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Abbreviations

Acronym	Definition
AECOM	AECOM Singapore Pte. Ltd.
ANZECC	Australian and New Zealand Environment and Conservation Council
ASR	Air Sensitive Receptor
BCA	Building and Construction Authority
BIA	Biodiversity Impact Assessment
COPPC	SS 593: Code of Practice for Pollution Control, 2013
COVID-19	Coronavirus Disease 2019
DGS	Deep Gravity Sewer
DTSS	Deep Tunnel Sewerage System
DTSS2	Deep Tunnel Sewerage System Project Phase 2
DOE	Department of Environment in Malaysia
ECM	Earth Control Measures
ECP	Erosion Control Plan
EIA	Environmental Impact Assessment
EMMP	Environmental Monitoring and Management Plan
EU	European Union
ES	Environmental Study
ESR	Ecologically Sensitive Receptor
GPS	Global Positioning System
HDV	Heavy Duty Vehicles
HK EIAO TM	Hong Kong Environmental Impact Assessment Ordinance – Technical Memorandum
IAQM	UK Institute of Air Quality Management
IUCN	International Union for Conservation of Nature
JS	Jacking Shaft
MA	Management Agent under Sentosa Cove
MND	Ministry of National Development
MSDS	Material Safety Data Sheet
MSS	Meteorological Service Singapore
NBSAP	National Biodiversity Strategy and Action Plan
NEA	National Environment Agency
NGO	Non-governmental organization
NParks	National Parks Board
NSR	Noise Sensitive Receptor
PHILMINAQ	Mitigating Impact from Aquaculture in the Philippines
PRO	Public Relation Officer
PME	Powered mechanical equipment
QECF	Qualified Erosion Control Professional
QSS	Qualified Site Supervisor
RS	Receiving Shaft
SCRM	Sentosa Cove Resort Management (SCRM)
SDC	Sentosa Development Corporation
SIDS	Silty Imagery Detection System
SOP	Standard Operation Procedure
SRDB	Singapore Red Data Book
STC	Sound Transmission Class
TPZ	Tree Protection Zone
UNECE	United Nations Economic Commission for Europe
URA	Urban Redevelopment Authority
UK	United Kingdom
US	United States
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

Glossary of Terms

Term	Explanation
Airborne Noise	Sound that is transmitted by the air e.g. speech. The term airborne noise and noise are used interchangeably in this report and have the same meaning
Air Pollution Control Plan	Plan implemented to ensure implementation of air mitigation measures
Arboricultural Survey	Assessment of tree — is the cultivation, management, and study of individual trees, shrubs, vines, and other perennial woody plants
Baseflow	Fair weather flow, the portion of the streamflow that is sustained between precipitation events, fed to streams by delayed pathways
dB(A)	A-weighted sound pressure levels (dB) – weighted to human hearing frequencies
Construction (Air Section)	Any type of construction activity involving new structures on construction worksites involving powered mechanical machinery
Construction Worksites/ Footprint	Construction areas where surface impacts may occur due to site worksites/ footprint above ground level.
Cryptogenic	Species with unknown origin.
Earthworks	This involves excavating material, haulage, tipping and stockpiling. This may also involve site levelling and landscaping
Emission Sources (Air Section)	Sources of air emissions for different activities such as earthworks, construction and trackout
Exotic Species	Plant or animal species introduced into an area where they do not occur naturally, non-native species.
Likelihood of impact	The impact characteristic of the change predicted to the resource/receptor, whether continuous, regular, occasional, rare or not expected to happen in the construction phase. See Section 6.4.2.2 for these individual definitions
Heavy Duty Vehicle	Heavy duty vehicles defined as vehicles with a gross weight greater than 3.5 tonnes
Hydrology	The study concerned with the properties of the earth's water, and especially its movement in relation to land
In-situ	Testing is carried out in the original place
LAeq (1 hour)	Equivalent noise levels, averaged over a 1 - hour time period
LAeq (12 hour)	Equivalent noise levels, averaged over a 12 - hour time period
LAeq (5 min)	Equivalent noise levels, averaged over a 5 - mins time period
Magnitude of impact	The intensity of the change that is predicted to occur in the resource/receptor as a result of the impact
Mt. Imbiah Study Area	This term generally represents the forested area of approximately 3.61 ha that is connected to Mt. Imbiah, which serves as the study area for the Biodiversity Impact Assessment in this report.
Mt. Serapong Study Area	This term generally represents the forested area of approximately 9.91 ha that is connected to Mt. Serapong, which serves as the study area for the Biodiversity Impact Assessment in this report.
Nature Areas	Identified as Mt. Imbiah and Mt. Serapong
Non-volant Mammals	Non-flying mammals, i.e. all mammals in Singapore, excluding bats
PUB	Singapore's national water agency in public communication materials and non-legal documents.
Receptor sensitivity	The sensitivity of the resource/receptor which is assessed based on their susceptibility to adverse impacts from the Project's construction phase in terms of vulnerability, importance, legal protection, government policy, stakeholder views or economic value.
Sound Pressure Level, Lp	Sound pressure is the difference between the pressure produced by a sound wave and the ambient pressure at the same point in space

