment facility shall be provided for above ground bulk storage tanks (including skid tanks). The capacity of the containment facility shall not be less than the capacity of the largest tank. ■ For a secondary containment facility that is fully enclosed, a leak detection system with an alarm device shall be provided within the secondary containment facility. A leak test shall be conducted before the tank is put into use. The leak test shall conform to the following guidelines: - The leak test method shall be able to measure a leak rate of at least 0.19 litre per hour, and be capable of testing the entire tank system, including piping; - If the tank has a loss rate in excess of 0.19 litre per hour, the tank shall be considered to be leaking; and - The leak tests shall be carried out in accordance with an established leak test method and certified by professional engineers. The test results shall be submitted to the NEA's Pollution Control Department (PCD). ■ A contingency plan shall be developed and put in place to deal with leaks. The contingency plan shall meet the following requirements: - To appoint a competent party or person to deal with leaks from above ground tanks; - To set up guidelines to activate the contingency plan (i.e. who, when and how to contact, emergency coordinator, confirmation of leak, etc); - To inform PCD as soon as leak is detected. Singapore Civil Defence Force (SCDF) shall also be informed if the chemical/ product is flammable or combustible; - To remove chemical/ product from the tank to a temporary storage by the competent party or person; - To remove the tank for inspection; - To remove the contaminated soil for proper disposal; - To carry out soil testing to ensure that all the pollutants have been removed; and

Legislation/ Standard/ Guideline	Relevance to Soil and Groundwater Quality for this EIA
	- To repair or replace the tank and re-construct the secondary containment chamber if necessary. ■ The connection point for a filling pipe of a bulk storage tank shall be provided with measures to contain spillage.

With the passing of the *EPMA* (formerly the *Environmental Pollution Control Act* in 1999), foundations were laid for the issuance of regulations relating to the prevention and clean-up of land contamination in Singapore. General guidance on site assessments, assessment of soil and groundwater quality and remediation works is provided in the *SS593:2013 COPPC,* which specifies the recommended pollution control requirements and good practices.

The abovementioned guidance documents refer to the Dutch Standards to assess land contamination and remediation in Singapore, using target values and intervention values from the *Soil Remediation Circular (2013)*. The Dutch guidelines are internationally recognised and accepted and have been widely used both locally in Singapore and internationally for the assessment of soil and groundwater contamination.

10.3 Assessment Criteria

The magnitude of potential impacts to soil and groundwater have been assessed in accordance with the agreed criteria in *Table 10-2.*

Table 10-2: Magnitude Criteria for Assessment of Soil and Groundwater Quality

Impact Magnitude	Definition
Negligible	■ No discharges to soil and groundwater; and ■ Abstractions from or discharge to aquifer(s) are unlikely to cause groundwater quality issues.
Small	■ Localised small-scale contamination to soil; and ■ Abstraction or discharge to aquifer(s) may cause small but local changes in groundwater quality in the aquifer system. These can be considered potential short-term localised effects on groundwater quality which is likely to return to equilibrium conditions within a short timeframe i.e. months.
Medium	■ Contaminant levels pose a significant risk to public health/ the environment; and ■ Abstraction or discharge to aquifer(s) are expected to cause potential localised effects on groundwater quality which are likely to be fairly long lasting and/ or give rise to indirect ecological and/ or socio-economic impacts.
Large	■ Abstraction or discharge to aquifer(s) are expected to cause potentially severe effects on groundwater quality which are likely to be long-lasting (e.g., years or permanent) and/ or give rise to indirect ecological and/ or socio-economic impacts.

The sensitivity of the soil and groundwater resources, and the existing usage of these soil and groundwater resources are considered. The agreed sensitivity criteria adopted are presented in *Table 10-3.*

Table 10-3: Sensitivity Criteria for Soil and Groundwater Receptors

Sensitivity	Definitions
Low	■ The soil and groundwater resources are not protected; ■ The groundwater resource supports aquatic habitat or population, but the habitat/ population is common/ non-diverse/ insignificant; and/ or ■ The groundwater resource is unimportant in terms of resource use potential (e.g. there are no reasonably foreseeable users and the quality/ yield of the groundwater resource may preclude its use).

Sensitivity	Definitions
Medium	■ Protected sensitive soil and groundwater receptors within study boundary, including construction areas; ■ The groundwater resource supports diverse or susceptible populations of flora and/ or fauna; and/ or ■ The groundwater resource is an important water supply, and is currently used, but there is capacity and/ or adequate opportunity for alternative sources of comparable quality.
High	■ Protected sensitive soil & groundwater receptors within study boundary, including construction areas; ■ The groundwater resource supports economically important or biologically unique species or provides essential habitat/ nutrients to sustain such species; and/ or ■ The groundwater resource is wholly relied upon locally, with no suitable technically or economically feasible alternatives, or is important at a regional or transboundary level for water supply or contribution to groundwater dependent ecosystems (e.g. transboundary rivers).
Note: Protected soil and groundwater receptors are defined as any land or groundwater resource located within a 'Catchment Area' under the Public Utilities (Reservoirs, Catchment Areas and Waterway) Regulations 2006.	

10.4 Baseline Conditions

10.4.1 Methodology

A phased approach to soil and groundwater quality has been applied for the land-based sampling efforts at the proposed temporary Staging/ Launching Area and integrated Project Substation worksite. Due to accessibility constraints during this EIA phase, a limited Phase I Environmental Site Assessment (ESA) was conducted at the proposed temporary Staging/ Launching Area and integrated Project Substation location. The limited Phase I ESA was conducted in general accordance with the American Society for Testing and Materials (ASTM) Standard *E1527-13: Standard Practice for Environmental Facility Assessments: Phase I Environmental Facility Assessment Process* to the extent applicable in Singapore. The objective of the limited Phase I ESA was to identify any Recognised Environmental Conditions (RECs) and potential liabilities. According to the ASTM definition, a REC is defined as "the presence or likely presence of any hazardous substances or petroleum products in, on, or at a property: (1) due to release to the environment; (2) under conditions indicative of a release to the environment; or (3) under conditions that pose a material threat of a future release to the environment".

The limited Phase I ESA comprised of desktop research and a site visit to identify potential contamination hotspots related to the site. This limited Phase I ESA, as part of the EIA, provide recommendations for further sampling and analysis (so called "Phase II" ESA) to be carried out during the later stages of the proposed development to inform the detailed design and construction on potential soil and groundwater contamination and recommend remedial measures, where appropriate (see *Section 10.4.3*).

It is noted this limited Phase I ESA was conducted whilst the land-based proposed temporary Staging/ Launching Area and integrated Project Substation worksite was occupied by temporary industrial uses; subsequently the land has been reinstated to vacant (grass) land, thus this is considered a conservative assessment.

10.4.2 Phase I ESA Findings

The proposed temporary Staging/ Launching Area and integrated Project Substation worksite is located at 12 Sungei Kadut Drive, within the Sungei Kadut Industrial Estate, adjacent to the shoreline of the eastern Kranji Reservoir. In 2022, the northern half of the area (12A Sungei Kadut Drive) was occupied by Team Build – Wyn Construction for machinery storage, while the southern half of the area (12B Sungei Kadut Drive) was occupied by Team Alliance for the storage of boring tools and welding works. According to the Urban Redevelopment Authority (URA) 1980 Master Plan, since 1980 the area has been zoned for industrial use.

Elevation data from Google Earth Pro (2022) shows that the worksite lies on generally flat and low-lying ground, approximately 5 – 6 m above mean sea level (msl). Based on the Geology of Singapore (DSTA, 2009), the area comprises of the Kallang Formation (Transitional Member).

A photolog of the area surrounding the proposed temporary Staging/ Launching Area and integrated Project Substation worksite, historical maps and aerial images from publicly available sources are presented in *Appendix 10.1*. A summary of historical land use changes that have occurred at the worksite are presented in *Table 10-4.*

Table 10-4: Summary of Historical Land Uses at the Proposed Temporary Staging/ Launching Area and Integrated Project Substation Worksite

Year	Historical Land Use	Source
1942	■ The worksite is in the vicinity of the Battle of Kranji war site, suggesting possible use by military activities at or in the surrounding area.	■ National Heritage Board (n.d.)
1943	■ Predominantly mangrove swamp at the worksite and its surrounding area.	■ 1943 Topographical Map, NUS Department of Geography (1:63,360) (NUS Libraries, n.d.)
1969	■ Mangrove swamp at the worksite and its surrounding area was cleared.	■ 1969 Topographical Map, NUS Department of Geography (1:63,360) (NUS Libraries, n.d.)
1974	■ Development of the present Sungei Kadut Industrial Estate was first observed. Construction of a main road (presently Sungei Kadut Drive) at the eastern border of the worksite.	■ 1974 Topographical Map, NUS Department of Geography (1:50,000) (NUS Libraries, n.d.)
1975	■ Construction of a cluster of buildings (factory complex) noted on the northern half of the worksite.	■ 1975 Topographical Map, NUS Department of Geography (1:25,000) (NUS Libraries, n.d.)
1983	■ Extension of industrial park land area towards the south of the worksite via land reclamation. ■ Southward extension of main road (presently Sungei Kadut Drive) along the eastern border of the worksite. ■ Sundry tree cultivation noted at the northern portion of the worksite.	■ 1983 Topographical Map, NUS Department of Geography (1:50,000) (NUS Libraries, n.d.)
1987	■ Southward extension of sundry tree cultivation towards the remaining area of the worksite.	■ 1987 Topographical Map, NUS Department of Geography (1:50,000) (NUS Libraries, n.d.)
1993	■ Construction of a minor road towards the north of the worksite. ■ Construction of a water channel (per map legend) at the southern corner of the worksite running towards the south along Sungei Kadut Drive. ■ Expansion of the cluster of buildings towards the east of the worksite.	■ 1993 Topographical Map, NUS Department of Geography (1:50,000) (NUS Libraries, n.d.)
1994	■ Worksite was occupied by a woodwork factory.	■ URA Planning Decision No. P210794-19J1-Z000 (URA Master Plan, 2022)
1998	■ Removal of water channel (per map legend) at the southern corner of the worksite (as observed in 1993). ■ Demolition of a minor road towards the northwest of the worksite (as observed in 1987).	■ 1998 Topographical Map, NUS Department of Geography (1:50,000) (NUS Libraries, n.d.)
2002	■ Construction of buildings at the northeast corner and southern corner of the worksite.	■ 2002 Topographical Map, NUS Department of Geography (1:50,000) (NUS Libraries, n.d.)
2005	■ Demolition of buildings and construction of new Kranji Link at the northeast of the worksite	■ 2005 Topographical Map, NUS Department of Geography (1:25,000) (NUS Libraries, n.d.)

Year	Historical Land Use	Source
2008	■ Construction of a single building at the northern border of the worksite, and a cluster of buildings adjacent to the north of the worksite. The remaining area of the proposed temporary Staging/ Launching Area appears to be utilised for material laydown and storage.	■ 2008 Satellite Image, Google Earth Pro (Google Earth, 2022)
2010	■ Area adjacent to the northwest of the worksite appears to be utilised for container and material storage. ■ Remaining undeveloped land area to the northwest of the worksite was revegetated with grass.	■ 2010 Topographical Map, NUS Department of Geography (1:50,000) (NUS Libraries, n.d.)
2012	■ Expansion of storage area to the northwest of the worksite. Ground surface appears largely paved.	■ 2012 Satellite Image, Google Earth Pro (Google Earth, 2022)
2013	■ All infrastructures and materials at the worksite location were removed. Ground surface was unpaved.	■ 2013 Satellite Image, Google Earth Pro (Google Earth, 2022)
2014	■ Signs of construction activities at the northern portion of the worksite. Ground surface appears paved. ■ Construction of a two-storey production block and four-storey workers dormitory block to the northeast of worksite.	■ 2014 Satellite Image, Google Earth Pro (Google Earth, 2022) ■ URA Planning Decision No. P161110-17F5-E011 (URA Master Plan, 2022)
2015	■ Worksite location appears to be utilised for material laydown and storage. ■ In the December 2015 satellite image, land at the worksite location was cleared and revegetated with grass.	■ 2015 Satellite Image, Google Earth Pro (Google Earth, 2022)
2016	■ Land at worksite location paved and utilised for storage of materials.	■ 2016 Satellite Image, Google Earth Pro (Google Earth, 2022)
2022	■ Northern half of the worksite (12A Sungei Kadut Drive) is occupied by Team Build – Wyn Construction for machinery storage. ■ Southern half of the worksite (12B Sungei Kadut Drive) is occupied by Team Alliance for the storage of boring tools and welding works.	■ 14 April 2022 site visit
2022	■ Temporary uses removed from 12A and 12B Sungei Kadut Drive and site reinstated to vacant (grass) land.	■ 13 September 2022 site visit

Based on the limited Phase I ESA conducted at the proposed temporary Staging/ Launching Area and integrated Project Substation worksite, which included a site visit on 14 April 2022 (prior to the site's reinstated to vacant land in September 2022), the following observations and RECs from the site visit are noted in *Table 10-5*. A figure with locations of the following RECs is presented in *Appendix 10.1*.

Table 10-5: Summary of RECs at the Proposed Temporary Staging/ Launching Area and Integrated Project Substation Worksite (as at April 2022)

Area	Recognised Environmental Concerns (RECs)
12A Sungei Kadut Drive (northern portion)	■ Diesel oil stains around diesel drums storage and generator on ground and bottom of boundary slope (along eastern border). ■ Diesel stain on ground on the eastern portion.
12B Sungei Kadut Drive (southern portion)	■ Unknown staining around engine oil/lubricant drums storage area. ■ Unknown staining around hydraulic hoses laydown area. ■ Diesel staining around the aboveground diesel storage tank.
Note: As of September 2022, the site had been vacated and site reinstated to vacant (grass) land (see Appendix 10.1)	

No previously known site-specific soil and groundwater investigations have been conducted at the proposed temporary Staging/ Launching Area and integrated Project Substation worksite, and no further information on soil and groundwater quality were publicly available for inclusion at the time of writing.

10.4.3 Phase I ESA Recommendations

Based on the Phase I ESA findings, it is recommended for a targeted soil and groundwater Phase II ESA (also known as an Environmental Baseline Study (EBS)) be carried out at the proposed temporary Staging/ Launching Area and integrated Project Substation worksite, (i) to determine if the identified hotspots have impacted the underlying soil, (ii) to establish the baseline soil and groundwater conditions, (iii) to recommend any remedial measures required (e.g. removal or treatment of potential contamination sources), and (iv) to inform the detailed design and construction approaches.

10.5 Sensitive Receptors

Regarding soil receptors, the proposed temporary Staging/ Launching Area and integrated Project Substation worksite and surroundings is located within a predominantly urbanised and industrial area where the soil is generally not sensitive as there is no protected soil resources or agricultural land use in the vicinity. According to *Table 10-3*, soil resource receptors are considered Low where "the soil resources are not protected".

Regarding groundwater resource receptors, for the proposed temporary Staging/ Launching Area and integrated Project Substation worksite, no protected groundwater resources were identified. Given typical groundwater velocity in Singapore, it would generally require an unintended release of hazardous substances at significant volumes for groundwater quality impacts to reach the reservoir. It should also be noted that groundwater is typically not extracted for use in Singapore. With reference to the Surface Water Quality *Section 6*, the sensitivity of surface water in Kranji Reservoir is considered to be High (see *Table 6-8 (Surface Water Sensitive Receptors and Level of Sensitivity*); conservatively (assuming the groundwater is a main water source for Kranji Reservoir[1] and high groundwater velocity) the groundwater resource in the vicinity of Kranji Reservoir is also considered up to a High sensitivity.

10.6 Impact Assessment – Construction Unplanned Events

10.6.1 Construction Phase Unplanned Events

10.6.1.1 Potential Sources of Impact

Soil and groundwater impacts are anticipated to arise from land-based construction activities undertaken at the proposed temporary Staging/ Launching Area and integrated Project Substation worksite. Depending on the nature of the activities, soil and groundwater impacts may arise from:

- Equipment maintenance and storage and handling of fuel, oil and lubricants;
- Refuelling of diesel-powered land-based equipment.

Note that impacts from refuelling of work boats and in-reservoir construction equipment is considered in *Section 6* (Surface Water Quality).

The scale of impact to soil and groundwater will depend on the nature of the hazardous material and quantity discharged. The quality of the soil and/ or groundwater could be adversely impacted if the hazardous materials migrate through the soil into the groundwater. The volume of hazardous materials or chemicals (e.g. diesel, paint, thinner, lubricants and hydraulic oil etc.) which will be stored within the proposed temporary Staging/ Launching Area and integrated Project Substation worksite at any one

[1] Where, *Appendix 6.1 (Water Quality Model Technical Appendix)* indicates that water in Kranji Reservoir originates from broadly three categories of sources: (i) Rainfall-runoff from the catchment area of Kranji Reservoir, (ii) Transfers from other sources, including reservoirs, and (iii) Rainfall directly on the surface of the Kranji Reservoir. The dominant source of water is identified as rainfall-runoff from the catchment area. Therefore, assuming groundwater as a main water source for Kranji Reservoir is conservative.

point of time is not known at the time of writing this report, however, given the scale and nature of construction work it is anticipated to be limited.

Specific activities during construction phases which may result in impacts to soil and groundwater include the following:

Proposed Temporary Staging/ Launching Area & Integrated Project Substation – Construction Works on Land

- Geotechnical/site investigation at the proposed temporary Staging/ Launching Area and integrated Project Substation site;
- Preparation of the proposed temporary Staging/Launching Area;
- Assembly of the FPV system; and
- Construction of the integrated Project Substation and land-based connector cable.

Unplanned Events (on land)

It is considered that the source of impacts during the above activities will only occur from unplanned, accidental spills or leaks (particularly considering the embedded controls to be established, see below). Additionally, given the Kranji Reservoir is immediately adjacent to the worksite, impacts from unplanned events from environmental spills to Surface Water Quality are considered to be assessed under *Section 6, Table 6-8, Item U2*).

- Environmental Spill (including related to spills from responses to explosions and fire, and failure of ECM).

The impacts that may arise due to the above land-based construction unplanned events that are considered in *Section 10.6.1.3* include:

- Degradation/ change of soil and groundwater from unplanned event of environmental spill.

10.6.1.2 Embedded Controls

Embedded controls are measures (physical or procedural) that are planned to be put in place as part of the Project design, construction and operation from the outset. These actions are to manage the Project's compliance with relevant legislation, regulations and guidelines in relation to development and soil and groundwater. The below are further to the construction embedded controls outlined for Surface Water Quality (*Section 6*), Biodiversity (*Section 7*), Air Quality (*Section 8*), Airborne Noise and Vibration (*Section 9*) and Vectors (*Section 11*).

Any outcomes of the Phase II ESA/ EBS and related recommended remedial measures (e.g. removal or treatment of potential contamination sources), are considered to be embedded controls, as they will be Project commitments. In addition, both industry standard waste management practices are to be embedded within the Project, alongside the embedded controls for Surface Water Quality, see *Section 6*.