Term	Explanation
Species Abundance	The number of individuals per species in an area. Relative abundance refers to the evenness of distribution of individuals amongst species in the area
Species Distribution	Refers to how a species is distributed throughout the area
Topography	The study of the shape and feature of land surfaces
Trackout	The transport of dust and dirt from the construction site worksites/ footprint onto the public road network, where it may be deposited and then re-suspended by vehicles using the network. This arises when heavy duty vehicles (HDVs) leave the construction site with dusty materials, which may then spill onto the road, and/or when HDVs transfer dust and dirt onto the road having travelled over muddy ground on site.
Type of impact	The impact characteristic of the change predicted to the resource/receptor, whether direct or indirect
Wet Weather	Indicated weather with rainfall more than 10mm based on real-time observations from the online public domain under Meteorological Service Singapore.

1. Executive Summary

This **Environmental Study Final Report** is written in two parts, where **Part II (this document)** details the main study findings, while Part I (refer to the separate document attached) provides the executive summary of the detailed findings from this document.

2. Introduction

AECOM Singapore Pte Ltd was appointed by the Sentosa Development Corporation (hereinafter referred to as “SDC” or “the Client”) to conduct an Environmental Study under the Contract No. SDC/21.8.2/19 - Provision of Multi-Disciplinary Consultancy Services For The Proposed Deep Gravity Sewer Project at Sentosa (hereinafter referred to as “the Project”).

This Project falls within Sentosa island located at the southern part of Singapore. The existing sewer network on Sentosa comprises a combination of gravitational surface sewer networks and sewer pumping systems (including pumping stations, pumping mains and mechanical & electrical parts). This sewer network was constructed about 30 to 40 years ago and is now showing signs of dilapidation with frequent breakdowns and chokage, posing constant odour and contamination risks. Moreover, the aging pumping systems now require more effort to monitor/maintain and are in need of periodic replacement. As such, while aligning with the Public Utilities Board (PUB)’s approach in phasing out and replacing sewer pumping systems on main land Singapore with the Deep Tunnel Sewerage System (DTSS), SDC intends to phase out 11 sewer pumping stations on Sentosa island by implementing pure gravitational Deep Gravity Sewers (hereinafter referred to as “DGS”) system as a more efficient, reliable and sustainable long term solution. This new DGS system is intended to serve Sentosa Island for the next 100 years.

According to current planning, the proposed DGS of this Project will consist of approximately 3.9 km of 1,200 mm diameter pipes, 2.0 km of 1,500 mm diameter pipes and 148 m of 2,000 mm diameter pipes with a total of 40 proposed manholes, as well as other ancillary sewer pipes connected to the DGS system with small ancillary manholes of diameter ranging from 300 mm to 600 mm. It will carry the wastewater discharge collected from all the existing surface sewers and discharge into a proposed link sewer manhole located on Sentosa, near the Sentosa Gateway Gantry at the northern side of the island, which is under construction by PUB’s appointed contractor under Phase 2 of the Deep Tunnel Sewerage System Project (DTSS2).

The Objective of this Environmental Study was to assess the potential environmental impacts arising from the construction phase of the Project on human and ecologically sensitive receptors. This Environmental Study provided a pre-construction environmental baseline status along the route of the project alignment. It covers the construction impacts on the environment mainly from the above-ground manhole/ shaft construction and underground pipejacking activities (i.e. biodiversity, airborne noise, air quality, surface water quality). Additionally, where the impacts were deemed to be “Significant” or “Moderate/Major”, appropriate mitigation measures to be implemented during the construction works were also recommended.

It should be noted that this report was written based on the preliminary proposed design and baseline environment surveyed between November 2020 to January 2021 (during the COVID-19 pandemic period). If there are major changes in the engineering design in the future and/or changes in baseline environment (e.g. increase in baseline human noise after COVID-19 period), the findings of this report shall be discussed and re-evaluated where necessary.

2.1 Scope of Work

Prior to the commission of the Environmental Study, authority consultation was undertaken by SDC with relevant agencies (e.g. NEA, NParks) for the scoping of the Environmental Study. Following a scoping meeting with the Technical Agencies (TAs), the scope of the Environmental Study was documented in the form of the Inception Report [G-1] accepted by NEA and NParks on 8 January 2021 and 2 March 2021 respectively. The scope was summarized as follows:

- Definition of a study area from around the Project construction footprint, considered for the assessment of environmental impacts;

- Identification of sensitive receptors for biodiversity, airborne noise, air quality, as well as surface water quality;
- Prediction and evaluation of impacts;
- Recommendation of mitigation measures;
- Assessment of residual impact; and
- Recommendation of Environmental Monitoring and Management Plan (EMMP).

This Environmental Study had assessed design elements, construction methodology, project components, within the engineering design scope available at the time of writing. Understanding of the project construction methods was clearly stated in Section 3, and detailed assumptions, if any, were described in individual assessment sections thereafter. Should the preliminary design make alterations to these assumptions/approaches at later stage, a revised impact assessment shall be undertaken by SDC to address these changes.

2.2 Report Structure

The structure of the report was presented as follows:

- **Section 1** – Executive Summary provided an overview of the key highlights in this report which included the Objective of Environmental Study, Project Activities and Schedule, Design Optimization, and a Summary of Impact Assessment for this Project;
- **Section 2** – Introduction of this report provided an overview of the Scope of Work, Report Structure, and Study Limitations, Assumptions and Constraints of this Environmental Study;
- **Section 3** – Description of the Project provided a general description of the background and components including location overview, design optimization, construction activities and schedule of this Project;
- **Section 4** – Description of the Environment provided a general description of the site setting/ study area, land use, historical features, topography, geology, water catchment and climate of the Project;
- **Section 5** – Environmental Legislations, Policies, Guidelines, Plans, Standards and Criteria for the impact assessments in this report;
- **Section 6** – Description of Assessment Methodologies provided the overview of the methodology used for the assessment;
- **Section 7** – Biodiversity presented the methodology, baseline environment, sensitive receptors, and potential sources of impacts, minimum controls and evaluation of impacts to biodiversity within the study area, along with recommendations for mitigation measures;
- **Section 8** – Airborne Noise presented the methodology, baseline environment, sensitive receptors, potential sources of impacts, minimum controls and evaluation of airborne noise impacts on human and ecologically sensitive receptors within the study area, along with recommendations for mitigation measures;
- **Section 9** – Air Quality presented the methodology, baseline environment, sensitive receptors, potential sources of impacts, minimum controls and evaluation of air quality impacts on human and ecologically sensitive receptors within the study area, along with recommendations for mitigation measures;
- **Section 10** – Surface Water Quality presented the methodology, baseline environment, sensitive receptors, potential sources of impacts, minimum controls and evaluation of impacts to surface water quality within the study area, along with recommendations for mitigation measures;
- **Section 11** – Environmental Monitoring and Management Plan (EMMP) detailed the organizational framework, stakeholder roles and responsibilities, monitoring program requirements and detailed EMMP; and
- **Section 12** – Conclusion provided a summary of the outcomes.

2.3 Study Limitations, Assumptions and Constraints

The information contained in this document originally produced by AECOM Singapore Pte. Ltd. ("AECOM") was produced solely for the use of the Client and was prepared to assist in this Environmental Study required for the Project under Contract No. SDC/21.8.2/19 - Provision of Multi-Disciplinary Consultancy Services For The Proposed Deep Gravity Sewer Project at Sentosa. The focus of this report was limited to the assessment of potential biodiversity, airborne noise, air quality and surface water quality impacts arising from the construction phase of the Project, on ecologically sensitive receptors around the Nature Areas and human receptors along the Project alignment.

AECOM devoted normal professional efforts compatible with the time and budget available in the bid process. AECOM's findings represent its reasonable judgments within the time and budget context of its commission and utilizing the information available to it at the time.

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3. Project Description

This section described the background of the Project, which including the Project location, schedule, construction components, resources required, and wastes generated.

3.1 Project Location

This Project is located in Sentosa Island of Singapore. It is a partially reclaimed island with an area of approximately 5 km² and lies about half a kilometre away from the southern coast of Singapore's main island. Sentosa Island was formerly used as a British military base and then a Japanese prisoner-of-war camp. It is now a popular tourist destination that receives more than 20 million visitors per year. It comprises 3.2 km-long sandy beaches (e.g. Siloso, Palawan, Tanjong beaches) and the associated beach facilities (e.g. Nestopia at Siloso Beach, etc.), transport network (e.g. Sentosa Cable Car, Sentosa Express Monorail, Sentosa Beach Tram), hotel and residential areas (e.g. Festive Hotel, Equarius Hotel, residences at Sentosa Cove etc.), as well as a variety of other entertainment facilities or attractions, such as Universal Studios Singapore theme park, Madame Tussauds Singapore, casino, golf courses and so on [G-1].