All hazardous materials will be stored and handled following relevant regulatory requirements outlined in *Section 10.2*. The storage methods for all hazardous materials, containment facilities and contingency plans (herein called "Spill Prevention and Emergency Response Plan") to manage leaks will be in compliance with the *Environmental Protection and Management (Hazardous Substances) Regulations, 2008* for the storage of any hazardous chemicals listed within the Schedule; and the *Fire Safety (Petroleum & Flammable Materials) Regulations, 2019*, for the storage of any petroleum or flammable materials in quantities exceeding that listed in the First Schedule of the *Fire Safety (Petroleum & Flammable Materials – Exemption) Order, 2018* and *Singapore Standard SS593: 2013 COPPC*.

There are no additional design-related embedded controls to be considered for soil and groundwater for the construction phase beyond those identified in *Section 10.2*.

10.6.1.3 Impact Assessment and Mitigation Measures

A summary of the assessment of impacts to soil and groundwater and proposed mitigation measures during Project land-based construction unplanned events of environmental spills is provided in *Table 10-6.*

It is noted that potential construction unplanned event impacts from environmental spills to Kranji Reservoir from the Project is discussed in *Section 6* (Surface Water Quality).

Table 10-6: Impact Assessment for Soil and Groundwater of (Land-based Construction Unplanned Event)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
U1	**Degradation/ change of soil and groundwater from unplanned event of environmental spill (including related to spills from responses to explosions and fire, and failure of ECM)** (see also *Section 6* for assessment related to Kranji Reservoir's Surface Water Quality)	■ **Nature**: Degradation of soil and groundwater quality is considered **negative**. ■ **Type**: **Direct** impacts to soil and groundwater receptors from leaks and spills. ■ **Duration**: These impacts will be present **temporarily** for a short period of time after the unplanned event. ■ **Extent**: Impacts are **localised** within the land-based worksite and the immediate surroundings. ■ **Scale**: Scale of impact depends on location and nature of spill/ leak. Effect of land-based spill/ leak would likely be limited to the immediate surroundings with embedded controls. ■ **Frequency**: **Infrequent**, due to the unlikely event of environmental spillage (and fire and explosion and ECM failure) with embedded controls. Any outcomes of the Phase II ESA and related recommended remedial measures (e.g. removal or treatment of potential contamination sources), are considered to be embedded controls. Accidental spills or leakages of fuel, oil and lubricants may occur from the use of construction vehicles and equipment, fuel and chemical storage areas, improper management of construction waste, or other unplanned environmental spills (including related to spills from responses to explosions and fire, and failure of ECM). This will impact soil and groundwater quality if it enters the ground. Storage and use of chemicals and fuels during construction are subjected to stringent control as stated under *Section 10.2* therefore the risk for spillage on land is low and is likely to be highly localised after taking into account the embedded control measures, including those described in Surface Water Quality *Section 6.6.1.2.* A Spill Prevention and Emergency Response Plan detailing how spillage, leakage or accidents involving hazardous materials will be dealt with will be prepared. The implementation of Spill Prevention and Emergency Response Plan would minimise the soil and groundwater quality impact from any accidental spillage or release. Impact magnitude is expected to be ***Small*** at the proposed temporary Staging/ Launching Area and integrated Project Substation worksite, where impacts are expected to be (i) localised small-scale contamination to soil, and (ii) discharge to groundwater aquifer(s) may cause small but local changes in groundwater quality in the aquifer system, where these can be considered potential short-term localised effects on groundwater quality which is likely to return to equilibrium conditions within a short timeframe.	Impact Magnitude: **Small** Receptor Sensitivity: **Low** (soil) **to High** (groundwater) Pre-Likelihood Significance: **Negligible** (soil) **to Moderate** (groundwater)	Likelihood Evaluation With the implementation of embedded controls, notable change in soil and groundwater quality as a result of land-based spillage is unlikely. Mitigation The following measures will also be implemented to further mitigate the consequence of the unplanned event of environmental spill: ■ Chemicals and/ or hydrocarbons will be handled and stored in compliance with the Material Safety Data Sheet (MSDS). ■ All chemical and/ or hydrocarbon wastes will be segregated into clearly marked containers prior to onshore disposal by a licensed waste management contractor, as per the relevant MSDSs. Secondary containment should also be provided for these chemicals. ■ Daily inspection of machinery to avoid fuel leakage. ■ Practise due diligence in proper storage and handling of machinery to prevent leaching of oil or harmful materials. ■ Regular maintenance of vehicles and equipment, proper training to operators to avoid fuel leakage or spillage into reservoir. ■ Train workers in implementation of the Spill Prevention and Emergency Response Plan. ■ Joint exercises/ drills for spillage and fire will be conducted by the Developer/ Owner with SCDF each year to ensure preparedness on spillage containment and clean up, as well as fire preventing and fighting among site staff. No significant (above minor) residual impacts are anticipated related to soil and groundwater quality, as such specific soil and groundwater quality monitoring is not considered necessary. However, it is recommended to conduct regular environmental site inspections, i.e. on a weekly basis, see the *Section 12* (EMMP).	Pre-Likelihood Significance: **Negligible** (soil) **to Moderate** (groundwater) Likelihood of Occurrence: **Unlikely** Post-Likelihood Impact Significance: **Negligible** (soil) **to Minor** (groundwater)

10.6.1.4 Summary of Construction and Unplanned Event Impacts

Adoption of the abovementioned mitigation measures are expected to reduce the construction unplanned event residual impact magnitudes of the described impacts on soil and groundwater quality.

Unplanned events for environmental spills during construction on soil and groundwater quality are considered unlikely to occur with embedded controls. The residual impact significance (considering their likelihood and mitigation measures) are anticipated to be ***Negligible*** (for soil) and ***Minor*** (for groundwater) for land-based construction unplanned events.

No significant (above minor) residual construction unplanned event impacts on soil and groundwater quality are anticipated.

Should any of the design, construction and/or unplanned event assumptions assessed in this Section change (i.e. be considered to be greater, or more impactful, than those assumed in this assessment) as a result of the Developer/ Owner’s detailed design and construction methodology, the above impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein.

A summary of the impact assessment for the construction phase unplanned events is presented in *Table 10-7.*

Table 10-7: Impact Summary of Soil and Groundwater during Land-based Construction Unplanned Event

<table>
<tr><td>Impact</td><td colspan="5">■ Degradation/ change of soil and groundwater from unplanned event of environmental spill (including related to spills from responses to explosions and fire, and failure of ECM) (U1)</td></tr>
<tr><td rowspan="2">Impact Nature</td><td colspan="2">Negative</td><td colspan="2">Positive</td><td>Neutral</td></tr>
<tr><td colspan="5">Degradation of soil and groundwater quality is considered negative.</td></tr>
<tr><td rowspan="2">Impact Type</td><td colspan="2">Direct</td><td colspan="2">Indirect</td><td>Induced</td></tr>
<tr><td colspan="5">Direct impacts to soil and groundwater receptors from leaks and spills.</td></tr>
<tr><td rowspan="2">Impact Duration</td><td>Temporary</td><td colspan="2">Short-term</td><td colspan="2">Long-term</td><td>Permanent</td></tr>
<tr><td colspan="5">These impacts will be present temporarily for a short period of time after the unplanned event.</td></tr>
<tr><td rowspan="2">Impact Extent</td><td colspan="2">Local</td><td colspan="2">Regional</td><td>Global</td></tr>
<tr><td colspan="5">Impacts are localised within the land-based worksite and the immediate surroundings.</td></tr>
<tr><td>Impact Scale</td><td colspan="5">Scale of impact depends on location and nature of spill/ leak. Effect of land-based spill/ leak would likely be limited to the immediate surroundings with embedded controls.</td></tr>
<tr><td>Impact Frequency</td><td colspan="5">Infrequent, with embedded controls.</td></tr>
<tr><td rowspan="2">Impact Magnitude</td><td>Positive</td><td>Negligible</td><td>Small</td><td>Medium</td><td>Large</td></tr>
<tr><td colspan="5">With embedded controls impact magnitude for impacts during construction phase unplanned events is Small considering anticipated short-term localised small-scale effects to soil and groundwater.</td></tr>
<tr><td rowspan="2">Receptor Sensitivity</td><td colspan="2">Low</td><td colspan="2">Medium</td><td>High</td></tr>
<tr><td colspan="5">■ Soil within the proposed temporary Staging/ Launching Area and integrated Project Substation worksite (Low)
■ Groundwater under the proposed temporary Staging/ Launching Area and integrated Project Substation worksite (conservatively assuming the groundwater is a main water source for Kranji Reservoir and high groundwater velocity) (High)</td></tr>
<tr><td>Key Embedded Controls (beyond legislation, regulations, standards and guidelines)</td><td colspan="5">In addition to key embedded controls identified in Section 6 (Surface Water Quality):
■ Implementation of remedial measures (if any) from the Phase II ESA/ EBS and related recommended remedial measures (e.g. removal or treatment of potential contamination sources)
■ All hazardous materials will be stored and handled in compliance with relevant regulations
■ Spill Prevention and Emergency Response Plan detailing how spillage, leakage or accidents involving hazardous materials will be dealt with will be prepared.
■ Train workers in use of equipment and machinery</td></tr>
</table>

<table>
<tr><td rowspan="2">Pre-likelihood Significance (without mitigation)</td><td>Negligible</td><td>Minor</td><td>Moderate</td><td>Major</td></tr>
<tr><td colspan="4">The pre-likelihood significance ranges from Negligible (soil) to Moderate (groundwater). Significant (above minor) impacts are:
Moderate (without mitigation):
Degradation/change of groundwater from unplanned event of environmental spill (including related to spills from responses to explosions and fire, and failure of ECM) (U1)</td></tr>
<tr><td>Key Mitigation and Monitoring Measures</td><td colspan="4">In addition to key mitigation and monitoring identified in Section 6 (Surface Water Quality):
Chemicals and/ or hydrocarbons will be handled and stored in compliance with the Material Safety Data Sheet (MSDS)
All chemical and/ or hydrocarbon wastes will be segregated into clearly marked containers prior to onshore disposal by a licensed waste management contractor, as per the relevant MSDSs
Regular maintenance and daily inspection of vehicles and equipment
Train workers in implementation of Spill Prevention and Emergency Response Plan
Joint exercises/ drills for spillage and fire will be conducted by the Developer/ Owner with SCDF each year</td></tr>
<tr><td rowspan="2">Likelihood of Occurrence</td><td colspan="2">Unlikely</td><td>Possible</td><td>Likely</td></tr>
<tr><td colspan="4">Environmental spills (including related to spills from responses to explosions and fire, and failure of ECM) are considered unlikely to happen during construction phase with embedded controls.</td></tr>
<tr><td rowspan="2">Post-likelihood Residual Significance (with mitigation)</td><td>Negligible</td><td>Minor</td><td>Moderate</td><td>Major</td></tr>
<tr><td colspan="4">The post-likelihood residual significance with mitigation ranges from Negligible (soil) to Minor (groundwater). No significant (above minor) residual impacts are anticipated. Regular environmental site inspections, i.e. on a weekly basis, at the land-based worksite during construction are recommended, see Section 10.6.3 and Section 12 (EMMP) for further details.</td></tr>
</table>

10.6.2 Soil and Groundwater Quality Monitoring

As outlined in *Section 10.6.1.3* above, no significant (above minor) residual impacts are anticipated related to soil and groundwater quality, as such specific soil and groundwater quality monitoring is not considered necessary.

However, it is recommended to conduct regular environmental site inspections, i.e. on a weekly basis, at the proposed temporary Staging/ Launching Area and integrated Project Substation worksite during construction to check the implementation of the embedded controls and mitigation measures, see the Environmental Management and Monitoring Plan (EMMP), *Section 12*.

10.6.3 Potential Cumulative Impacts from Other Major Concurrent Developments

Consultation between URA and MND has been undertaken during the course of this study to identify other known concurrent projects in the immediate vicinity of the Project Sites for which works will occur at the same time as this Project, see *Section 4.3.1, Table 4-2*. The detailed schedules for such developments are not available at the time of writing. Cumulative impacts have therefore not been undertaken in this EIA due to the lack of available information. In the event that information on surrounding committed developments does become available, the Kranji FPV Project should be assessed under the cumulative impact assessments within the EIAs of these surrounding committed developments. Details of this Project, where appropriate, will be coordinated and provided to the EIA owners of surrounding developments to support their cumulative impact assessment.

11. VECTORS

11.1 Overview

Vectors are organisms that transmit diseases from one host to another; these vector-borne diseases can be fatal to humans. Construction activities of the Project may have the potential to promote breeding of vectors and the transmission of vector-borne diseases.

This Section of the EIA reviews the potential vectors associated with the land-based construction phase of the Project, i.e. the proposed temporary Staging/ Launching Area and integrated Project Substation worksite. Where required, the mitigation hierarchy of avoidance, minimisation, reduction or compensation has been applied to potentially significant impacts to reduce impact levels to as low as reasonably practicable.

Vector-related impacts from activities which may be conducive for mosquito and rat/ rodent breeding at the proposed temporary Staging/ Launching Area and integrated Project Substation worksite have been assessed qualitatively.

In-reservoir construction will be phased with work boats/ barges etc being transient (not static for long periods of time), thus the construction work activities in the Reservoir Project Site are not anticipated to be significant with regards to vectors, with the embedded controls applied from land-based construction worksites, and have been scoped out from this assessment.

Operational impacts related to vectors from the in-reservoir FPV system and land-based integrated Project Substation operations are not anticipated to be significant and have been scoped out from this assessment.

11.2 Regulatory Framework

The legislation, standards and/or guidelines applicable to governing vector control at construction sites in Singapore relevant to this Project include those listed in *Table 11-1*.

As the majority of vector-borne diseases in Singapore are transmitted by mosquitoes, vector control in the applicable standards mainly focuses on mosquito control. To prevent and control the breeding of vectors and transmission of vector-borne diseases, Singapore has established the *Control of Vectors and Pesticides Act* (*CVPA, 2016), Environmental Public Health Act, (EPHA, 2019),* and the *Infectious Diseases Act (IDA, 2020).* These laws deal with the destruction and prevention of vectors such as Mosquitoes and Rats, as well as the control of vector-borne diseases in Singapore. The NEA's *Code of Practice for Environmental Control Officers*, is intended to guide Environmental Control Officers (ECOs) and contractors in carrying out works on their construction sites.

Table 11-1: Summary of Legislative Requirements and Guidelines for Vector Control

Legislation/ Standard/ Guideline	Relevance to Vector Control for this EIA
Control of Vectors and Pesticides Act (Chapter 59) (Amendment), 2021	■ Ensure that no conditions favourable to breeding, propagation and harbouring of vectors are created. ■ Prevention of clearing undergrowth or vegetation on any land which may have running or standing water which may be afforded by the development of vegetation. ■ Abide by any order served to carry out vector control work or measures, as may be specified in the order, regarding the treatment, destruction or removal of anything therein as may bring the premises into a condition unfavourable to the propagation of harbouring of vectors. ■ Abide by any notice served to carry out spraying or fogging with pesticides within the specified time frame.
Environmental Public Health Act (Amendment), 2022	■ Deal with areas or conditions that are dangerous to health or may promote the breeding of flies or mosquitoes.
Infectious Diseases Act (Amendment), 2022	■ Prohibit any person from bringing to Singapore any vectors capable of transmitting a disease.

Legislation/ Standard/ Guideline	Relevance to Vector Control for this EIA
	■ Notification of any person who is aware or suspected of being a carrier of an infectious disease. ■ Prohibit any person for any period from carrying on any occupation, trade or business if it is conducted in such manner as is likely to cause the spread of any infectious disease.
NEA's Code of Practice for Environmental Control Officers for Construction Sites, 2021	■ Provides recommended guidelines on practice measures to manage vectors on construction sites. ■ The Environmental Control Officer (ECO) Scheme under the Code of Practice assists contractors and site managers in identifying problems related to vector control at construction sites.

11.3 Assessment Criteria

The assessment criteria for impacts of vectors on human receptors are based on the understanding of vector-borne diseases in Singapore and the susceptibility of the community to these effects.

The magnitude of potential impacts on vectors have been assessed in accordance with the agreed criteria presented in *Table 11-2.*

Table 11-2: Magnitude Criteria for Assessment of Vectors

Magnitude	Definitions
Negligible	■ The Project is likely to result in zero incidences of vector breeding in the construction site at any time.
Small	■ The Project is likely to result in occasional incidences of vector breeding conditions that can be controlled easily before the transmission of vector-borne diseases.
Medium	■ The Project is likely to result in the breeding of vectors and sporadic cases of vector-borne diseases in the area.
Large	■ The Project is likely to result in the breeding of vectors and the proliferation of vector-borne diseases, causing an epidemic.

The agreed sensitivity criteria related to the sensitivity of human receptors adopted for this assessment are presented in *Table 11-3.*

Table 11-3: Sensitivity Criteria for Vector Receptors

Sensitivity	Definitions
Low	■ Only transient spaces intended for human receptors to pass through, e.g. parks are within a 400 m radius [a] of the work area; ■ No known potential hotspots for rats, e.g. food centres, communal food waste collection areas within a 100 m radius of the work area [b]; and/ or ■ No Mosquito-borne disease cases or clusters within the study area, or clusters with green alert level [c], i.e. clusters of Dengue, Chikungunya, Zika etc.
Medium	■ The majority of the spaces within a 400 m radius [a] of the work area consist of transient spaces for human receptors to pass through, e.g. parks; ■ Existing potential hotspots for rats, e.g. food centres, communal food waste collection areas within a 100 m radius of the work area [b]; and/ or ■ Existing Mosquito-borne disease clusters (yellow alert level) [b] within the study area, i.e. clusters of Dengue, Chikungunya, Zika etc.
High	■ The majority of the spaces within a 400 m radius [a] of the work area consist of permanent dwellings or semi-permanent spaces, e.g. residences, hospitals, schools, areas of congregation & food centres; ■ Existing potential hotspots for rats, e.g. food centres, communal food waste collection areas within a 100 m radius of the work area [b]; and/ or ■ Existing Mosquito-borne disease clusters (red alert level) [b] within the study boundary, i.e. clusters of Dengue, Chikungunya, Zika etc.;

Sensitivity	Definitions
Notes: *(a) Aedes mosquitoes usually fly an average of 400 m after they emerge as adults.* *(b) Rats may travel between 50 to 100 m from their nest to forage (University of California, n.d.).* *(c) NEA alert level definitions (NEA[a], n.d.):* *Red alert level: High-risk area with 10 or more cases* *Yellow alert level: High-risk area with less than 10 cases* *Green alert level: No new cases, under surveillance for the next 21 days*	

11.4 Baseline Conditions

In view of Singapore's high population density, vector-borne disease outbreaks can have serious consequences on the local community and may even lead to fatalities. In particular, Singapore experiences its peak dengue season in the warmer months of June to October annually, due to accelerated breeding and maturation cycles for the *Aedes* mosquitoes and shorter incubation periods for the dengue virus.

The five main vectors in Singapore are mosquitoes, fleas, rats/ rodents, cockroaches and flies. The diseases that these vectors are capable of transmitting are detailed in *Table 11-4*. This assessment focuses on mosquitoes and rats.