Besides, the island is interspersed by secondary rainforests and coastal forests that serve as a home for a number of native flora and fauna, with Mt. Imbiah at the east and Mt. Serapong at the west, both of which were identified as Nature Areas and assessed in this Environmental Study.

As introduced in Section 2, a new DGS system is proposed in this Project to replace the existing sewer network in Sentosa Island. The proposed DGS alignment crosses the entire Sentosa Island from west to east along Artillery Avenue and Allanbrooke Road (east/west-bound) as shown in Figure 3-1. The DGS section along Artillery Avenue and Allanbrooke Road (east/west-bound) is linked to another DGS section along the beach walks (i.e. Siloso Beach Walk, Palawan Beach Walk and Tanjong Beach Walk) at the southern part of the island via Imbiah Road and Allanbrooke Road (south/north-bound).

3.2 Project Component

As introduced in Section 2, the project component of this Project will comprise the construction of approximately 3.9 km of 1200 mm diameter pipes, 2.0 km of 1500 mm diameter pipes and 148 m of 2000 mm diameter pipes with a total of 40 proposed manholes, as well as other ancillary sewer pipes connected to the DGS system with small ancillary manholes of diameter ranging from 300 mm to 600 mm. A total of forty (40) above-ground worksites which range from 300 m² to 700 m² are planned to support the construction of this proposed DGS system.

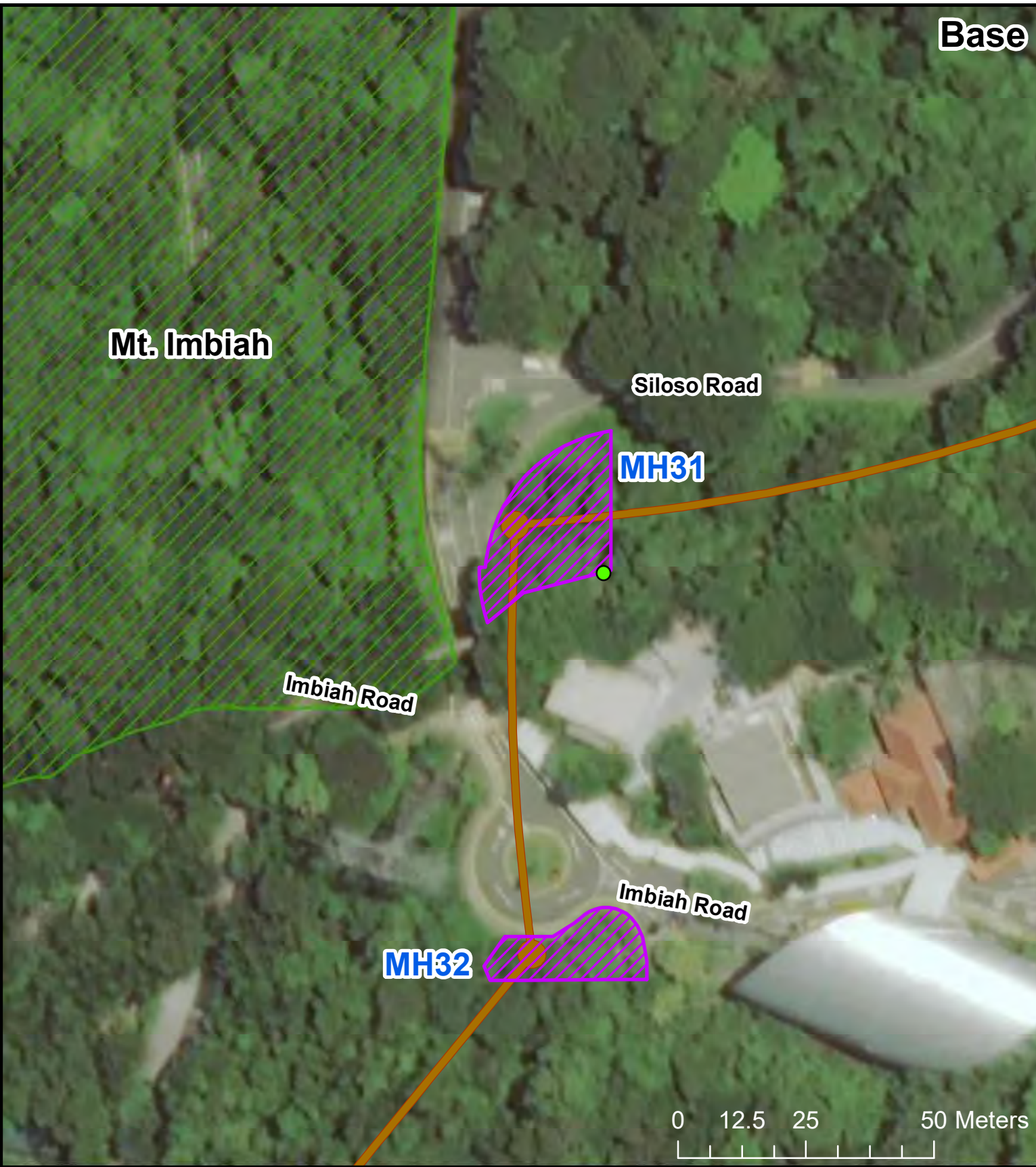
3.2.1 Design Optimization of MH31 Worksite