Table 11-4: Types of Vector-Borne Diseases

Vectors	Diseases
Mosquito	▪ Dengue and Dengue Haemorrhagic Fever ▪ Chikungunya ▪ Zika ▪ Malaria ▪ Japanese Encephalitis ▪ Filariasis
Rat Flea	▪ Murine Typhus ▪ Plague
Rat/ rodent	▪ Rat Bite Fever ▪ Leptospirosis
Cockroach	▪ Cholera ▪ Food-Borne Diseases
Fly	▪ Cholera ▪ Typhoid and Para Typhoid ▪ Salmonellosis ▪ Dysentry

Source: NEA, n.d.

11.4.1 Mosquitoes

The main vector of concern in Singapore is the *Aedes* mosquito as they are carriers of the virus that causes dengue fever and Zika. The *Aedes* mosquito breeds easily under the climatic conditions of warm temperature, abundant rainfall and high humidity, which is prevalent throughout the year in Singapore. Almost 10,000 dengue cases were reported in 2023 (The Star, 2024), which is down from the 32,000 cases in 2022. While this figure is less than the 2020 and 2022 surges, the current rate of infection is still higher than that of previous years. The first half of 2023 saw a serotype, DenV-3 overtaking the other strains (i.e. DenV-1, DenV-2 and DenV-4), while DenV-1 subsequently surpassed the DenV-3 infections as of July 2023 (The Straits Times, 2024).

The NEA maintains an online portal[1] which reports on the status of dengue cases and clusters. Dengue clusters are identified when two or more dengue cases are reported within 14 days where the victims reside within 150 m of each other. The dengue clusters are categorised according to three alert levels as shown in *Table 11-5.*

[1]The online portal can be assessed here: https://www.nea.gov.sg/dengue-zika/dengue/dengue-clusters

Table 11-5: Dengue Cluster Alert Level Definitions

Definition	Alert Level
High-risk area with 10 or more cases	Red
High-risk area with less than 10 cases	Yellow
No new cases, under surveillance for the next 21 days	Green

Source: NEAa, n.d.

As at the time of writing, there are no existing dengue clusters identified by NEA within 400m of the proposed temporary Staging/ Launching Area and integrated Project Substation worksite.

11.4.2 Rats

At the time of writing, there are no potential rodent hotspots within 100m of the proposed temporary Staging/ Launching Area and integrated Project Substation worksite. The worksite is located within an industrial area with no food centres or food waste collection areas in the vicinity.

11.5 Vector Sensitive Receptors

The human receptors susceptible to vector-borne diseases are the general population that work at, or visit facilities, located near the land-based construction worksite. The proposed temporary Staging/ Launching Area and integrated Project Substation worksite is located near industrial developments in Sungei Kadut Industrial Estate. As such, ineffective vector control in the land-based construction worksite will put the health of visitors and workers in the area at risk. The land uses of receptors within 400m of the proposed temporary Staging/ Launching Area and integrated Project Substation worksite are shown in *Figure 11-1*. A list of the identified vector sensitive receptors is detailed in *Appendix 11.1*.

Receptor sensitivity for mosquitoes is considered High, where majority of the spaces within a 400m radius of the worksite consists of permanent dwellings or semi-permanent spaces, e.g. residences, hospitals, schools, areas of congregation & food centres; in this case industrial workplaces are occupied for long hours.

Receptor sensitivity for rats is considered Low, where no known potential hotspots for rats, e.g. food centres, communal food waste collection areas are located within a 100 m radius of the worksite.

Figure 11-1: Vector Sensitive Receptors near the Proposed Temporary Staging/ Launching Area and Integrated Project Substation Worksite

11.6 Impact Assessment – Construction

11.6.1 Construction Phase

11.6.1.1 Potential Sources of Impact

Land-based construction activities for the proposed temporary Staging/ Launching Area and integrated Project Substation may generate vector impacts. Construction activities and equipment within worksites have the potential to serve as breeding grounds for vectors, leading to an increase in vector populations, in particular as a result of the formation of stagnant pools and blocked drains etc. Locations typically conducive for mosquito and rat/ rodent breeding within construction worksites include:

- Improper waste management;
- Discarded receptacles and building wastes;
- Food areas/ domestic waste collection points;
- Building materials, canvas sheets, zinc sheets, plastic sheets, equipment and machinery;
- Water puddles on the ground;
- Ground depressions;
- Water storage drums, tanks and containers;
- Bulk waste containers;
- Trenches;
- Hollow metal rods;
- Safety barriers; and
- Any other water-bearing receptacles.

Specific activities within the construction worksite which may result in impacts to vector populations include the following:

Proposed Temporary Staging/ Launching Area & Integrated Project Substation – Construction Works on Land

- Geotechnical/site investigation at the proposed temporary Staging/Launching Area and integrated Project Substation site;
- Preparation of the proposed temporary Staging/Launching Area, including ramp into reservoir;
- Assembly of the FPV system; and
- Construction of the integrated Project Substation and land-based connector cable.

The impacts that may arise due to the above activities that are considered in *Section 11.6.1.3* include:

- Increase in vector populations (mosquitoes and rats).

11.6.1.2 Embedded Controls

Embedded controls are measures (physical or procedural) that are planned to be put in place as part of the Project design, construction and operation from the outset. These actions are to manage the Project's compliance with relevant legislation, regulations and guidelines in relation to development and vectors. The below are further to the construction embedded controls outlined for Surface Water Quality (*Section 6*), Biodiversity (*Section 7*), Air Quality (*Section 8*), Airborne Noise and Vibration (*Section 9*) and Soil and Groundwater (*Section 10*).

The controls that will be implemented to minimise the breeding of vectors and transmission of vector-borne diseases (at both land-based and in-reservoir construction worksites) are detailed in *Table 11-1*. Best practices to control the increase in rodent populations at construction sites will also be implemented in accordance with guidelines in the NEA's *Code of Practice for Environmental Control Officers* (see *Table 11-1*). Relevant additional embedded controls identified in other Sections include:

- Ensure good housekeeping controls such as food consumption at designated food and rest areas with storage areas and wildlife proof bins, away from natural habitat where possible, to prevent attracting wildlife to the area as a food source.

As indicated in *Section 11.1*, these embedded controls will be applied to in-reservoir worksites as well.

11.6.1.3 Impact Assessment and Mitigation Measures

A summary of the assessment of vector impacts and proposed mitigation measures during the Project's land-based construction is provided in *Table 11-6.*

Table 11-6: Impact Assessment for Vector (Land-based Construction Phase)

S/N	Impact	Impact Magnitude Description	Pre-Mitigation Impact Significance	Mitigation Measures and Monitoring	Residual (with mitigation) Impact Significance
C1	**Increase in Vector Populations (Mosquitoes and Rats) at proposed temporary Staging/ Launching Area and integrated Project Substation**	■ **Nature**: Increased vector populations of mosquitoes/ rats or transmission of diseases is considered **negative**. ■ **Type**: **Direct** impact on human receptors due to the transmission of vector-borne diseases. ■ **Duration**: The worksite will be active throughout construction (3 years) which is considered relatively **long term** for vector impacts, and is reversible upon completion of the construction. ■ **Extent**: Impacts are **localised** within the land-based worksite and the immediate surroundings. ■ **Scale**: For Mosquitoes, 400 m from worksite as per the flying range of an *Aedes* mosquito capable of transmitting diseases; and for Rats, 100 m from worksite as per the foraging distance of rats from their nests. ■ **Frequency**: **Intermittent** over approximately 3 years of construction. Worksite activities could lead to increased formation of stagnant pools following rainfall events. These stagnant pools of water would be breeding grounds for *Aedes* mosquitoes. Receptor sensitivity for mosquitoes is considered High, as majority of the spaces within a 400 m radius of the worksite consist of industrial workplaces occupied for long hours. As there are no known potential hotspots for rats due to no presence of food centres or food consumption areas nearby, receptor sensitivity for rats is considered Low. However, it is notable that the temporary storage or improper disposal of organic wastes such as food from workers within the construction site may result in an increase in the population of vectors such as rats. With embedded controls, the impact magnitude is expected to be ***Small*** for vectors, where there may be occasional incidences of vector breeding conditions that can be controlled easily before the transmission of vector-borne diseases.	Impact Magnitude: **Small** Receptor Sensitivity: **Low** (from rats) to **High** (from mosquitoes) Impact Significance: **Negligible** (rats) **Moderate** (mosquitoes)	■ Detailed design and construction methodology and scheduling to minimise potential for vector proliferation, where feasible. ■ Informing stakeholders (i.e. neighbours) of construction activities, controls in place and schedule prior to the start of the Project construction activities. ■ Setting up a grievance mechanism to ensure that any complaints from stakeholders with regards to vector (mosquito) breeding / pest infestation due to the Project, are identified and promptly addressed. ■ Visual inspection of excavation sites, pits, worksites, internal and perimeter drainages, ECM collection basin(s), waste collection areas etc for still water/ rat population. ■ To implement preventive measures by removing sources of stagnant water. ■ Ensure regular food waste collection by licensed collector. Embedded controls and above mitigation measures should be applied to in-reservoir worksites as well. No significant (above minor) residual impacts are anticipated related to vectors, as such specific vector monitoring is not considered necessary. However, it is recommended to conduct regular environmental site inspections, i.e. on a weekly basis, (for land-based and in-reservoir worksites) see the EMMP *Section 12*.	Impact Magnitude: **Negligible** Impact Significance: **Negligible**

11.6.1.4 Summary of Construction Impacts

Adoption of the abovementioned mitigation measures are expected to reduce the construction residual impact magnitudes of the described impacts on vectors. Potential construction residual impact significance for vectors are anticipated to be reduced to ***Negligible***.

No significant (above minor) residual construction impacts to vectors are anticipated.

Embedded controls and mitigation measures for land-based construction worksites should be applied to in-reservoir worksites as well.

Should any of the design and construction assumptions assessed in this Section change (i.e. be considered to be greater, or more impactful, than those assumed in this assessment) as a result of the Developer/ Owner's detailed design and construction methodology, the above impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein.

A summary of the impact assessment for the construction phase is presented in *Table 11-7.*

Table 11-7: Impact Summary of Vectors during Land Based Construction

Impact	■ Increase in Vector Populations (Mosquitoes and Rats) at proposed temporary Staging/ Launching Area and integrated Project Substation (C1)				
Impact Nature	**Negative**	Positive	Neutral		
	Increased vector populations of mosquitoes/ rats or transmission of diseases is considered negative.				
Impact Type	**Direct**	Indirect	Induced		
	Direct impact on human receptors due to the transmission of vector-borne diseases.				
Impact Duration	Temporary	Short-term	**Long-term**	Permanent	
	The worksite will be active throughout construction (3 years) which is considered relatively long term for vector impacts, and is reversible upon completion of the construction.				
Impact Extent	**Local**	Regional	Global		
	Impacts are localised within the land-based worksite and the immediate surroundings				
Impact Scale	For Mosquitoes, 400m from worksite as per the flying range of an Aedes Mosquito capable of transmitting diseases. For Rats, 100m from worksite as per the foraging distance of rats from their nests.				
Impact Frequency	Intermittent over approximately 3 years of construction.				
Impact Magnitude	Positive	Negligible	**Small**	Medium	Large
	Without mitigation impact magnitude for impacts during construction is **Small**, considering there may be occasional incidences of vector breeding conditions that can be controlled.				
Receptor Sensitivity	**Low**	**Medium**	**High**		
	■ Humans from mosquitoes (**High**) ■ Humans from rats (**Low**)				
Key Embedded Controls (beyond legislation, regulations, standards and guidelines)	■ Ensure that no conditions favourable to breeding, propagation and harbouring of vectors are created ■ Abide by any notice served to carry out spraying or fogging with pesticides within the specified time frame ■ Deal with areas or conditions that are dangerous to health, or may promote the breeding of flies or mosquitoes ■ The Environmental Control Officer (ECO) Scheme under the Code of Practice assists contractors and site managers in identifying problems related to vector control at construction sites ■ Ensure good housekeeping controls such as food consumption at designated food and rest areas with storage areas and wildlife proof bins				
Significance (without mitigation)	**Negligible**	**Minor**	**Moderate**	Major	
	The pre-likelihood significance ranges from **Negligible** (rats) **to Moderate** (mosquitoes). Significant (above minor) impacts are: ■ Moderate (without mitigation) - Increase in Vector Populations (Mosquitoes and Rats) (C1) - mosquitoes				

Key Mitigation and Monitoring Measures	■ Detailed design and construction methodology and scheduling to minimise potential for vector proliferation, where feasible ■ Informing stakeholders (i.e. neighbours) of construction activities, controls in place and schedule prior to the start of the Project construction activities ■ Setting up a grievance mechanism to ensure that any complaints from stakeholders with regards to vector (mosquito) breeding / pest infestation due to the Project, are identified and promptly addressed ■ Visual inspection of excavation sites, pits, worksites, internal and perimeter drainages, ECM collection basin(s), waste collection areas etc for still water/ rat population ■ Ensure regular food waste collection by licensed collector					
Residual Impact Magnitude (with mitigation)	Positive		**Negligible**	Small	Medium	Large
	The residual impact magnitude is expected to be reduced to **Negligible** with mitigation.					
Residual Impact Significance (with mitigation)	**Negligible**		Minor	Moderate	Major	
	The residual impact significance with mitigation is **Negligible**. No significant (above minor) residual impacts are anticipated. Embedded controls and mitigation measures for land-based construction worksites should be applied to in-reservoir worksites as well. Regular environmental site inspections, i.e. on a weekly basis, at the land-based and in-reservoir worksites during construction are recommended, see *Section 11.6.3* and *Section 12* (EMMP) for further details.					

11.6.2 Vector Monitoring

As outlined in *Section 11.6.1.3* above, no significant (above minor) residual impacts are anticipated related to vectors, as such specific vectors monitoring is not considered necessary.

However, it is recommended to conduct regular environmental site inspections, i.e. on a weekly basis, at the proposed temporary Staging/ Launching Area and integrated Project Substation worksites, and in-reservoir worksites, during construction to check the implementation of the embedded controls and mitigation measures, see the Environmental Management and Monitoring Plan (EMMP), *Section 12*.

11.6.3 Potential Cumulative Impacts from Other Major Concurrent Developments

Consultation between URA and MND has been undertaken during the course of this study to identify other known concurrent projects in the immediate vicinity of the Project Sites for which works will occur at the same time as this Project, see *Section 4.3.1, Table 4-2*. The detailed schedules for such developments are not available at the time of writing. Cumulative impacts have therefore not been undertaken in this EIA due to the lack of available information. In the event that information on surrounding committed developments does become available, the Kranji FPV Project should be assessed under the cumulative impact assessments within the EIAs of these surrounding committed developments. Details of this Project, where appropriate, will be coordinated and provided to the EIA owners of surrounding developments to support their cumulative impact assessment.

12. ENVIRONMENTAL MANAGEMENT AND MONITORING PLAN (EMMP)

12.1 Overview

The Environmental Management and Monitoring Plan (EMMP) sets out actions for the pre-construction, construction and operation phases (including decommissioning) of the Project. The EMMP establishes actions that need to be undertaken in order to avoid, alleviate, mitigate and remediate the potential impacts that were systematically identified during the development of the Project's EIA.

The EMMP was developed following the assessment of impacts, which was undertaken in accordance with the approach adopted for the EIA. The Project activities were reviewed to identify potential impacts across a range of environmental aspects e.g. surface water quality, biodiversity, air quality, airborne noise and vibration, soil and groundwater and vectors. Embedded controls[1] were taken into account during the impacts assessment and mitigation measures to reduce potential impacts were identified. These embedded controls are presented in *Appendix 2.2*.

The EMMP also assigns responsibilities for implementing and monitoring the actions required prior to and during the pre-construction, construction and operation work phases.

This EIA was undertaken based on a study of the conceptual design of the Project. As part of the EIA, additional engineering design mitigation considerations have been identified for incorporation into the Final Design by the Developer/ Owner. These design considerations are summarised in *Section 12.8.1* (*Table 12-1*).

12.2 EMMP Objectives

The objectives of the EMMP include:

- Provide a database of environmental parameters against which to determine any short-term or long-term environmental impacts;
- Provide an early indication should any of the environmental control measures or practices fail to achieve the acceptable standards;
- Confirm that the mitigation recommendations of the EIA are included in the design of the Project;
- Clarify and identify potential sources of pollution, impact and nuisance arising from the works for the responsible parties;
- Confirm compliance with regulatory requirements and EIA recommendations, such as mitigation measures and monitoring recommendations;
- Confirm compliance of environmental designs during the design phase of the Project with the specifications stated in the EIA;
- Monitor performance of the mitigation measures and to assess their effectiveness;
- Take remedial action if unexpected issues or unacceptable impacts arise;
- Verify the environmental impacts predicted in the EIA;
- Provide the basis for adaptive management, whenever necessary, identifying any further need for additional or alternative measures, where impacts are determined to be resulting from the Project; and

[1] Embedded controls are defined as measures (physical or procedural) that are planned to be put in place as part of the Project design, construction and operation from the outset. They are predominantly based on the regulatory and industry standard requirements, reservoir operational requirements from PUB, as a result of engagements with relevant Government agencies. For further details refer to *Appendix 2.2*. The mitigation measures presented herein are over and above the Project "embedded controls".

- Audit environmental performance.

12.3 EMMP Structure

12.3.1 Mitigation Implementation

Table 12-1 sets out the following main elements for the mitigation measures/ actions identified and recommended through the EIA process for the construction and operational phases, respectively:

- **Environmental Aspect** affected by the works;
- **EIA Reference** to the relevant Section within the EIA;
- Potential **environmental impact/ issue**;
- **Mitigation measures** that the Project will implement, as identified through the impact assessment process;
- **Location** of mitigation measure application, where identified at this stage of Project;
- **Responsible Person** for ensuring action/ implementation of the defined mitigation measure;
- **Means of Verification** that the commitment has been met; and
- **Related Documents** into which the mitigation measures would need to be incorporated.

12.3.2 Monitoring Programme

Table 12-2 sets out the main components of the monitoring programme identified and recommended through the EIA process. The monitoring programme comprises monitoring to address specific impacts, which also complement and tie into the monitoring of ecosystem level Limits of Acceptable Change (LACs), identified through the Ecological Character Description (ECD) (details in *Appendix 7.3*), which may indicate that the ecological character of Kranji Reservoir could be approaching a tipping point and trigger the need for additional monitoring and investigation in case adaptive management measures are required.

12.4 EMMP Roles and Responsibilities

A number of parties will be involved in the management and mitigation of potential environmental impacts associated with the pre-construction, construction and operation phases of the Project. Details on the roles and responsibilities for implementing the EMMP throughout the Project are described below. The organisation and lines of communication are presented in *Figure 12-1*.