During this Environmental Study process, feedback was provided to the design engineers when the biodiversity specialist discovered a bamboo cluster with the presence of bamboo bats within the original MH31 worksite of approximately 600 m². It was noted that Bamboo bats are nationally threatened in Singapore and are known to roost inside the internodes of bamboo branches. After multiple discussions with the design team, the MH31 worksite was optimized with a reduced footprint of 400 m². This optimization was targeted to avoid felling of bamboo by setting up a Tree Protection Zone (TPZ) of 6 m radius from the centre of the bamboo cluster, therefore mitigating the biodiversity impact from the construction activities of this Project. The difference between the original and the optimized MH31 worksite was presented in Figure 3-2.

This design recommendation was assessed as one of the mitigation measures for all environmental parameters in this Environmental Study. The impact assessment of the optimized MH31 worksite was detailed in the respective sections of this report.



Legend Pumping Station to be demolished (Separate work package - excluded from Study) Base Construction Worksites DGS Manholes & Pipeline Nature Areas							Qualified Person Endorsement : NA	Consultant : AECOM	Sentosa FOR THE PEOPLE OF SINGAPORE					
								Client Endorsement : NA	Project Title : Contract No. SDC/21.8.2/19: Environmental Study For The Proposed Deep Gravity Sewer Project at Sentosa			Figure Title : Project Overview		
	B	NOV 2021	SYT	Final Report Rev B	JAG/NHT	JAG								
	A	JUL 2021	SYT	Final Report Rev A	JAG/NHT	JAG								
	-	MAY 2021	SYT	Final Report	JAG/NHT	JAG	Designed SYT		Checked JAG/NHT	Approved JAG	Figure No. : 3-1	Rev. B	Sheet 1 of 1	
	Rev.	Date	By	Description	Chk'd	App'd			Drawn SYT	Date NOV 2021	CAD File Name :NA		A3	



Legend Base Construction Worksites Optimized Construction Worksites DGS Manholes & Pipeline Nature Areas Bamboo Cluster							Qualified Person Endorsement : NA	Consultant : AECOM	Sentosa							
												Client Endorsement : NA	Project Title : Contract No. SDC/21.8.2/19: Environmental Study For The Proposed Deep Gravity Sewer Project at Sentosa			Figure Title : Design Optimization for MH31 Worksite
								Designed LYE	Checked JAG/NHT	Approved JAG	Figure No. : 3-2		Rev. B	Sheet 1 of 1		
									Drawn LYE	Date NOV 2021	CAD File Name :NA			A3		
	B	NOV 2021	LYE	Final Report Rev B	JAG/NHT	JAG										
	A	JUL 2021	LYE	Final Report Rev A	JAG/NHT	JAG										
	-	MAY 2021	LYE	Final Report	JAG/NHT	JAG										
	Rev.	Date	By	Description	Chk'd	App'd										

3.3 Project Activities

This section mainly described the pre-construction and main construction activities involved in this Project. Generally in terms of construction hours, above-ground night works could be minimized and/or avoided as much as possible after 6pm as advised by NParks, except for safety-critical works, i.e. pipejacking works where some ancillary equipment (e.g. generator, slurry pump) would need to be continuously switched on for 24 hours during the pipejacking period, whence, the Contractor shall seek SDC's and Agencies' permission in case of emergency (e.g. when challenging underground geological zone is detected) or due to other occasions when night work is necessary to be carried out involving human intervention.

3.3.1 Pre-Construction Activities

Prior to the main construction works, a series of pre-construction activities have to be conducted, which may include temporary traffic and drainage diversion works, site clearance and tree-felling, as well as the establishment of temporary worksites.

3.3.1.1 Temporary Traffic and Drainage Diversion Works

The proposed shaft construction is located mostly at the existing open space or the roadside where the disturbance to traffic is minimal and confined within the designated worksite. If there are sections of selected roads/ footpaths that can be potentially affected by construction works, or restricted where temporary traffic diversion is required, proper hoarding will be set up to demarcate the work boundary and minimize hazard to the public. Proper direction signs will be installed near or along the affected roads to direct public and road vehicles to access the original destination in a safe manner.

The Contractor's Qualified Erosion Control Professional (QECP) will implement proper ECM plan and ensure compliance with PUB's *Code of Water Practice on Surface Water Drainage* for any temporary diversion of existing drains resulting from shaft construction.

3.3.1.2 Site Clearance

The site clearance stage will involve clearance of existing open space and clearance of trees or vegetation. For this, the Contractor's QECP will prepare Erosion Control Plan (ECP) and obtain approval from the Public Utilities Board (PUB). Before tree-felling, the Contractor will also map the trees on site and consult SDC on the tree-felling plan for the trees planned for removal or retention prior to submission for NParks' approval. A separate arboriculture assessment report will be prepared in parallel to this report to identify trees for removal and to evaluate the impact and propose relevant mitigations for unavoidable tree-felling.

At this time, this report must be consulted by the Contractor for following requirements and therefore, plan of action:

- For any areas rich in trees of conservation interest where tree-felling of girth more than 1 m is required [R-48][R-49], the contractor shall employ a certified arborist to map the trees carefully while applying for tree felling approval. This is to gauge the health, species, size, and conservation significance of the tree;
- If there are trees that are required to be protected or transplanted, the trees shall be clearly demarcated by the tree protection zone or suitably tagged prior to commencing site clearance;
- If the area is rich in wildlife, the Contractor shall consult the wildlife specialist and prepare a wildlife shepherding plan. The plan shall be approved by SDC and NParks prior to/ along the site clearance process. In this case, the direction of clearance is set by the Wildlife Shepherding plan. The site clearance is led by wildlife specialist(s), who helps shepherd, save, relocate wildlife as necessary;
- It is best to avoid site clearance in migratory birds or breeding season, as many nests and therefore birds may be sacrificed. In such an event, the wildlife specialist will not only assist in shepherding, but also to spot the birds' nests, and recommend on the spot measures to be taken to avoid disruption;
- Site hoarding process and extent will also be governed by the above factors and the approved plans by NParks; and
- The construction site debris, felled trees and spoil will be temporarily stored on site and then collected by licensed third parties for offsite disposal.

The Safety, Health and Environmental (SHE) Personnel engaged by the Contractor during the construction phase shall incorporate the above-mentioned requirements into the EMMP.

3.3.1.2.1 Demolition of Existing Buildings/ Structures (as part of Site Clearance)

As of the latest planning, the demolition of existing buildings/structures to facilitate the Project were only expected at two (2) areas located outside of Nature Areas:

- Partial demolition of unused Arches building near MH28 along Siloso Road near Nature Area; and
- Removal of small cycling kiosk between MH3 to MH4 along Siloso Beach Walk.

These demolition activities were expected to be conducted during site clearance stage with the same set of equipment, therefore were assessed as part of the site clearance stage in this Environmental Study. The conduct of the above-mentioned demolition works will be subject to changes in detailed design and timeline of the Project at later stage. It should be noted that any changes to the preliminary design of this Environmental Study will require updates and re-assessment by the contractor if available at later stage. Should further consultation with authorities reveal a need to clarify the impact assessment findings for pre-construction demolition activities, a technical memo can be provided to further supplement this Environmental Study.

3.3.1.3 Establishment of Temporary Worksites

Following the site clearance, temporary worksites will be established for the construction of proposed manholes/shafts and alignment, where the worksite areas will range from 300 m² to 700 m². A typical worksite layout is planned as shown in Figure 3-3. It basically includes equipment laydown area (e.g. crane, generators, cables box, excavators, power pack etc.), material storage area (e.g. reinforced concrete pipes), control room, sedimentation tanks, ECM control and slurry treatment facilities.

Since the proposed manholes and shaft are mostly at the roadside, therefore access to the particular worksite/manhole is assumed to be via the existing roads nearby. For the purposes of work activities at the worksite, porous soil and groundcover vegetation will be replaced by impervious surfaces. This will reduce infiltration of water into the ground but will increase surface water run-off which will be treated by the ECM control measures before release from the work site.