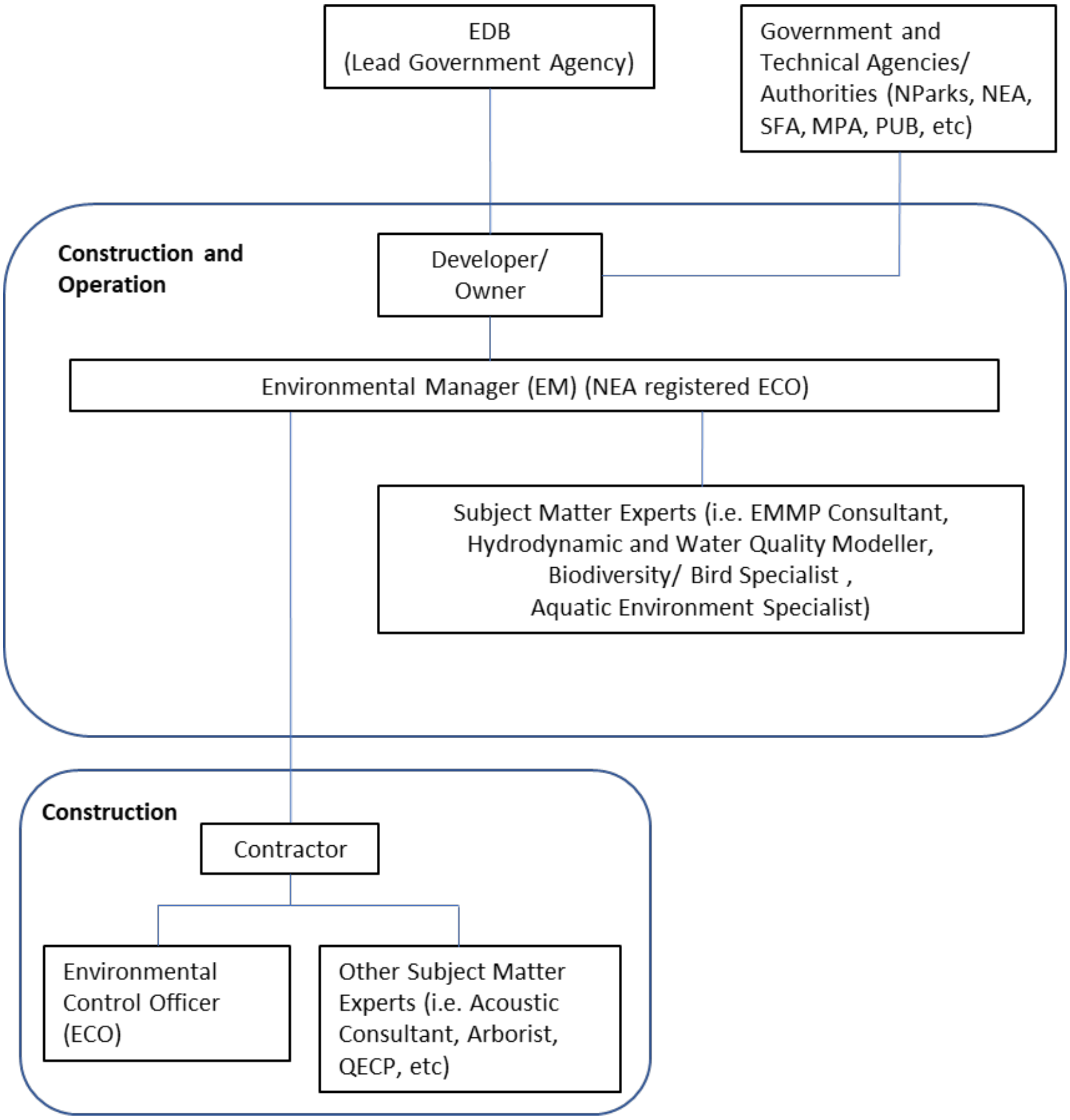


Figure 12-1: Project Organisation for EMMP Implementation during Pre-Construction, Construction and Operation

12.4.1 Economic Development Board (EDB)

The EDB is the lead government agency for the Project.

12.4.2 Government and Technical Agencies/ Authorities

Government and Technical Agencies/ Authorities including (but not limited to) PUB, NParks, and NEA shall review and approve the Construction and Operational EMMPs by the Developer/ Owner prior to commencement of the construction works and operations, respectively; and other relevant submissions throughout the course of the Project.

The relevant Government and Technical Agencies/ Authorities will agree with the Developer/ Owner and/ or their Contractor on the threshold criteria for Action and Limit Levels for inclusion in the Construction and Operational EMMPs.

Consultation and engagement with Government and Technical Agencies/ Authorities, may be required if, for example, environmental degradation associated with the monitoring is investigated and not found to be attributable to the Project.

12.4.3 Developer/ Owner

The Developer/ Owner will own, design, install, operate and maintain the FPV system. The Developer/ Owner will be responsible for the overall development of the Project, including detailed design, pre-construction, construction and operation in accordance with the design and boundary limits established through this EIA. As indicated in *Section 1.2.1* the electricity and its associated environmental attributes generated by the Developer/ Owner's FPV system on Kranji Reservoir will be used by EDB's selected Project Proponent/ Renewable Energy User.

The Developer/ Owner will:

- Have overall accountability for environmental performance during the Project's phases;
- Assumes ultimate ownership over the Project's compliance with relevant legislation, guidelines and best practice;
- Develop a Construction EMMP prior to the construction works commence, to be approved by relevant Government Agencies/ Authorities, based on the detailed design and construction methodology and approach;
- Develop an Operational EMMP prior to the operation commences, to be approved by relevant Government Agencies/ Authorities;
- Ensure the roles identified under *Figure 12-1* are adequately resourced;
- Appoint an Environmental Manager (EM) and necessary subject matter experts to advise on environmental performance improvement and to implement the Construction and Operational EMMP;
- Establish and maintain a corrective action/ grievance mechanism and lines of communication within the Project Organisation to ensure stakeholders' (including the public and other Government agencies) concerns are addressed in a timely manner;
- Develop regular EMMP reporting during construction and operational phases;
- Maintain close liaison with relevant Government Agencies (e.g. PUB, NParks etc) on the monitoring outcomes throughout the Project's phases.
- Collaborate with relevant Government and Technical Agencies/ Authorities to investigate whether or not the monitoring outcomes can be attributed to the Project. If affirmative, the Developer/ Owner will be responsible to review the cause and seek agreement on rectification action(s) to be conducted. Where monitoring outcomes are not attributable to the Project, the Developer/ Owner will liaise with relevant Government Agencies responsible for managing the identified effect for their action.

Given the nature, and duration of main environmental impacts, i.e. those relating to surface water quality and biodiversity, and the potential need for adaptive management, the Developer/ Owner will be responsible for directly appointing the following roles during the design, pre-construction, construction and operational phases of the Project (see further details below):

- EMMP Consultant;
- Hydrodynamic and Water Quality Modeller;
- Biodiversity/ Bird Specialist; and
- Aquatic Environment Specialist.

12.4.3.1 Environmental Manager (EM) (or equivalent)

The Developer/ Owner shall be required to hire an appropriately qualified Environmental Manager (EM) during the construction and operation phase. The EM is to be a NEA-registered Environmental Control Officer (ECO) with extensive experience (e.g. 10 years) and relevant experience in developing and implementing Construction and Operational EMMP for similar or large scale projects. The EM's role will include:

- Coordination of the environmental management aspects of the Project;
- Ensure proper housekeeping;
- Regular inspections of the construction (e.g. worksites and Contractor activities etc) and operational activities to ensure full compliance against legal and EMMP recommendations of the Project;
- Identify, record and report promptly any environmental non-compliance issues, incidents and near misses to the Developer/ Owner; and
- Regularly report the results of the environmental monitoring programme, and any required changes, to the Developer/ Owner.

12.4.3.2 EMMP Consultant(s) (EC)

The Developer/ Owner shall be required to hire an appropriately qualified EMMP Consultant(s) (ECs) during the construction and operation phases to:

- Develop the Construction and Operational EMMP for implementation;
- Carry out monitoring, if necessary, to re-establish the baseline environmental conditions (with specialist inputs, including those identified below);
- Coordinate and/ or perform the environmental monitoring (with specialist inputs, including those identified below) in the EMMP;
- Coordinate the regular inspections of the worksites to ensure full compliance against the legal and EMMP recommendations;
- Carry out various other tasks, such as monitoring trend data analysis, e.g. considering the LACs;
- Provide advice on corrective actions for environmental issues, or adaptive management arising during the works;
- Provide other environmental advisory services to the Developer/ Owner; and
- Liaise with relevant Government Agencies/ Authorities and stakeholders, where required.

The EMMP Consultant should have a degree (or equivalent) in environmental/ EMMP-related fields with extensive experience (e.g. 10 years) in EIAs and EMMPs.

12.4.3.3 Hydrodynamic and Water Quality Modeller

The Developer/ Owner shall be required to hire an appropriately qualified Hydrodynamic and Water Quality Modeller during the detailed design, construction and operation phases to:

- Conduct updated model runs (e.g. hydrodynamic and water quality) and hydraulic studies based on the final FPV layout. Review water quality impact assessment based on the findings of the updated model runs. Should changes (if any) be considered to be greater, or more impactful, than those assumed in this assessment, the impact assessments should be reviewed, and adaptive management measures should be implemented to ensure impacts are smaller than or equal to the impact significances assessed herein;
- Carry out various other tasks, such as monitoring trend data analysis, e.g. for surface water quality;
- Provide advice on corrective actions for surface water quality related environmental issues, or adaptive management arising during the works;

- Provide other surface water quality advisory services to the Developer/ Owner/ EM/ EC; and
- Liaise with relevant Government agencies/ authorities and stakeholders, where required.

The Hydrodynamic and Water Quality Modeller should have a degree (or equivalent) in water quality-related fields with extensive experience (e.g. 10 years) in surface water quality modelling.

12.4.3.4 Biodiversity and Bird Specialists

The Developer/ Owner shall be required to hire an appropriately qualified Biodiversity/ Bird Specialist during the construction and operation phases to:

- Carry out biodiversity-related EMMP implementation, per the agreed Construction and Operational EMMP;
- Carry out fauna monitoring, e.g. Vantage Point Surveys, etc;
- Carry out pre-felling fauna inspections (see example protocol in *Appendix 12.1*);
- Support the Wildlife Incident Response Plan and Reporting (see example protocol in *Appendix 12.1*);
- Carry out various other tasks, such as monitoring trend data analysis, e.g. for biodiversity;
- Provide advice on corrective actions for biodiversity related environmental issues, or adaptive management arising during the works;
- Provide other biodiversity advisory services to the Developer/ Owner/ EM/ EC; and
- Liaise with relevant Government agencies/ authorities and stakeholders, where required.

The Biodiversity/ Bird Specialist should have a degree (or equivalent) in ecology-related fields with extensive experience (e.g. 10 years) in fauna monitoring and management and Vantage Point Surveys for birds.

12.4.3.5 Aquatic Environment Specialist

The Developer/ Owner shall be required to hire an appropriately qualified Aquatic Environmental Specialist during the construction and operation phases to:

- Carry out aquatic environment-related EMMP implementation, per the agreed Construction and Operational EMMP;
- Carry out aquatic environment monitoring, e.g. surface water quality, aquatic vegetation, etc;
- Carry out various other tasks, such as monitoring trend data analysis, e.g. for aquatic environment;
- Provide advice on corrective actions for aquatic environment related environmental issues, or adaptive management arising during the works;
- Provide other aquatic environment advisory services to the Developer/ Owner/ EM/ EC; and
- Liaise with relevant Government agencies/ authorities and stakeholders, where required.

The Aquatic Environmental Specialist should have a degree (or equivalent) in aquatic environment-related fields with relevant extensive experience (e.g. 10 years) of relevant monitoring and sampling techniques.

12.4.4 Contractor (CT)

The Contractor shall be responsible to identify, manage and mitigate all environmental impacts arising from construction works. The CT shall be required to:

- Take ownership of the Construction EMMP implementation and ensure that the construction works are undertaken in accordance with the design limits and mitigation measures outlined within this EMMP and statutory requirements;
- Appoint an Environmental Control Officer (ECO) and necessary subject matter experts to advise on environmental performance improvement and to implement the Construction EMMP;
- Provide the EM/ ECO/ subject matter experts with the necessary assistance required to carry out monitoring programmes (where not under the Developer/ Owner), site inspections and implement all other EMMP related actions;
- Implement the EIA/ EMMP recommendations where applicable;
- Submit proposals on adaptive management measures during construction in case of exceedances of Action and Limit levels in the Construction EMMP;
- Implement measures to reduce impact where Action and Limit levels are exceeded, where identified to be attributable to Project;
- Implement the corrective actions instructed by the Developer/ Owner/ EM;
- Participate in the site inspections undertaken by EM, as required, and undertake any corrective actions instructed by the Developer/ Owner/ EM; and
- Adhere to the procedures for carrying out complaint investigation.

12.4.4.1 Environmental Control Officer (ECO)

The Contractor shall be required to hire an appropriately qualified Environmental Control Officer (ECO) during the construction phase. The ECO is also to be NEA-registered, with strong experience (e.g. 5 years) and relevant experience in developing and implementing Construction EMMP for similar or large scale projects. The ECO will support the EM to perform his/ her duties in the implementation of the Construction EMMP. The Contractor and ECO will report to the EM for aspects of EMMP requirements.

The appointment and qualifications of the ECO should be in compliance with the Environmental Public Health Regulations and the latest Code of Practice for Environmental Control Officers; which also set out the mandatory duties of an ECO. The ECO is expected to hold the requisite and relevant experience to carry out various tasks such as monitoring, data analysis, compliance checking, site inspections as well as provide advice on corrective actions for environmental issues/ mitigation measures arising during the works.

In general, the role of an ECO is to work with the “Occupier” (i.e. Contractor) of the construction site to comply with environmental laws, advise on environmental remediation measures, carry out site inspections and to engage workers and stakeholders on maintaining good environmental health standards (NEA, n.d.). Reporting should be carried out by the ECO, as required.

The environmental issues which the ECO is required to pay attention to are:

- Vector Control;
- Food Hygiene;
- Waste Management;
- Noise Management;
- Air Pollution and Dust Abatement;
- Earth Littering;
- Water Pollution and Earth Control; and
- Sanitary Facilities Management.

For this Project the ECO shall support the liaison with Government Agencies and stakeholders on environmental related matters where necessary.

12.4.4.2 Other Subject Matter Experts (SMEs)

From time to time throughout the construction and operation phases of the Project, various specialists will be required to provide advice in relation to environmental management. Depending on the site condition, other subject matter experts that could be required include Qualified Erosion Control Professional (QECP) for the design of ECM system at the worksite; and certified Arborist for tree assessment and removals. The QECP will carry out monthly monitoring to verify ECM implementation and its effectiveness.

12.5 Construction Environmental Site Inspection/ Audits

The Developer/ Owner shall ensure the EM/ EC will inspect/ audit the in-reservoir and land-based construction worksites regularly and routinely (i.e. weekly) to ensure that the appropriate environmental protection and pollution control mitigation measures identified in the EMMP are properly and timely implemented as well as to identify and resolve potential environmental incompliances. Inspections/ audits should also review the areas surrounding worksites, which may be affected by works activities. The format and content for site inspection, deficiencies, remedial action and reporting in the form of Environmental Site Inspection Reports should be established and agreed by the Developer/ Owner/ EM and CT representative prior to construction works commencing.

12.6 Reporting

12.6.1 Documentation

All environmental documentation will be electronic and filed in a traceable and systematic manner.

- During construction, all Construction EMMP results and findings shall be documented in the Monthly Construction EMMP report prepared within 10 working days of each calendar month by the EC (with inputs from the CT, EM, ECO and subject matter experts) and reviewed by the EM.
- During operation, all Operational EMMP results and findings shall be documented in the Quarterly Operational EMMP report prepared within 20 working days of each calendar quarter by the EC (with inputs from the subject matter experts) and reviewed by the EM.

All reports and records, including details of monitoring (e.g. surface water quality, biodiversity), shall also be documented as appropriate, and are to be stored on site and are to be made available to relevant Government and Technical Agencies/ Authorities upon request, or at a frequency agreed with Government and Technical Agencies/ Authorities.

12.6.2 Construction Phase

12.6.2.1 Construction EMMP

The contents and structure of the Construction EMMP will follow legal and this EMMP recommendations, and shall be agreed with relevant Government Technical Agencies/ Authorities prior to construction commencing.

The Construction EMMP shall set out the overall construction management and monitoring requirements (e.g. setting action and limit levels) to be agreed with relevant Government Agencies, and to be carried out during the construction phase, and shall include, as a minimum:

- Final Project design information;
- Current relevant legislation and best practice;

- Environmental Impact Register;
- Handling and storage of hazardous chemicals;
- Standard checklists and communication flows, e.g. for site inspections, wildlife management etc.;
- Monitoring Programme (including but not limited to surface water quality, biodiversity etc, and agreed action/ limit levels); and
- Management Plans (see *Section 12.8.1).*

12.6.2.2 Monthly Construction EMMP Report Content

The Monthly Construction EMMP Report shall regularly document the management and monitoring findings. The contents and structure of the Monthly Construction EMMP Report shall include the following:

a. Title page;

b. Executive summary (1-2 pages) including:
   - Exceedances of threshold criteria;
   - Complaints log;
   - Reporting of Construction EMMP changes; and
   - Future main potential issues.

c. Contents;

d. Basic Project information including a synopsis of the works undertaken during the month;

e. Environmental status, comprising:
   - Drawing showing the Project area(s), any environmental sensitive receivers and the locations of the monitoring stations;
   - Summary of non-compliance with the environmental quality performance limits; and
   - Summary of complaints.

f. Environmental monitoring summary:
   - Summary of environmental monitoring findings in reporting month;
   - Summary of environmental monitoring trends since monitoring commenced; and
   - Analysis and discussion on monitoring and LACs, as required.

g. Environmental issues and actions, comprising:
   - Review issues carried forward and any follow-up procedures related to earlier non-compliance (complaints and deficiencies);
   - Description of the actions taken in the event of non-compliance and deficiency reporting;
   - Recommendations (specific and target the appropriate party for action); and
   - Implementation status of the mitigatory measures and the corresponding effectiveness of the measures.

h. Appendices, including:
   - Monitored environmental aspects tabulated against threshold criteria;
   - Graphical plots of trends of monitored parameters over the past four reporting periods (or duration as agreed with EM/ Government Agencies) annotated against the following:

  - Major activities being carried out on site during the period;
  - Weather conditions during the period; and
  - Any other factors which might affect the monitoring results.
- Monitoring schedule for the present and next reporting period;
- Cumulative complaints statistics; and
- Details of complaints, outstanding issues and deficiencies.

12.6.3 Operational Phase

12.6.3.1 Operational EMMP

The contents and structure of the Operational EMMP will follow legal and this EMMP recommendations, and shall be agreed with relevant Government Technical Agencies/ Authorities prior to operations commencing, and will draw on the Construction EMMP and related Monthly Construction EMMP Reports, as appropriate. The Operational EMMP shall set out the overall operational management and monitoring requirements (e.g. setting action/ limit levels) to be agreed with relevant Government Agencies, and to be carried out during the operational phase.

12.6.3.2 Quarterly Operational EMMP Reports

The contents and structure of the Quarterly Operational EMMP Report shall be agreed with relevant Government Technical Agencies/ Authorities prior to operations commencing and will draw on the reporting developed for the Monthly Construction EMMP. The Quarterly Operational EMMP Report shall regularly document the management and monitoring findings and provide a consolidated annual review of available (i.e. including pre-construction and construction) long-term data sets and temporal analyses.

12.6.4 Data Keeping

The site documents such as the training attendance records, monitoring field records, laboratory analysis records, site inspection forms, etc. are not required to be included in the Construction and Operational EMMP Reports for submission. However, the documents shall be kept by the Developer/ Owner and be ready for inspection upon request by the Government Technical Agencies/ Authorities. All relevant information shall be clearly and systematically recorded in the documents. The monitoring data shall also be recorded and stored in an online database. All the documents and data shall be kept by the Developer/ Owner for the duration of the Project (i.e. construction and operation, including decommissioning).

12.6.5 Exceedances of Environmental Quality Limit and Limits of Acceptable Change

For the purpose of environmental management and monitoring, environmental quality performance limits are normally in the form of a set of action/ limit levels, which are defined as (EPD, 1997):

- Action Levels – the levels beyond which there is an indication of a deteriorating ambient environmental quality. Appropriate remedial actions may be necessary to prevent the environmental quality from going beyond the limit levels, which would be unacceptable.
- Limit Levels – the levels stipulated in relevant legislation, standard, guidelines or as agreed with relevant Government Technical Agencies/ Authorities for a particular project, beyond which the works shall not proceed without appropriate remedial action, including a critical review of plant and work methods.

In addition to the action/ limit levels, a trigger level below the action level may be set up to provide early warning of deteriorating environmental quality that may exceed the action level.

With reference to Event Action Plans and Limits of Acceptable Change, when the agreed limits are exceeded, the EC, EM, ECO, subject matter expert or other relevant party identifying the change shall immediately notify the Developer/ Owner/ EM and relevant Government Technical Agencies/ Authorities, as appropriate. The notification shall be followed up with advice to each party on the results of the investigation, proposed action and success of the action taken, with any necessary follow-up proposals.

12.7 Complaints and Corrective Actions

The Developer/ Owner is responsible for handling all environmental complaints that may be received from the public. Complaint investigation procedures will be developed and followed through. The main elements of complaint investigation procedures encompass:

- Prompt acknowledgement and response to stakeholder complaints, keeping them informed of the progress and outcomes;
- Accurate records of complaints, investigations and outcomes are maintained;
- Resolution by the Developer/ Owner/ EM or CT and/or EM/ ECO within a specified timeframe (four weeks is suggested);
- An escalation mechanism in the event that grievance cannot be resolved by CT and/or EM/ ECO within the nominated timeframe; and
- Government Agencies/ Authorities are kept informed of complaints, where required.

If complaints are made directly to the relevant agencies i.e. NEA, PUB, NParks etc, the Developer/ Owner/ EM or CT and/or EM/ ECO should submit to the relevant agencies sufficient investigative and corrective action reports to demonstrate that the complaint is being addressed.

12.8 Summary of EMMP

The EMMP has been drawn up to provide a framework for dealing with impacts to the environment during the construction and operation phase of the Project.

Table 12-1 presents the management plans and mitigation measures required to manage and mitigate impacts to respective main environmental aspects, alongside embedded controls (see *Appendix 2.2*). *Table 12-2* presents the environmental monitoring programme throughout the pre-construction, construction and operational period.

12.8.1 Environmental Management Plan

The EMMP for the Project is summarised in *Table 12-1*. Relevant Project phases where the mitigation measures apply are indicated in the table.

Given the cross-cutting nature of the mitigation measures, monitoring and adaptive management measures (i.e. one mitigation measure can reduce impacts on several environmental aspects), and to bring together the mitigation measures into a focused EMMP to support the Project's further development, where possible mitigation measures etc have been grouped into:

- General – design and construction methodology and schedule;
- General – monitoring and adaptive management;
- Further specific impact mitigation – referencing back to General, or other specific impact mitigation measures, where appropriate; and
- Unplanned events.

Management Plans and Reporting recommended in this EMMP for the Project include:

- Construction Phase:

  - Construction EMMP (including final design and agreed monitoring programme); and
  - Monthly Construction EMMP Reporting.
- Operational Phase:
  - Operational EMMP (including agreed monitoring programme); and
  - Quarterly Operational EMMP Reporting.
- Construction and Operational Phases:
  - Vessel operation procedures;
  - Aquatic Vegetation/ Invasive Species Management Plan (includes removal of aquatic vegetation). This plan should be prepared and submitted to PUB for agreement prior to commencement of the removal works for construction and operation phases;
  - Wildlife Incident Response Plan and Reporting; and
  - Spill Prevention and Emergency Response Plan.
- Embedded controls were taken into account during the impacts assessment and mitigation measures to reduce potential impacts were identified. These embedded controls, including regulatory and industry standard requirements, and iterative project design developments are presented in *Appendix 2.2*.

See *Section 12.8.2* for further details of the monitoring programme which will support the adaptive management measures and approach proposed during the construction and operational phases.

The Developer/ Owner will need to ensure that detailed design is developed within the parameters, boundaries and limits (e.g. adhering to mitigation measures) identified through the EIA process. The Developer/ Owner is to demonstrate to relevant Government Agencies that the final design conforms to the EIA. Should any of the design, construction, operational and/ or unplanned event assumptions assessed in the EIA change (i.e. be considered to be greater, or more impactful, than those assumed in this assessment) as a result of the Developer/ Owner's detailed design, construction methodology and operation, the impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein.

Table 12-1: Environmental Management Plan for the Project

S/N	Aspect (& EIA Reference)	Potential Environmental Impact/ Issue	Location	Project Phase (FD, PC, C, O)[2]	Mitigation measures (developed from the mitigation measures identified in this EIA, refer to *Appendix 2.2* for Project embedded controls)	Responsible Person	Means of Verification
GENERAL (DESIGN & CONSTRUCTION METHODOLOGY & SCHEDULE)							

1.1	Surface Water Quality (*Section 6*)	Site runoff, wastewater, sediment disturbance from:
		- Geotechnical/ site investigation
		- Site preparation
		- Construction of integrated Project Substation and connector cable
		
		Sediment disturbance from:
		- Geotechnical/ site investigation
		- Deployment of anchors/ ballasted foundations/ piles and mooring lines
		- Launching, towing and installation of FPV and ancillary equipment
		- Installation of connector cables (between FPV islands and to shore)
		- Construction of O&M Berthing Facility (location subject to approval from agencies)
		- O&M of FPV facilities (including cleaning of PV panels)
		
		Potential degradation/ change of surface water quality from:
		- Removal of aquatic vegetation
		- Presence of FPV in reservoir (including change of hydrodynamics impacts)
			Proposed temporary Staging/ Launching Area (including ramp) and the integrated Project Substation worksite
			
			And
			
			Reservoir Project Site
				FD, PC, C, O	- Detailed design to optimise/ minimise, where feasible:
					  - Footprint of proposed temporary Staging/ Launching Area worksite and integrated Project Substation.
					  - FPV layout/ island footprint;
					    o It is recommended to reduce the FPV layout footprint in the higher observed bird foraging area within the Reservoir Project Site, in the central west edge (near VP3, adjacent to Kranji Marshes) (see *Section 7*, *Figure 7-15*). Based on bird the baseline survey data analysis, a mitigated biodiversity FPV layout footprint (inclusive of a 50m western shoreline setback to FPV panels) has been proposed, and is presented as the final FPV layout in the EIA's Project Description for approval (*Section 2*, *Figure 2-3*). The mitigated FPV layout footprint (inclusive of intra-island spacing) will occupy approximately 112 ha (subject to final design) or 21.5% of the total Kranji Reservoir surface area (inclusive of all in-reservoir Project permanent infrastructure).
					  - Conduct updated model runs (e.g. hydrodynamic and water quality) and hydraulic studies based on the final FPV layout to be developed. Review water quality impact assessment based on the findings of the updated model runs. Should changes (if any) be considered to be greater, or more impactful, than those assumed in this assessment, the impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein.
					  - If any operational fencing is required at locations around the Reservoir Project Site, due to operational safety and security concerns, the Developer/ Owner should, in consultation with relevant Government authorities, establish wildlife-friendly fencing, crossings, access into the fencing design.
					  - Integrated Project Substation - louvres are orientated to face the public roads to the east to minimise noise to the Kranji Reservoir and future park to the west (embedded control).
					- Construction methodology and schedule to optimise/ minimise, where feasible:
					  - Proposed temporary Staging/ Launching Area and integrated Project Substation worksite footprint and vegetation clearance;
					  - Site runoff, wastewater and sediment disturbance, from:
					    o Land-based:
					      • Geotechnical/ site investigation extent and number of borehole locations;
					      • Site preparation extent (including launching ramp) and construction works; and
					      • Construction of integrated Project Substation and connector cable.
					    o Reservoir-based:
					      • Geotechnical / site investigation (e.g. by phasing, extent and number of borehole locations);
					      • Piles / anchors / ballasted foundations;
					      • Connector cables length;
					      • Launching/ towing and installation of FPVs and ancillary equipment;
					      • O&M Berthing Facility;
					      • Aquatic vegetation management/ trimming; and
					      • Review the analysis conducted under *Appendix D* and *E* of *Appendix 6.1* based on to update estimation of potential surface water quality impact. Should changes (if any) be considered to be greater, or more impactful, than those assumed in this assessment, the impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein.
					  - Dusty activities from land-based worksites.
					  - Noisy activities (e.g. reduce continuously operating equipment and simultaneous equipment operation etc) and installation of 4 m noise barrier on north, east and south boundaries of the land-based worksite (see item 5.1 below).
					  - Vibration activities - minimise extent, duration and distance to VSRs (e.g. minimum 4m).
					  - Vector proliferation
					    o Embedded controls and mitigation measures for land-based construction worksites should be applied to in-reservoir worksites as well.
					    o Regular environmental site inspections, i.e. on a weekly basis, at the land-based and in-reservoir worksites during construction are recommended
					  - Silt fencing on land at or near the water edge to prevent on-shore sediments from washing into the reservoir.
						Embedded controls and mitigation measures for land-based construction worksites should be applied to in-reservoir worksites as well.
						
						Regular environmental site inspections, i.e. on a weekly basis, at the land-based and in-reservoir worksites during construction are recommended
							- Final design
							- Construction EMMP
							- Monthly Construction EMMP Report

	Biodiversity (Section 7)	Benthic habitat/ fauna loss/ disturbance Changes due to trimming of aquatic vegetation Terrestrial habitat clearing/ fragmentation Disturbance to terrestrial fauna (piling in reservoir) Disturbance to terrestrial fauna (land-based worksite) Changes to the planktonic and/or benthic communities Changes to the fish community Reduced foraging opportunities on reservoir surface for terrestrial fauna Barrier effects/ habitat fragmentation across reservoir surface and integrated Project Substation site Generation of dust from land-based construction					
	Air Quality (Section 8)	Generation of dust from land-based construction					
	Airborne Noise and	Generation of noise during the land-based construction at the proposed					

[2] FD= Final Design, PC = Pre-Construction, C = Construction, O = Operation.

S/N	Aspect (& EIA Reference)	Potential Environmental Impact/ Issue	Location	Project Phase (FD, PC, C, O)[2]	Mitigation measures (developed from the mitigation measures identified in this EIA, refer to *Appendix 2.2* for Project embedded controls)	Responsible Person	Means of Verification
	Vibration (Section 9)	temporary Staging/ Launching Area and integrated Project Substation (with O&M facility) worksite Generation of noise from operation of integrated Project Substation (with O&M Facility)			- Piling, for example: o Extent and number of piles, simultaneous piling workstations (e.g. in-reservoir piling activities could be controlled according to works phasing, intensity, distance between piling workstations, distance from the shoreline, etc.); o No night time piling works in-reservoir . This will avoid in-reservoir night time noise and light impacts, particularly to biodiversity; o Minimise use of driven piling. Use low-noise piling methods instead, e.g. vibratory piling or drilling. If driven piles is selected, apply noise mitigation measures, e.g. ramp up piling gradually, install enclosed shrouds around the piling equipment etc. Based on ERM's existing database, the noise level reduction for enclosed shrouds is predicted to be up to 9 dB(A). Consider the in-reservoir piling noise assessment in *Section 7, Table 7-12, C7 and Appendix 7.7*).		
	Vector (*Section 11*)	Increase in Vector Populations (Mosquitoes and Rats)					
GENERAL (MONITORING & ADAPTIVE MANAGEMENT)							

2.1	Surface Water Quality (*Section 6*)	Sediment disturbance from:
		- Geotechnical / site investigation
		- Deployment of anchors/ ballasted foundations/ piles and mooring lines
		- Launching, towing and installation of FPV and ancillary equipment
		- Installation of connector cables (between FPV islands and to shore)
		- Construction of O&M Berthing Facility (location subject to approval from agencies)
		- O&M of FPV facilities (including cleaning of PV panels)
		Potential degradation/ change of surface water quality from:
		- Removal of aquatic vegetation
		- Presence of FPV in reservoir (including change of hydrodynamics impacts)
			Reservoir Project Site	PC, C, O	**Monitoring and adaptive management measures** (see *Section 12.8.2* for further details on monitoring) including:
					- Agree construction and operation phase surface water quality threshold criteria and monitoring frequency with relevant Government Agency prior to construction and operation commencing, respectively.
					- Establish construction and operational phase surface water quality/ sediment quality monitoring programme in agreement with relevant Government Agency prior to construction and operation commencement, respectively, to inform the Developer/ Owner on any potential deterioration of surface water quality from the Project, and provide analysis of long-term changes and trends.
					  - Online water quality systems, pre-agreed with PUB, should be deployed in the reservoir pre-construction prior to works being carried out in the reservoir and through to operation (including decommissioning).
					  - Pre-construction and unplanned event only - sediment quality monitoring parameters to include: Nutrients, contaminants/ metals and hydrocarbons.
					  - Surface water quality monitoring parameters to include: Temperature (°C), pH, EC (µS/cm) (conductivity), Turbidity (NTU), Secchi Depth, , Dissolved oxygen (DO), Metals and metalloids (including Aluminium, Arsenic, Copper, Iron, Lead, Manganese), Major ions (including chloride), grease and oil, PAR, Chlorophyll-a (fluorescence-based spectrophotometer), Nutrients (TP, TN, TOC, DOC, Nitrate (as N), Phosphate, and ammonia (as N)), 2-MIB, Geosmin, Microcystin-LR, and Total Suspended Solids (TSS).
					- Any notable deterioration of surface water quality observed, the relevant Government agencies should be notified, and the cause should be investigated. Investigation should determine whether or not the observed deterioration can be attributed to the construction and operational phase work. If affirmative during construction, the relevant construction work procedures should be ceased temporarily and reviewed with PUB. Further mitigation should be identified and implemented in agreement with PUB until the identified issue(s) is rectified. During operation phase, the Developer/ Owner should liaise with relevant Government Agency closely on monitoring results and investigation findings and seek agreement on rectification action(s) which may include potential layout changes, removal of the FPV etc where appropriately agreed between responsible agencies and the Developer/ Owner. Where observations are not attributable to the Project, the Developer/ Owner will liaise with relevant Government Agencies responsible for managing the identified effect for their action.
					- In case surface water quality monitoring results indicate notable change in surface water quality in reservoir as a result of Project construction and operation phase works, the Developer/ Owner to agree with PUB on monitoring results, investigation findings and adoption of further mitigation measures, for example:
					For construction:
					  - At the beginning of anchoring operations, work fronts should preferably be chosen at location sufficiently far away from the water intake to minimise potential impact from sediment disturbance. Surface water quality monitoring should be regularly reviewed (e.g. when work front moves) to inform work rate adjustments, for example, according to the distance of the work fronts to the water intake for treatment plant (such as, where work front is closer to water intake, monitoring may indicate the Developer/ Owner should consider a reduced work rate). Work rate should start low and be allowed to ramp up for successive days showing no notable deterioration of surface water quality contributed by project works.
					  - Silt curtains around the two reservoir water intakes, geotechnical/ site investigation and/ or worksites;
					  - Propose alternate construction methodologies;
					  - Cease works temporarily;
					  - Agreed work rates; and
					  - Aquatic vegetation management/ trimming.
					For operation:
						Developer/ Owner, CT	- Construction EMMP
							- Monthly Construction EMMP Report
							- Operational EMMP
							- Quarterly Operational EMMP Report

S/N	Aspect (& EIA Reference)	Potential Environmental Impact/ Issue	Location	Project Phase (FD, PC, C, O)[2]	Mitigation measures (developed from the mitigation measures identified in this EIA, refer to *Appendix 2.2* for Project embedded controls)	Responsible Person	Means of Verification
					- Artificial aerators could be installed and potential locations for these will be determined in consultation with PUB when the final layout is confirmed, for example during the final layout model rerun, and installation would be subject to ongoing monitoring results; - Layout changes; and - Removal of the FPV.		