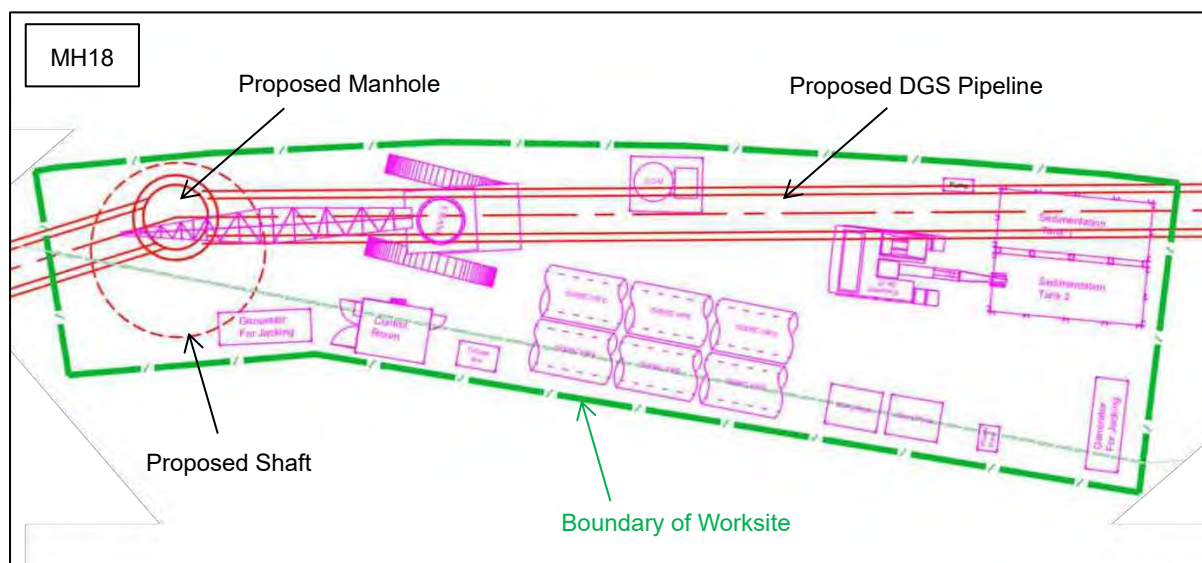


Figure 3-3 Example of Planned Worksite Layout

According to current design planning, the construction works of this Project were expected to be localized at the temporary worksites of each manhole which mostly located beside the main roads. The work areas could be opened and reinstated in phases based on the Contractor's work sequencing and approvals from stakeholders.

3.3.2 Main Construction Activities

After all the site preparation or pre-construction works, the main construction activities will follow by the ground improvement works, construction of temporary shafts, pipejacking works, construction of sewer manholes, general landscaping and finishing works. At the time of writing this report, no open trenching was expected for this Project.

Brief discussion on ground improvement work were provided as follows:

3.3.2.1 Ground Improvement Works

Ground improvement works may be carried out at relevant worksites where the soil condition requires ground improvement before excavation. Equipment required for ground or soil improvement works for sewer construction works would usually involve jet grouting to eliminate seeps and leakages. Jet grouting is a process of improving the ground by cutting it with high pressure jet(s) and mixing and replacing the resulting slurry with cement grout [W-42]. The process will be supported jet grouting pile rig (JGP) high pressure pump, air compressor, power generator, and a vertical silo wet cement. Various steps of ground improvement are as below:

- Concrete breaking of the asphalt/ concrete covering the surface, where necessary;
- A 300mm diameter casing is installed into the ground by excavator up to 1.5m deep to act as guide for the JGP arrangement around the shaft;
- The 100mm diameter JGP drills down to the design depth and uses a jet system at the end of the drill probe to erode the surrounding soil column using high pressure water and/ or air;
- The jetting is carried out from the design depth up to 3m below ground so as to not disturb surrounding services.
- The slurry formed from eroded soil and water is pushed up to the surface where it is initially contained within a 1.5m by 1.5m metal box installed around the bore site, and subsequently pumped out into a tote tank for collection and off-site disposal; and
- A grouting mix (formed by grout mixer) is pumped into the drill probe and injected into the soil column to form a concrete column within the soil strata.