2.2	Biodiversity (*Section 7*)	Elevation of pollutants and/or nutrients within the reservoir
		Changes due to trimming of aquatic vegetation
		Disturbance to aquatic fauna (piling, boat movements)
		Disturbance to terrestrial fauna (General)
		Changes to the planktonic and/or benthic communities
		Changes to the fish community
		Reduced foraging opportunities on reservoir surface for terrestrial fauna
		Barrier effects/ habitat fragmentation across reservoir surface and integrated Project Substation site
			Proposed temporary Staging / Launching Area (including ramp) and the integrated Project Substation worksite
			
			And
			
			Reservoir Project Site
				PC, C, O	**Monitoring and adaptive management measures** (see *Section 12.8.2* for further details on monitoring) including:
					- Establish construction and operational phase biodiversity monitoring programme in agreement with relevant Government Agency prior to construction and operation commencement, respectively, to inform the Developer/ Owner on any potential deterioration of biodiversity from the Project, and provide analysis of long-term changes and trends.
					  - Biodiversity monitoring to include: focal-/ waterbird species (including bird flight paths) and smooth-coated otters, plankton (zooplankton and phytoplankton), fish biomass and size.
					  - Monitoring of bird flight paths post-construction against pre-construction behaviour to identify if there are any significant changes in flight behaviour.
					  - Establish construction phase noise monitoring programme in agreement with relevant Government authorities prior to works commencement, to inform the Developer/ Owner on any potential impact of noise on biodiversity from the works, e.g. in the vicinity of Kranji Marshes and the black-crowned night heron roosts, and the Staging/ Launching Area and the integrated Project Substation worksite.
					  - Should monitoring show a decline in fish biomass, the Developer/ Owner is to consider opportunities, in consultation with relevant Government authorities for additional nature based solutions, e.g. for fish habitat enhancement in the retained habitats areas within the reservoir, for example:
					    o Patches of floating vegetation in designated areas (especially south of the Reservoir Project Site) to be retained, where possible, subject to the FPV system's and PUB's reservoir operational requirements.
					    o If the fish population is observed to be significantly affected despite above adaptive measures then consider other adaptive management which may include, for example, potential layout changes, removal of FPV panels, etc where appropriately agreed between responsible agencies and the Developer/ Owner.
					- Any notable deterioration of biodiversity observed, the relevant Government Agencies should be notified, and the cause should be investigated. Investigation should determine whether or not the observed deterioration can be attributed to the operation of the Project. If affirmative, the cause of adverse biodiversity events should be reviewed and targeted mitigation. The Developer/ Owner should liaise with relevant Government Agencies closely on monitoring results and investigation findings and seek agreement on management action(s), which may include potential layout changes, removal of the FPV etc where appropriately agreed between responsible agencies and the Developer/ Owner. Where observations are not attributable to the Project, the Developer/ Owner will liaise with relevant Government Agencies responsible for managing the identified effect for their action.
						Developer/ Owner, CT	- Construction EMMP
							- Monthly Construction EMMP Report
							- Operational EMMP
							- Quarterly Operational EMMP Report

2.3	Airborne Noise and Vibration (Section 9)	Generation of noise during the land-based construction at the proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M facility) worksite	Proposed temporary Staging / Launching Area (including ramp) and the integrated Project Substation worksite	PC, C	- Conduct noise monitoring throughout construction at proposed temporary Staging/ Launching Area and integrated Project Substation to verify the impacts assessed herein.	CT	- Construction EMMP - Monthly Construction EMMP Report
FURTHER SPECIFIC IMPACT MITIGATION							
3.1	Surface Water Quality (*Section 6*)	Sediment disturbance from: - Geotechnical / site investigation - Deployment of anchors/ ballasted foundations/ piles and mooring lines - Launching, towing and installation of FPV and ancillary equipment	Reservoir Project Site	FD, PC, C, O PC, C	- Conduct lowering of anchors/ piles/ weights/ connector cables in controlled manner to reservoir bed to minimise sediment disturbance and the use of diver to assist with the underwater works (if necessary). - Design of the vessel operation procedures to account for the relatively shallow water off the launching ramp and shorelines to avoid the work boats/ barges from getting into the shallow depths and running their engines at full throttle. Account for heavy loads activity procedures/navigation routes. Ensure boat operators are familiar with water depths across the reservoir.	Developer/ Owner, CT	- Final design - Construction EMMP - Monthly Construction EMMP Report

S/N	Aspect (& EIA Reference)	Potential Environmental Impact/ Issue	Location	Project Phase (FD, PC, C, O)[2]	Mitigation measures (developed from the mitigation measures identified in this EIA, refer to *Appendix 2.2* for Project embedded controls)	Responsible Person	Means of Verification
		- Installation of connector cables (between FPV islands and to shore) - Construction of O&M Berthing Facility (location subject to approval from agencies) - O&M of FPV facilities (including cleaning of PV panels)			- Vessels required for transportation of crew and/ or materials/ equipment should account for the additional load when considering navigation routes to ensure sufficient reservoir bed clearance.		- Operational EMMP - Quarterly Operational EMMP Report - Vessel operation procedures
3.2		Potential degradation/ change of surface water quality from: - Removal of aquatic vegetation - Presence of FPV in reservoir (including change of hydrodynamics impacts)		FD, PC, C, O	- All aquatic vegetation trimmings to be collected and removed from the water column immediately for disposal offsite by a licenced contractor. - Establish an Aquatic Vegetation/Invasive Species Management Plan (includes removal of aquatic vegetation). This plan will be prepared and submitted to PUB for agreement prior to commencement of the removal works for construction and operation.	Developer/ Owner, CT	- Final design - Aquatic Vegetation/ Invasive Species Management Plan - Construction EMMP - Monthly Construction EMMP Report - Operational EMMP - Quarterly Operational EMMP Report
4.1	Biodiversity (*Section 7*)	Benthic habitat/ fauna loss / disturbance	Reservoir Project Site	FD, PC, C	- See also mitigation measures applied in item 3.1 above.	Developer/ Owner, CT	- Final design - Construction EMMP - Monthly Construction EMMP Report
4.2		Elevation of suspended sediments within the reservoir		PC, C	- See also mitigation measures applied in items 3.1 to 3.2 above.		
4.3		Elevation of pollutants and/or nutrients within the reservoir		PC, C			
4.4		Changes due to trimming of aquatic vegetation		FD, PC, C			
4.5		Disturbance to aquatic fauna (piling, boat movements)	Reservoir Project Site	PC, C	- See also mitigation measures applied in items 3.1 to 3.2 above, and items 4.7 and 4.8 below.	Developer/ Owner, CT	- Construction EMMP - Monthly Construction EMMP Report

4.6		Terrestrial habitat clearing/ fragmentation	Proposed temporary Staging / Launching Area and the integrated Project Substation worksite	FD, PC, C	- See also mitigation measures applied in items 4.7 below.
					- Avoid felling trees and clearing vegetation during the peak bird breeding season (March to July).
					- Pre-felling fauna inspection by qualified Biodiversity Specialist should be conducted before felling any trees or removing any vegetation.
					- Re-plant shoreline vegetation as early as possible in the construction schedule.
					  - Plant keystone flora such as fig trees. They provide important food source for avian fauna and small mammals. It is recommended that only native plant species are planted.
					  - It is recommended to select a diversity of flowering and fruiting plants species so that the area will be flowering and fruiting throughout the year to provide food and improve ecological processes.
					  - Consult with NParks on the land-based worksite re-planting/ landscaping scheme considering the future land use of the shoreline as Park.
					- Ensure there are no works outside of the in-reservoir and land-based worksites.
						Developer/ Owner, CT	- Final design
							- Construction EMMP
							- Monthly Construction EMMP Report

S/N	Aspect (& EIA Reference)	Potential Environmental Impact/ Issue	Location	Project Phase (FD, PC, C, O)[2]	Mitigation measures (developed from the mitigation measures identified in this EIA, refer to *Appendix 2.2* for Project embedded controls)	Responsible Person	Means of Verification
					- Conduct regular inspections to ensure compliance and identify any impacts unnecessary clearance.		
4.7		Disturbance to terrestrial fauna (General)	Proposed temporary Staging / Launching Area (including ramp) and the integrated Project Substation worksite And Reservoir Project Site	PC, C, O	- Regulate contractor movements and activities to areas only within the construction and operational footprint (Reservoir Project Site)) and prohibiting access to other areas without prior agreement of the Site's Environmental Manager (e.g. retained terrestrial and aquatic habitats and parts of the setback zone around the reservoir edges not required for access). - Minimise the construction works during sunrise and sunset periods. - Establish a Wildlife Incident Response Plan and Reporting (including for birds, bats, snakes, crocodiles etc.) to be enacted when a trapped/injured/dead/dangerous animal is encountered around or within the worksite. - Conduct regular inspections to ensure compliance and identify impacts to adjacent biodiversity areas, fauna entrapments etc. - Train site personnel on biodiversity awareness and actions to take when encountering wildlife. - Erosion control blankets should be removed after construction to avoid trapping fossorial fauna.	Developer/ Owner, CT	- Construction EMMP - Monthly Construction EMMP Report - Operational EMMP - Quarterly Operational EMMP Report - Wildlife Incident Response Plan and Reporting
4.8		Disturbance to terrestrial fauna (piling in reservoir)	Reservoir Project Site	PC, C	- See also mitigation measures applied in items 3.1 above. - Agree on construction phase ambient noise threshold criteria for birds (i.e. <70 dB(A)) with relevant Government authorities prior to works commencement, taking into consideration biodiversity values.	Developer/ Owner, CT	- Construction EMMP - Monthly Construction EMMP Report
4.9		Disturbance to terrestrial fauna (land-based worksite)	Reservoir Project Site	PC, C	- Detailed design and construction methodology – see item 1.1 above. - See also mitigation measures applied in items 4.7 above, and item 5.1 below, including installation of 4 m noise barrier around north, east and south boundaries of the proposed temporary Staging/ Launching Area and integrated Project Substation worksite.		
4.10		Disturbance to terrestrial fauna (in-reservoir piling and land-based worksite night lighting)	Reservoir Project Site	PC, C	- See also mitigation measures applied in items 4.7 above. - Use minimal number of luminaires, at low positions in relation to the ground, directed and shielded to provide the least amount of spill to adjacent habitats. Baffles, hoods, or louvres can be used to reduce light spill and direct it to only where it is needed. - Set up dark buffers, illuminance limits, and zonation. - Limit the duration of lighting, e.g. where peak nocturnal fauna activity is avoided, where possible. - Lights with reduced or filtered blue, violet and ultra-violet wavelengths should be used. As a general rule, only lights with little or no short wavelength (400–500 nm) violet or blue light should be used to avoid unintended effects. - Where wildlife is sensitive to longer wavelength light (e.g. some bird species), consideration should be given to wavelength selection on a case by case basis. Where possible, warm colour temperature light sources to be employed preferably at <2,700 Kelvin.		
4.11		Disturbance to terrestrial fauna (boat movements and use of helicopters)	Reservoir Project Site	PC, C	- See also mitigation measures applied in items 4.7 above. - For boat movements, regular traffic routes should be established for routine works. Moreover, offset from shoreline as well as corridors between FPV islands allow safe navigation access and will minimise the risk of disturbing bird shoreline foraging areas. - For helicopters, no fly zone within 100 m of grey-headed fish eagle nest and/or black-crowned night heron roosts, or Protected Areas.		
4.12		Changes to the planktonic and/or benthic communities And Changes to the fish community	Reservoir Project Site	O	- See also mitigation measures applied in items 1.1 above for impacts to benthic communities. The detailed design of FPV layout to optimise/ minimise FPV island footprint is a mitigation measure to prevent impacts to benthic and fish communities. - An operation phase biodiversity monitoring programme (for planktons, fish and benthic communities) in agreement with relevant Government Authorities prior to works commencement, to inform the Developer/ Owner on any potential deterioration of biodiversity from the works. - Patches of floating vegetation to be retained, where feasible, in the Reservoir Project Site, subject to FPV system and PUB's reservoir operational requirements.	Developer/ Owner	- Operational EMMP - Quarterly Operational EMMP Report

S/N	Aspect (& EIA Reference)	Potential Environmental Impact/ Issue	Location	Project Phase (FD, PC, C, O)[2]	Mitigation measures (developed from the mitigation measures identified in this EIA, refer to *Appendix 2.2* for Project embedded controls)	Responsible Person	Means of Verification
					- If the fish population is observed to be significantly affected despite above adaptive measures then consider other adaptive management which may include, for example, potential layout changes, removal of FPV panels etc, where appropriately agreed between responsible agencies and the Developer/ Owner.		
4.13		Reduced foraging opportunities on reservoir surface for terrestrial fauna	Reservoir Project Site	O	- See also mitigation measures applied in items 1.1 above on utilising a biodiversity mitigated FPV layout and optimising FPV layout to avoid areas of high bird foraging.		
4.14		Bird and/or bat collision with FPV panels	Reservoir Project Site	O	- See also mitigation measures applied in items 1.1 above on utilising a biodiversity mitigated FPV layout and optimising FPV layout to avoid areas of high bird foraging hence collision with panels. - See also mitigation measures applied in items 4.7 above on general biodiversity disturbance mitigation.	Developer/ Owner, CT	- Operational EMMP - Quarterly Operational EMMP Report
4.15		Loss/ degradation of integrity of Protected Areas	Proposed temporary Staging / Launching Area (including ramp) and the integrated Project Substation worksite And Reservoir Project Site	PC, C, O	- Mitigation measures applied in items 4.1 to 4.14 adopted for terrestrial and bird biodiversity in the operation phase above to control the impacts in relation to optimising the FPV layout and related to managing works in and around the reservoir, will generally avoid and minimise their magnitude on the Protected Areas.	Developer/ Owner, CT	- Construction EMMP - Monthly Construction EMMP Report - Operational EMMP - Quarterly Operational EMMP Report
5.1	Airborne Noise and Vibration (*Section 9*)	Generation of noise during the land-based construction at the proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M facility) worksite	Proposed temporary Staging / Launching Area and the integrated Project Substation worksite	C	- Installation of temporary 4 meter-high noise barrier along the northern, eastern and southern boundaries (see illustration in *Section 9, Figure 9-4)* throughout the construction phase. - The temporary noise barriers shall have a minimum surface density of 20kg/m^2 or a minimum sound transmission loss of 20dB, e.g. steel with a 22-gauge with thickness of 0.79 mm, surface density of 6.1 kg/m2 and sound transmission loss of 20 dB. Additionally, there shall be no gaps at the bottom of the noise barriers or in between the panels, as far as reasonably practicable. Any gaps must be sealed with rubber gasketing to minimise noise propagation to the nearest off-site receptors. - If required, access ways along the barriers should be minimised as much as possible as well. - Such materials and principals described above shall be applied to the worksite access gates, which should remain closed as far as reasonably practicable throughout the construction period.	Developer/ Owner, CT	- Final design - Construction EMMP - Monthly Construction EMMP Report
6.1	Vector (*Section 11*)	Increase in Vector Populations (Mosquitoes and Rats)	Proposed temporary Staging / Launching Area and the integrated Project Substation worksite	FD, PC, C	- Informing stakeholders (i.e. neighbours) of construction activities, controls in place and schedule prior to the start of the Project construction activities. - Setting up a grievance mechanism to ensure that any complaints from stakeholders with regards to vector (mosquito) breeding / pest infestation due to the Project, are identified and promptly addressed. - Visual inspection of excavation sites, pits, worksites, internal and perimeter drainages, ECM collection basin(s), waste collection areas etc for still water/ rat population. - To implement preventive measures by removing sources of stagnant water. - Ensure regular food waste collection by licenced collector. - Embedded controls and mitigation measures for land-based construction worksites should be applied to in-reservoir worksites as well. - Regular environmental site inspections, i.e. on a weekly basis, at the land-based and in-reservoir worksites during construction are recommended	Developer/ Owner, CT	- Final design - Construction EMMP - Monthly Construction EMMP Report

S/N	Aspect (& EIA Reference)	Potential Environmental Impact/ Issue	Location	Project Phase (FD, PC, C, O)[2]	Mitigation measures (developed from the mitigation measures identified in this EIA, refer to *Appendix 2.2* for Project embedded controls)	Responsible Person	Means of Verification
7.1		Unplanned events of: Fire and explosion Failure of erosion control measures (ECM) Environmental spill Impacting the following:	Proposed temporary Staging / Launching Area (including ramp) and the integrated Project Substation worksite And Reservoir Project Site	FD, PC, C, O	- Contractor to conduct thorough quality checks and inspections of materials prior to installation to ensure there are no manufacturing defects. - Proper material handling practices and inspections of installed materials should be done to ensure there are no defects during construction. - Developer/ Owner to conduct a review of past FPV design failure modes and incorporate main findings into the newer designs. - Where possible, drains/ body of water where fire and explosion occurs should be cut off from the Kranji Reservoir. Firefighting water will be contained within the ECM system and holding pond, where appropriate. Such water will be collected and be disposed by a licensed waste collector as soon as possible to ensure normal ECM/ holding pond operation can continue. - Only non-toxic firefighting reagent (if needed) will be used for firefighting. This will minimise human health and ecological risk in case using of such reagent is needed and such reagent ends up in reservoir water. Developer/ Owner to agree with PUB on the proposed firefighting reagent to be used on site prior to usage. - In case of a fire and explosion in reservoir, a perimeter floating boom should be set up (where possible and safe) to allow containment of any floating debris from the event. - Preparation and implementation of vessel standard operating procedures. - Chemicals and/ or hydrocarbons will be handled and stored in compliance with the Material Safety Data Sheet (MSDS). - All chemical and/ or hydrocarbon wastes will be segregated into clearly marked containers prior to onshore disposal by a licensed waste management contractor, as per the relevant MSDSs. Secondary containment should also be provided for these chemicals. - Daily inspection of boat and machinery to avoid fuel leakage. - Practice due diligence in proper storage and handling of machinery to prevent leaching of oil or harmful materials. - Regular maintenance of vehicles and equipment, proper training to operators to avoid fuel leakage or spillage into reservoir. - Work boats will be refuelled at specified locations following standard procedures. Refuelling location(s) should be equipped with spill control kits and measures, e.g. floating booms at the perimeter, clean up kits ready to use, etc. This means any spillage from refuelling would be contained and cleaned up properly. - Provision of navigation aids and establishment of regular traffic routes would further reduce the risk of collision. - Train workers in implementation of the Spill Prevention and Emergency Response Plan (to address surface water quality and air quality). - Joint exercises/ drills for spillage and fire will be conducted by the Developer/ Owner with SCDF each year to ensure preparedness on spillage containment and clean up, as well as fire preventing and fighting among workers. - Do not use "PVStop" chemical spray as a fire retardant to render PV panels electrically safe (operation only). Instead, electricity generation will be cut off remotely at the Project's control room to facilitate firefighting. - Spill Prevention and Emergency Response Plan to have inclusions for addressing wildlife and biodiversity concerns from events.	Developer/ Owner, CT	- Final design - Construction EMMP - Monthly Construction EMMP Report - Spill Prevention and Emergency Response Plan - Vessel operation procedures - Operational EMMP - Quarterly Operational EMMP Report
	Surface Water Quality (*Section 6*)	Degradation/ change of surface water quality					
	Biodiversity (*Section 7*)	Habitat degradation					
	Air Quality (*Section 8*)	Release of ash or smoke from burning					
	Soil and Groundwater Quality (*Section 10*)	Degradation/ change of soil and groundwater					

12.8.2 Environmental Monitoring Programme

12.8.2.1 Accredited Laboratories

Where monitoring requires (for surface water quality, noise, etc) appropriately certified/ calibrated equipment and/ or accredited laboratories (e.g. Singapore Laboratory Accreditation Scheme, SINGLAS) should be commissioned.

12.8.2.2 Monitoring Approach

Monitoring of the main environmental aspects/ parameters will be fundamental to the adaptive management of the environmental impacts of the Project during its pre-construction, construction and operational phases.

Through the impact assessment and Ecological Character Description (ECD) (i.e. an ecosystem approach which identifies longer term Limits of Acceptable Change), main monitoring recommendations of critical ecosystem components (both biotic and abiotic) have been established (see *Table 12-2*). It is recommended that monitoring programmes are carried out:

- Pre-construction;
- Throughout construction, and
- Initial three years post-construction (i.e. initial operation).

At the end of this initial three years post-construction period, a review is recommended to be undertaken in consultation with relevant Government Agencies/ Authorities, and stakeholders, where appropriate.

The objective of the review would include, but not limited to, the following:

- Confirm the significance of impacts predicted in the EIA;
- The data trends against the impact monitoring and LAC criteria;
- Whether the impact monitoring and LAC criteria are being met or not;
- The cause of any changes in impact monitoring and LAC criteria;
- If change, if any, is attributable to the Project, or not;
- Whether adaptive management actions[3] have been carried out, and their success;
- Whether future management actions are required (and the responsible party for those actions, including relevant responsible Government agencies/ authorities if causes of monitoring or LAC exceedance is not attributable to the Project); and
- Whether ongoing monitoring is required, and if so, whether changes, or refinement, to the monitoring programme are necessary. It is anticipated that within three years of post-construction any variation in site conditions as a result of the FPVs will be detected and inform the need for any continued or reduced monitoring after that time or not. It is noted surface water quality monitoring will occur throughout the operational lifespan of the FPV (including decommissioning).

The review should take account of any new information, monitoring results (e.g. throughout pre-construction, construction and initial three years post-construction), or changes in the conservation context of the site. Any monitoring programme upon decommissioning should be reviewed in advance of decommissioning commencing.

The monitoring protocol is described in *Figure 12-2*. The monitoring programme of the EMMP is summarised in *Table 12-2*.

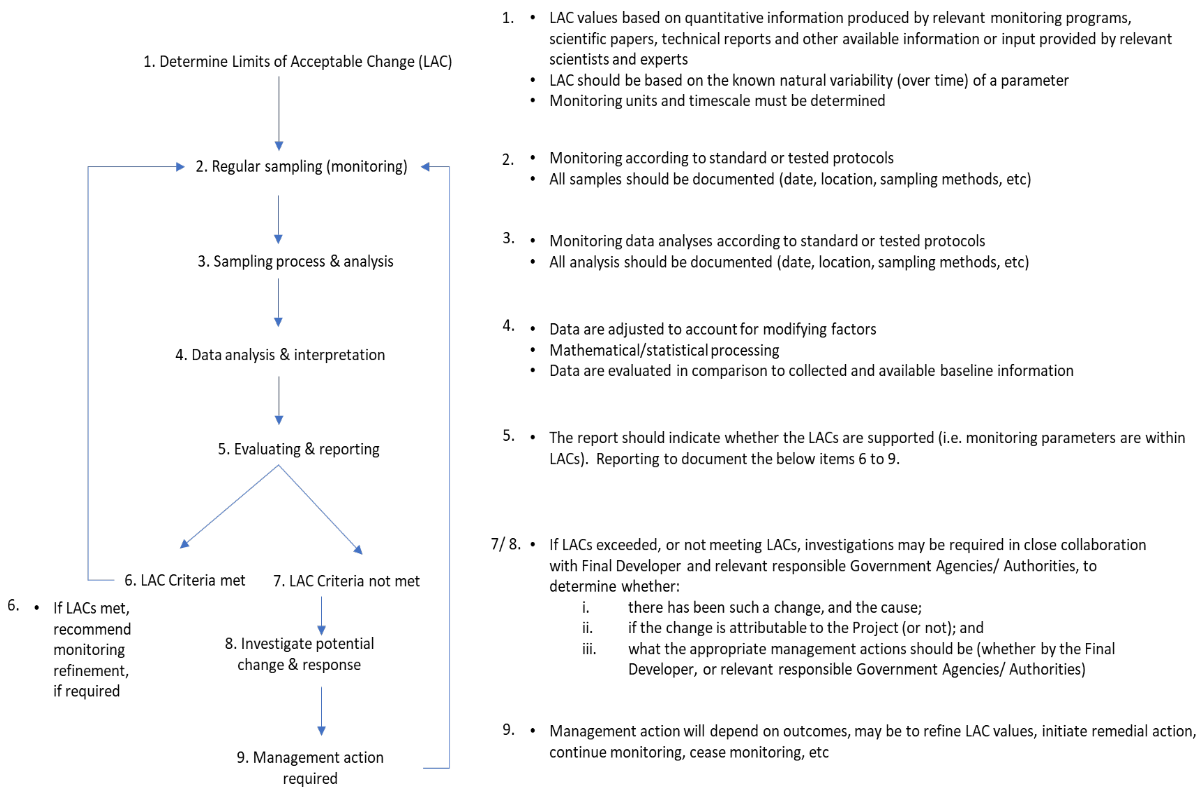
[3] Adaptive management actions may include, in addition to physical mitigation measures: refinement of LAC criteria, initiation of remedial action, continued monitoring, ceasing monitoring, etc.

12.8.2.3 Monitoring Protocol

LACs and related impact monitoring programmes provide early indicators to enable effective adaptive management, if required. The Developer/ Owner will take responsibility for managing effects that are identified to be directly attributable to impacts from the Project.

Should any notable deterioration or adverse trend in the LACs and monitoring parameters against the ecosystem level LAC criteria or other established criteria/ thresholds be observed, relevant Government Agencies should be notified and the cause should be investigated. The investigation should determine whether or not the observed deterioration/ trend can be attributed to the construction or operation of the Project. If affirmative, the cause of the events should be reviewed and adaptive management implemented, for example, through targeted monitoring or mitigation. The Developer/ Owner should liaise with relevant Government Technical Agencies/ Authorities closely on monitoring results and investigation findings and seek agreement on management action(s) which may include potential layout changes, removal of the FPV etc, where appropriately agreed between responsible Government Agencies and the Developer/ Owner. Where observations are not attributable to the Project, the Developer/ Owner will liaise with relevant Government Agencies responsible for managing the identified effect for their action. The monitoring protocol flow is depicted in *Figure 12-2.*

The details of monitoring programme and relationship to each LAC are set out in *Table 12-2* the details of which should be finalised and agreed with relevant Government Technical Agencies/ Authorities prior to the commencement of construction and operation.



Source: Adapted from Finlayson, 1996 and Ramsar Convention, 1996

Figure 12-2: Monitoring Protocol for this Project

12.8.2.4 Monitoring Programme

Table 12-2: Recommended Environmental Monitoring Programme

S/N	Aspects	Project Phase (PC, C, O[4])	Monitoring Parameters	Monitoring Method	Frequency/ Duration/ Location	Responsible Person	Reporting/ Notes	Related Ecosystem Level LAC (see *Appendix 7.3*) and/or Other Criteria
1	Surface Water Quality (physio-chemical)	PC, C, O	In-situ measurement: - Temperature (°C) - pH - EC (µS/cm) (conductivity) - Turbidity (NTU) - Secchi Depth - Dissolved oxygen (DO) - Chlorophyll-a (in-situ chlorophyll sensor) Laboratory (ex-situ) analysis: - pH - EC (µS/cm) (conductivity) - Turbidity (NTU) - Chlorophyll-a (fluorescence-based spectrophotometer) - Metals and metalloids (including Aluminium, Arsenic, Copper, Iron, Lead, Manganese) - Total Suspended Solids (TSS) - Major ions (including chloride) - Grease and oil - 2-MIB - Geosmin - Microcystin-LR	- In-situ measurement via calibrated YSI probe, 0.5 m below water surface, mid-depth, and 0.5 m above reservoir bed. - Water sampling at mid-depth and 0.5 m above the reservoir bed for lab (ex-situ) analyses. - Vertical profiles using Fine Scale instrument at <0.1m vertical resolution using Fine Scale profiler (e.g. high end YSI or Seabird). - Temperature probe to detect 0.1 °C differences. - All equipment to be calibrated according to manufacturer's guidelines. - Analysis completed at accredited laboratory.	- At least 3 months pre-construction. In-Situ Measurement: - Continuous throughout project duration (pre-construction, construction and operation phase) for parameters monitored via online sensors. Laboratory (ex-situ) Analysis: - Monthly throughout construction. - Post-construction monitoring for three years: monthly for pH, turbidity, conductivity, chlorophyll-a, arsenic and manganese; other parameters to be monitored quarterly. - Noting surface water quality monitoring will occur throughout the operational lifespan of the FPV, reassess parameters/ frequency/ duration and location after initial 3 years post-construction. - Locations to be confirmed with relevant Government Agencies/ Authorities based on final design.	Developer/ Owner	- Informs LAC 1 and surface water quality and biodiversity impacts. - Temperature informs LAC accuracy. - Reporting of trends, monthly during construction and monthly/ quarterly during operations. Compare data against meteorological data and any available complementary biological monitoring (e.g. plankton etc). - Supplement data set with ongoing PUB surface water quality monitoring results.	**a) Ecosystem Level LAC 1 Criteria: Reservoir Water Temperature** Justification: Temperature governs the kinds and types of aquatic life, it partly regulates the maximum dissolved oxygen concentrations, mixing within the Kranji Reservoir and influences the rates of chemical and biological reactions, as well as the toxicity of chemicals. Criteria: Not more than 0.3°C increase in temperature throughout the whole water column (PUB guideline criteria). **b) Dissolved Oxygen (DO) Criteria:** - Not below 3 mg/L for dissolved oxygen throughout the whole water column. **c) Other Criteria:** Other water quality parameters to be monitored concern the treatability of the water for potable use include: - pH, turbidity, conductivity, chlorophyll-a, total nitrogen, total phosphorous, TOC, DOC, nitrate (as N), phosphate (as P), aluminium, arsenic, copper, iron, lead, manganese, ammonia (as N), and chloride. **d) Alert levels:** Two-tier alert levels are proposed in discussion with PUB, during construction and operation, based on latest baseline data sets from PUB, within an agreed time period, for Kranji Reservoir. Exact levels are to be agreed with PUB closer to the commencement of construction and operational stages. Alerts (% of agreed baseline data): - Level 1: 75th-percentile = investigation into cause (both construction and operation) - Level 2: 95th-percentile = cease works (during construction) and implement mitigation agreed with relevant stakeholders (during operation)

[4] PC = Pre-Construction, C = Construction, O = Operation

S/N	Aspects	Project Phase (PC, C, O[4])	Monitoring Parameters	Monitoring Method	Frequency/ Duration/ Location	Responsible Person	Reporting/ Notes	Related Ecosystem Level LAC (see *Appendix 7.3*) and/or Other Criteria
2	Surface Water Quality (Continuous, online)	PC, C, O	- Temperature (°C) - Turbidity - Dissolved Oxygen (DO) - pH - EC (µS/cm) (conductivity) - Chlorophyll-a (fluorescence-based spectrophotometer)	- Continuous online monitoring meters at multiple locations (at least three locations). - Routinely calibrate turbidity readings against regular TSS grab samples results	- Continuous at least 3 months pre-construction. - Continuous throughout construction - Continuous post-construction throughout the entire project operation (including decommissioning). - Noting surface water quality monitoring will occur throughout the operational lifespan of the FPV, reassess parameters/ frequency/ duration and location after initial 3 years post-construction. - Locations to be confirmed with relevant Government Agencies/ Authorities based on final design.	Developer/ Owner	- Informs LAC 1 and surface water quality and biodiversity impacts. - Reporting of trends, monthly during construction and monthly during operations. Compare data against meteorological data and any available complementary biological monitoring (e.g. plankton). - If guideline criteria not met, then investigation process to be initiated (which may include additional water quality parameters not listed).	See S/N 1.

3	Light penetration into water column	PC, C, O	- Light (Photosynthetically Active Radiation, PAR)	- Self-cleaning PAR logger.
				- Underwater PAR to facilitate derivation of extinction coefficient (cf with Secchi depth measurements)
				- All equipment to be calibrated according to manufacturer's guidelines.
				- Analysis completed at accredited laboratory.
				- Regularly serviced for cleanliness, power, malfunctions.
				- Duplicate deployment of paired loggers (for failsafe and data correlation) deployed coincidentally under 3 scenarios at depth of 1m:
				  - Beneath panel array.
				  - Within corridors between panel arrays.
				  - Distant from panel arrays and other shading factors.
				- At 1 site within each scenario, additional paired loggers deployed at 2m depth.
				- N= 14 loggers (at 1m) 6 loggers (at 2m) + another pair deployed above water surface away from shading factors = 20 loggers
				- Regularly serviced for cleanliness, power, and malfunctions.
				- Number of sites could be reassessed after the first 6 months of construction. If little variability between the replicates,
					- Continuous measurements taken during daylight hours every 10 minutes.
					- At least 3 months during pre-construction.
					- Throughout construction. Reassess the number of sites after the first 6 months of construction. If there is little variability between the then consider reducing number of PAR loggers.
					- 6-monthly post-construction for three years.
					- Noting surface water quality monitoring will occur throughout the operational lifespan of the FPV, reassess parameters/ frequency/ duration and location after initial 3 years post-construction.
					- Locations to be confirmed with relevant Government Agencies/ Authorities based on final design.
						Developer/ Owner	- Informs LAC 3 & 4 and surface water quality and biodiversity impacts.
							- Reporting of trends, monthly during construction and 6 monthly during first 3 years of operations. Compare against meteorological data and any available complementary biological monitoring (e.g. plankton).
								See S/N 6 & 7.

S/N	Aspects	Project Phase (PC, C, O[4])	Monitoring Parameters	Monitoring Method	Frequency/ Duration/ Location	Responsible Person	Reporting/ Notes	Related Ecosystem Level LAC (see *Appendix 7.3*) and/or Other Criteria
				then consider reducing to 1 site per scenario instead of 2 to 3.				
4	Nutrients	PC, C, O	- Nutrients (TP, TN, TOC, DOC, Nitrate (as N), Phosphate (as P), and Ammonia (as N))	- Water sampling can be carried out and reported alongside S/N 1, if appropriate. - All equipment to be calibrated according to manufacturer's guidelines. - Analysis completed at accredited laboratory.	- At least 3 months pre-construction. - Monthly throughout construction. - Post-construction monitoring for three years: monthly for total nitrogen, total phosphorous, TOC and ammonia (as N). Other parameters to be monitored quarterly. - Noting surface water quality monitoring will occur throughout the operational lifespan of the FPV, reassess parameters/ frequency/ duration and location after initial 3 years post-construction, as monitoring may be able to taper off once biotic and abiotic relationships is well established/ understood. - Locations to be confirmed with relevant Government Agencies/ Authorities based on final design.	Developer/ Owner	- Informs LAC 2 and surface water quality and biodiversity impacts. - TP concentration informs LAC accuracy. - Ammonia (as N) and TOC are both indicators for trophic states, as well as parameters affecting potability of water (and the necessary treatment). - Reporting of trends, monthly during construction and monthly/ quarterly during first 3 years of operations. Compare TP trends against any surface water quality monitoring data, meteorological data and any available complementary biological monitoring (e.g. plankton). - Supplement data set with ongoing PUB surface water quality monitoring results.	**<u>a) Ecosystem Level LAC 2 Criteria: Nutrients</u>** Justification: The empirical data suggest Kranji is a eutrophic system, where nutrients, in particular phosphorus (P), are readily available. Nutrients entering the reservoir, via surface runoff, appears to be driving the abundance and dominance of primary producing taxa and a main determinant of primary production. Nutrients could be affected by disturbance of the benthos during construction and run-off from the catchment. Criteria: Two-tier alert levels are proposed in discussion with PUB, during construction and operation, based on latest baseline data sets from PUB, within an agreed time period, for Kranji Reservoir. Exact levels are to be agreed with PUB closer to the commencement of construction and operational stages. **<u>b) TOC and Ammonia Criteria:</u>** Other water quality parameters to be monitored concern the treatability of the water for potable use. - Total organic carbon (TOC) to not exceed 10 mg/L throughout the whole water column - Ammonia to not exceed 0.5 mg/L throughout the whole water column **<u>c) Other Criteria:</u>** Other water quality parameters to be monitored concern the treatability of the water for potable use, including: - pH, turbidity, conductivity, chlorophyll-a, total nitrogen, total phosphorous, TOC, DOC, nitrate (as N), phosphate (as P), aluminium, arsenic, copper, iron, lead, manganese, ammonia (as N), and chloride. **<u>d) Alert levels:</u>** Two-tier alert levels are proposed in discussion with PUB, during construction and operation, based on latest baseline data sets from PUB, within an agreed time period, for Kranji Reservoir. Exact levels are to be agreed with PUB closer to the commencement of construction and operational stages. Alerts (% of agreed baseline data):

S/N	Aspects	Project Phase (PC, C, O[4])	Monitoring Parameters	Monitoring Method	Frequency/ Duration/ Location	Responsible Person	Reporting/ Notes	Related Ecosystem Level LAC (see *Appendix 7.3*) and/or Other Criteria
								- Level 1: 75th-percentile = investigation into cause (both construction and operation) - Level 2: 95th-percentile = cease works (during construction) and implement mitigation agreed with relevant stakeholders (during operation)
5	Sediment Quality	PC, C, O	- Nutrients - Contaminants/ metals - Hydrocarbons	- Sediment sampling via Ekman grab sampler. - Analysis completed at accredited laboratory.	- A single sample event during pre-construction at various locations. - At least one sampling event within 24 hours after unplanned event (spill) during construction or operation. - Additional monitoring as per unplanned event, as agreed with relevant Government Agencies/ Authorities. - Locations to be confirmed with relevant Government Agencies/ Authorities.	Developer/ Owner	- Informs surface water quality impacts. - Monitoring to be included in Spill Prevention and Emergency Response Plan, including unplanned event management process.	N/A
6	Plankton	PC, C, O	- Plankton (Phytoplankton and/ or Zooplankton)	- Method to be aligned with PUB's existing survey method statement, i.e. 1L water sample collection at 0.5m from water surface without the use of plankton net, alongside surface water sampling programme. - Supplement with PUB ongoing monitoring program data	- At least 3 months pre-construction. - Monthly throughout construction. - Quarterly post-construction for three years. - Reassess frequency/ duration and location after initial 3 years post-construction, as monitoring may be able to taper off once biotic and abiotic relationships is well established/ understood. - Locations to be confirmed with relevant Government Agencies/ Authorities.	Developer/ Owner	- Informs LAC 3 and 4 and biodiversity impacts. - Reporting of trends, monthly during construction and quarterly during first 3 years of operations. Compare against surface water quality (chlorophyll-a) measurements (fluorescence-based spectrophotometer and lab analysis) and meteorological data and any available complementary monitoring. - Supplement with PUB ongoing monitoring program data. - If guideline or LAC criteria not met, then investigation process to be initiated.	**a) Ecosystem Level LAC 3 Criteria: Plankton** . Justification: Zooplankton and/ or Phytoplankton serve as indicators of environmental conditions, trophic status, and maximum photosynthetic rates, and are sensitive to changes in surface water quality in the Kranji Reservoir, either as a result of the FPV or pressures from the catchment. Criteria: Large deviations that exceed those normally found by PUB in abundance of species that are indicative of eutrophic waters should be a trigger for more frequent monitoring surveys and investigation, where appropriate. Follow up investigation should ensure that sampling is representative of the whole project and includes sampling locations both along the shoreline and sites further away from the shoreline where water depth is likely to be greater. Sampling method should be consistent throughout, and replicates expected to produce similar results.
7	Fish	PC, C, O	- Fish biomass & size class	- Hydroacoustic survey. - A minimum of ten tracks around the reservoir edges and access between panels repeated using the same technique as Baseline surveys (as allowed within final project footprint) to determine whether biomass is increasing or decreasing. Location of tracks that will	- A single sample event during pre-construction. - Annually throughout construction in areas that are accessible. - Annually for three years post-construction.	Developer/ Owner	- Informs LAC 4 and 5 and biodiversity impacts. - Reporting of trends, annually during construction and three years post-construction. Compare to fish biomass data from previous years.	**a) Ecosystem Level LAC 5 Criteria: Fish biomass and size class** Justification: Changes in Kranji Reservoir surface water quality may have an impact on the biomass of fish present in the reservoir. Criteria:

S/N	Aspects	Project Phase (PC, C, O[4])	Monitoring Parameters	Monitoring Method	Frequency/ Duration/ Location	Responsible Person	Reporting/ Notes	Related Ecosystem Level LAC (see *Appendix 7.3*) and/or Other Criteria
				be assessed to be based on final FPV layout. - Consideration to be given to ongoing PUB management of aquatic vegetation outside of Reservoir Project Site (subject to further discussions between PUB and the Developer/ Owner).	- Reassess frequency/ duration and location after initial 3 years post-construction, as monitoring may be able to taper off once biotic and abiotic relationships is well established/ understood. - Locations to be confirmed with relevant Government Agencies/ Authorities.		- If guideline or LAC criteria not met, then investigation process to be initiated.	Fish biomass reduction no more than 50% of baseline values (based on high levels of natural variation reported in other reservoirs and professional judgement) across Reservoir Project Site. Greater biomass was recorded in deeper parts of the reservoir and to the south of the Reservoir Project Site.
8	Focal Bird Species and overall waterbird community	PC, C, O	- Minimum counts of species richness (focal birds) and species abundance (waterbirds)	- Point counts of focal bird species foraging and waterbirds by Vantage Point Survey (VPS). Focal bird foraging events: - 3 hrs per month per 6 no. VP (36 hrs per VP per year). Waterbirds number of species: - 20-minute count for waterbirds from each VPS each month. Mapping of flight paths to identify if any behavioural changes post construction	- At least 1 sample event at each of the 6 no. VP during pre-construction. - Monthly at each of the 6 no. VP throughout construction. - Monthly at each of the 6 no. VP for three years post-construction. - Reassess frequency/ duration and location after initial 3 years post-construction, as monitoring may be able to taper off once biotic and abiotic relationships is well established/ understood. - Locations to be confirmed with relevant Government Agencies/ Authorities.	Developer/ Owner	- Informs LAC 6 and biodiversity impacts. - Reporting of trends, annually during construction and three years post-construction. Compare to focal species and overall waterbird community data from previous years. - If guideline or LAC criteria not met, then investigation process to be initiated.	**a) Ecosystem Level LAC 6 Criteria:** **Focal Bird Species and overall waterbird community** Justification: Migratory and resident waterbirds use the reservoir as a foraging/ nesting/ roosting ground and are utilising the natural resources there. These values have the potential to be impacted by loss of foraging habitat, decreases in aquatic prey abundance, function, as well as the change of ecosystems/ habitats in the wider catchment. Criteria: Foraging by focal bird populations to not significantly fall below average count number recorded during baseline surveys and control site(s) (if any). See *Table 6-1 in Appendix 7.3* for species-specific targets. This includes species of conservation concern and others representative of the bird community. Waterbird assemblage to not significantly fall below average number of species recorded during baseline surveys and control sites(s) (if any). The average number during baseline surveys is 8 species.
9	Focal Species of high conservation concern	PC, C, O	- Continued presence at Kranji Reservoir	Focal birds: - Point counts via VPS (see above). Black-crowned night heron (BCNH): - Incidental observations during bird point counts (see above) to confirm BCNH continue to roost at eastern and western shoreline. Grey-headed fish eagle: - Incidental observations during bird point counts (see above) to confirm breeding behaviour at recorded nest site (during breeding season). Smooth-coated otter:	- At least 1 sample event (i.e. for birds, see above) during pre-construction - Throughout construction (i.e. monthly for birds, see above). - Monthly at each of the 6 no. VP for three years post-construction (i.e. monthly for birds, see above). - Reassess frequency/ duration and location after initial 3 years post-construction, as monitoring may be able to taper off once biotic and abiotic relationships is well established/ understood.	Developer/ Owner	- Informs LAC 7 and biodiversity impacts. - Reporting of presence/ trends, annually during construction and three years post-construction. - If guideline or LAC criteria not met, then investigation process to be initiated.	**a) Ecosystem Level LAC 7 Criteria: Focus Species of High Conservation Concern** Justification: Species dependent, or partly dependent, on the reservoir with a high (VU), very high (EN) or extremely high risk (CR) of extinction in Singapore (based on Singapore Red Data Book). These species are likely to be affected by loss of foraging habitat, decreased prey abundance and changes within the wider catchment. Criteria: Continued presence of black-crowned night heron (nationally EN) roost, detected on at least two occasions each year, 6 months apart.

S/N	Aspects	Project Phase (PC, C, O[4])	Monitoring Parameters	Monitoring Method	Frequency/ Duration/ Location	Responsible Person	Reporting/ Notes	Related Ecosystem Level LAC (see *Appendix 7.3*) and/or Other Criteria
				- Incidental observations during bird point counts (see above) of smooth-coated otter activity on reservoir.	- Locations to be confirmed with relevant Government Agencies/ Authorities.			Continued sighting within Kranji Reservoir and/ or active use of nest by grey-headed fish eagle (nationally VU) at Sungei Kadut Forest during this species' breeding season. Continued foraging of smooth coated otter (nationally EN) within Kranji Reservoir and immediately surrounding habitats.
10	Airborne Noise (for biodiversity)	PC, C	- Leq (5-minutes, 1 hr, 12 hr as applicable)	- Type 1 noise meter (conform with international standard IEC 61672-1 Electroacoustics – Sound level meters – Part 1: Specifications). - One continuous week during piling activities within 90 m of Kranji Marshes boundary. - One continuous week during piling activities within 50 m from BCNH roosting sites on eastern/ western shorelines.	- At least 1 sample event during pre-construction - One continuous week during piling activities within 90 m from the Kranji Marshes Boundary. Review monitoring requirements, subject to monitoring results. - One continuous week during piling activities within 50 m from the BCNH roosting sites on eastern/ western shorelines. Review monitoring requirements, subject to monitoring results. - Locations to be confirmed with relevant Government Agencies/ Authorities	CT	- Informs biodiversity impacts verification. - Logged levels above authority agreed limits for biodiversity to be highlighted. - Reporting monthly during monitoring events. Compare to relevant thresholds/ criteria, and monthly focal bird/ waterbird data. Comparison to be reviewed to determine if adaptive management is required. - If guideline criteria not met, then investigation process to be initiated.	N/A
11	Airborne Noise (for humans)	PC, C	- Leq (5-minutes, 1 hr, 12 hr as applicable)	- Type 1 noise meter (conform with international standard IEC 61672-1). - One continuous week during pre-construction - One continuous week every quarter during construction - Locations to be placed at the nearest affected noise sensitive receptors directly facing the Project worksites. - Noise monitoring devices to be installed at the exterior of the affected noise sensitive buildings at least 1 meter away from any large reflecting surfaces, such as a façade of the building. - The noise microphone shall have a direct line of sight to the Project worksites without any obstruction.	- At least 1 sample event during pre-construction - Quarterly throughout construction - Locations to be confirmed with relevant Government Agencies/ Authorities	CT	- Informs noise impacts verification. - Reporting quarterly during construction. - Compare to relevant thresholds/ criteria. Comparison to be reviewed to determine if adaptive management is required. - Recorded noise levels to be used to derive applicability of correction factors to the maximum permissible noise levels, as specified in the applicable regulatory. - Note down any other sources of noise (noise sources not associated to the construction phase of the Project) (e.g. traffic	N/A

S/N	Aspects	Project Phase (PC, C, O[4])	Monitoring Parameters	Monitoring Method	Frequency/ Duration/ Location	Responsible Person	Reporting/ Notes	Related Ecosystem Level LAC (see *Appendix 7.3*) and/or Other Criteria
							count, nearby construction sites, aircraft, etc.). - If regulatory or criteria not met, then investigation process to be initiated.	

13. CONCLUSION

An assessment of the potential environmental impacts associated with the pre-construction, construction and operation of the Project has been conducted. A Developer/ Owner will be selected after the acceptance of the EIA. The Developer/ Owner will ensure that detailed design is developed within the parameters, boundaries and limits (e.g. adhering to mitigation measures) identified through the EIA process. The Developer/ Owner is to demonstrate to relevant Government agencies that the final design conforms to the EIA.

The impact assessment draws on 20 months of environmental baseline field surveys including (but not limited to):

- Ambient air quality;
- Airborne noise;
- Reservoir water quality, light penetration and reservoir bed sediment quality; and
- Biodiversity (terrestrial and aquatic flora and fauna).

This Section summarises the main environmental outcomes associated with the Project, taking into account both embedded controls and mitigation measures[1]. The assessment of environmental impacts was based on a review of the Project construction and operation activities anticipated for the works against environmental aspects, namely surface water quality, biodiversity, air quality, airborne noise and vibration, soil and groundwater and vectors.

A precautionary approach has been taken for this Project's EIA. The EIA has considered conservative scenarios in the undertaking of the impact assessment for each environmental aspect, these are described in each *Section* as appropriate. In addition, a precautionary approach has been adopted for assigning some residual (post-mitigation) impact significance, e.g. despite mitigation, pre-mitigation significance levels may have been retained post-mitigation where, for example, there are limited baseline or study data, or uncertainties of impacts over the longer term. Residual impact significance levels are to be validated through establishment of comprehensive long-term monitoring, datasets and analysis throughout pre-construction, during construction and post-construction (see *Section 12, Environmental Management and Monitoring Plan*).

An ecosystem level approach, called Ecological Character Description (ECD)[2], was developed to understand the Kranji Reservoir ecosystem across a range of both abiotic (non-living) and biotic (living) elements of the waterbody, as well as an understanding of human use, existing environmental stresses and ecosystem services. The ECD considered the outcomes of the Project's development and how they could affect the Kranji Reservoir's main ecosystem components, processes, and services. The ECD establishes "Limits of Acceptable Change" (LAC) (similar to the typical impact monitoring threshold criteria) against which to monitor the Kranji Reservoir ecosystem changes and provide early indicators to enable effective adaptive management if required.

A number of potential positive environmental benefits have been identified through the EIA process from the Project, including:

- Improvement for certain surface water quality parameters (nutrients and chlorophyll-a levels) during operation;
- Management of non-native and invasive aquatic vegetation in the Reservoir Project Site during construction and operation;

[1] Embedded controls are defined as measures (physical or procedural) controls that are planned to be put in place as part of the Project design, construction and operation from the outset. They are predominantly based on the regulatory and industry standard requirements, reservoir operational requirements from PUB, as a result of engagements with relevant Government agencies. For further details refer to *Appendix 2.2*. The mitigation measures presented herein are over and above the Project "embedded controls".

[2] This approach is adapted from the Ramsar Convention on Wetlands ECD approach to wetland management.

- FPVs providing stable (non-moving) shade and nursery habitats for fish and resting habitat for species such as birds, including little tern, herons and egrets, and non-flying (i.e. swimming) terrestrial fauna during operation; and
- A reduction of Singapore's Greenhouse Gas emissions through the use of renewable energy, as well as a reduction in fossil fuel usage during operation.

Should any of the design, construction, operational and/ or unplanned event assumptions assessed in the EIA change (i.e. be considered to be greater, or more impactful, than those assumed in this assessment) as a result of the Developer/ Owner's detailed design, construction methodology and operation, the impact assessments should be reviewed, and adaptive management measures implemented to ensure impacts are smaller than or equal to the impact significances assessed herein.

Table 13-1 presents a summary of the overall assessment of impacts for each environmental aspect considered, and their impact significance with embedded controls only (i.e. without mitigation) and with mitigation (including monitoring and adaptive management), i.e. residual impact significance. Residual impacts, with mitigation, have been reduced to as low as reasonably practicable (ALARP), and range from ***Negligible to Moderate*** during both construction and operation phases. Residual moderate impacts are associated with:

- Construction:
  - Surface Water Quality:
    - Sediment disturbance from deployment of ballasted foundations/ piles and mooring lines; and
    - Degradation/ change of surface water quality from trimming of aquatic vegetation.
  - Biodiversity:
    - Disturbance to terrestrial fauna (piling in reservoir) – on a precautionary basis.
- Operation:
  - Surface Water Quality:
    - Change of hydrodynamics and surface water quality from the presence of FPV in reservoir.
  - Biodiversity:
    - Changes to the planktonic and/ or benthic communities – on a precautionary basis; and
    - Reduced foraging opportunities on reservoir surface for terrestrial fauna – on a precautionary basis.

Should any notable deterioration or adverse trend in the criteria and monitoring data be observed, relevant Government agencies should be notified, and the cause should be investigated. The investigation should determine whether the observed deterioration/ trend can be attributed to the construction or operation of the Project. The Developer/ Owner should liaise with relevant Government and Technical Agencies/ authorities closely on monitoring results and investigation findings and seek agreement on management action(s), which may include potential layout changes, removal of the FPV etc, where appropriately agreed between responsible Government Agencies and the Developer/ Owner. Where observations are not attributable to the Project, the Developer/ Owner will liaise with relevant Government Agencies responsible for managing the identified effects for their action.

A comprehensive monitoring programme is recommended during pre-construction, construction and operation to verify impacts assessed within the EIA, and to monitor the longer-term trends against established criteria, in particular related to surface water quality, biodiversity and airborne noise. The monitoring programme enables the application of adaptive management approaches to further minimise environmental impacts during the construction and operation of the Project, if necessary.

Table 13-1: Summary of the EIA Outcomes

Environmental Aspect	Pre-mitigation Impact Significance	Residual Impact Significance (with mitigation)	Notes
CONSTRUCTION			
Surface Water Quality (Section 6)	**Negligible to Major** **Major:** ■ Sediment disturbance from deployment of anchors/ ballasted foundations/ piles and mooring lines ■ Degradation/ change of surface water quality from trimming of aquatic vegetation **Moderate:** ■ Site runoff, wastewater and sediment disturbance from preparation of the proposed temporary Staging/ Launching Area ■ Sediment disturbance from geotechnical/ site investigation in reservoir ■ Sediment disturbance from launching, towing and installation of FPV and ancillary equipment at designed locations ■ Sediment disturbance from installation of connector cables (between FPV islands and to shore) ■ Sediment disturbance from construction of O&M berthing facility (location subject to approval from agencies) ■ Unplanned event - Degradation/change of surface water quality from unplanned events of fire and explosion – in-reservoir ■ Unplanned event - Degradation/change of surface water quality from unplanned event of failure of erosion control measures (ECM)/ environmental spill – in-reservoir	**Negligible to Moderate** **Moderate:** ■ Sediment disturbance from deployment of ballasted foundations/ piles and mooring lines ■ Degradation/ change of surface water quality from trimming of aquatic vegetation	■ A programme of monitoring and adaptive management is proposed to verify and minimise impacts on surface water quality during construction, see *Section 12* (EMMP) for further details.
Biodiversity (Section 7)	**Negligible to Moderate** **Moderate:** ■ Elevation of pollutants and/or nutrients within the reservoir ■ Disturbance to aquatic fauna (piling, boat movements) ■ Terrestrial habitat clearing/ fragmentation ■ Disturbance to terrestrial fauna (piling in reservoir) ■ Disturbance to terrestrial fauna (land-based worksite) ■ Disturbance to terrestrial fauna (in-reservoir piling and land-based worksite night lighting) ■ Disturbance to terrestrial fauna (boat movements and use of helicopters) ■ Generation of dust from land-based worksite ■ Loss/ degradation of integrity of Protected Areas ■ Unplanned event - Habitat degradation from unplanned event of fire/ explosion and environmental spills	**Negligible to Moderate** **Moderate (retained at pre-mitigation levels on a precautionary basis)**: ■ Disturbance to terrestrial fauna (piling in reservoir) – on a precautionary basis	■ Although the mitigation proposed is likely to reduce the piling noise level to less than the 70 dB(A) and 62dB(A) (western shoreline) and 64dB(A) (eastern shoreline), the residual impact magnitude and significance for this impact has been retained at pre-mitigation levels on a precautionary basis subject to Developer/ Owner selection of detailed construction approaches (e.g. location of piling, phasing, number of simultaneous piles etc) and related mitigation measures described in the EIA. ■ A **positive** impact may result from the management of non-native and invasive aquatic vegetation in the Reservoir Project Site. ■ A programme of monitoring and adaptive management is proposed to verify residual (post-mitigation) impacts, and minimise impacts on biodiversity during construction, see *Section 12* (EMMP) for further details.
Air Quality (Section 8)	**Negligible to Minor**	**Negligible**	-
Airborne Noise and Vibration (Section 9)	**Negligible to Major** **Major:** ■ Generation of noise during the land-based construction at the proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M facility) worksite **Moderate:** ■ Generation of vibration during the land-based construction at the proposed temporary Staging/ Launching Area and integrated Project Substation (with O&M facility) worksite	**Negligible to Minor** -	■ A programme of monitoring and adaptive management is proposed to verify and minimise impacts on airborne noise during construction, see *Section 12* (EMMP) for further details.
Soil and Groundwater (Section 10)	**Negligible to Moderate (unplanned event)** **Moderate (unplanned event):** ■ Degradation/ change of groundwater from unplanned event of environmental spill (including related to spills from responses to explosions and fire, and failure of ECM)	**Negligible to Minor (unplanned event)** -	-
Vector (Section 11)	**Negligible to Moderate** **Moderate:** ■ Increase in Vector Populations (Mosquitoes and Rats) at proposed temporary Staging/ Launching Area and integrated Project Substation	**Negligible** -	-

Environmental Aspect	Pre-mitigation Impact Significance	Residual Impact Significance (with mitigation)	Notes
OPERATION			
Surface Water Quality (Section 6)	**Negligible to Major** **Major:** ■ Change of hydrodynamics and surface water quality from the presence of FPV in reservoir **Moderate**: ■ Wastewater and sediment disturbance from the O&M of FPV facilities (including cleaning of PV panels) in reservoir **Moderate (unplanned event):** ■ Degradation/change of surface water quality from unplanned events of fire and explosion – in-reservoir ■ Degradation/change of surface water quality from unplanned event of environmental spill – in-reservoir	**Negligible to Moderate** **Moderate:** ■ Change of hydrodynamics and surface water quality from the presence of FPV in reservoir	■ A **positive** improvement for certain surface water quality parameters (nutrients and chlorophyll-a levels). ■ A programme of monitoring and adaptive management is proposed to verify residual (post-mitigation) impacts, and minimise impacts on surface water quality during operation, see *Section 12* (EMMP) for further details.
Biodiversity (Section 7)	**Negligible to Moderate** **Moderate:** ■ Changes to the planktonic and/or benthic communities ■ Reduced foraging opportunities on reservoir surface for terrestrial fauna ■ Loss/ degradation of integrity of Protected Areas ■ Unplanned event - Habitat degradation from unplanned event of fire/ explosion and environmental spills	**Negligible to Moderate** **Moderate (retained at pre-mitigation levels on a precautionary basis)**: ■ Changes to the planktonic and/or benthic communities – on a precautionary basis ■ Reduced foraging opportunities on reservoir surface for terrestrial fauna – on a precautionary basis	■ For the plankton community, although mitigation is proposed through detailed design development the residual impact magnitude and significance has been retained at pre-mitigation levels on a precautionary basis due to the (1) limited baseline data available, and (2) uncertainty of the long-term effects on plankton community. ■ For bird foraging, although the assessment is based on a conservative assumption that birds will not compensate for the loss of foraging by changing their foraging behaviours, and that mitigation is proposed through detailed design development and refinement of the FPV layout (i.e. biodiversity mitigation layout)), the residual impact magnitude and significance has been retained at pre-mitigation levels due to the uncertainty of bird responses to the FPV panels. ■ A programme of monitoring and adaptive management is proposed to verify residual (post-mitigation) impacts, and minimise impacts on biodiversity during operation, see *Section 12* (EMMP) for further details. ■ A **positive** impact may result from FPVs providing stable (non-moving) shade and nursery habitats for fish and resting habitat for species such as birds, including little tern, herons and egrets, and non-flying (i.e. swimming) terrestrial fauna. ■ A **positive** impact may also result from the management of non-native and invasive aquatic vegetation in the Reservoir Project Site.
Air Quality (Section 8)	N/A	N/A	■ A **positive** impact on Singapore's air quality is anticipated through the reduction of Singapore's Greenhouse Gas emissions due to the use of renewable energy, as well as reduced fossil fuel usage.
Airborne Noise and Vibration (Section 9)	**Negligible**	**Negligible**	-
Soil and Groundwater (Section 10)	N/A	N/A	-
Vector (Section 11)	N/A	N/A	-

14. REFERENCES

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