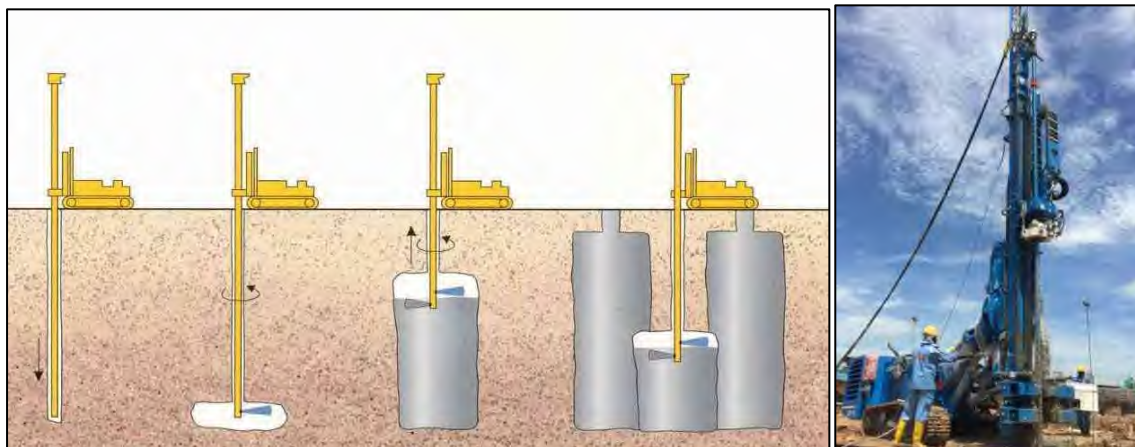


Figure 3-4 Schematic of jet grouting rig operational process [W-41]

3.3.2.2 Construction of Shaft

As shown in the previous Figure 3-3, the construction of temporary shaft is required for the construction of the proposed manhole. It will start upon completion of site investigation works and finalisation of construction design drawings. According to current design planning, the temporary shafts for this Project will be constructed by top down cast in place caisson method as visualized in Figure 3-5.

Before beginning the shaft construction, the temporary shaft location will be finalized and marked out on site, followed by site clearance at the designated location. During site clearance for shaft construction, earth will be cut down approximately 1.2 m deep, up to caisson internal diameter using a hydraulic excavator, whereas the sides of excavation will be manually trimmed. Then, the Contractor will proceed with installing the rebar and closing formwork, following by casting the first layer of caisson wall with ring beam.

After curing for one day, the steel form is removed to continue with cutting down earth to the same depth and width as previous (i.e. 1.2 m deep up to caisson internal diameter). Upon reaching the required depth, BRC Mesh which is a welded prefabricated steel reinforcement material typically used for concrete casting will be installed, followed by the casting of second layer of caisson wall. These steps will be repeated for the casting of subsequent caisson rings until the last layer at desired depth is reached, where earth is excavated to formation level and trimmed for the preparation of solid ground.

During shaft construction, water can enter the shaft from minor leaks and rain, therefore a pump sump will be installed for dewatering purpose before laying BRC mesh for the casting of base slab and trowel finish. Safety railing will also be installed around the circumference of the completed caisson shaft as a safety alert to the public and workers walking nearby above ground.

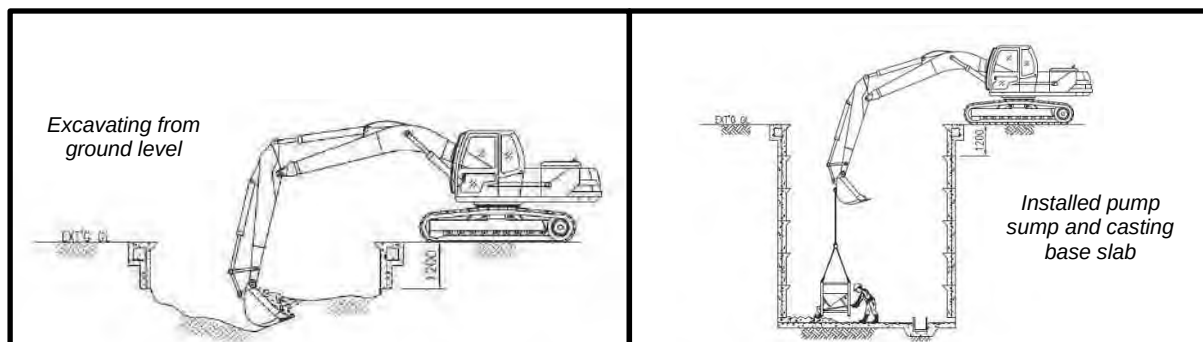


Figure 3-5 Simple Visualization of Shaft Construction

3.3.2.3 Construction of Pipelines via Pipejacking Method

The entire DGS alignment will consist of approximately 3.9 km of 1200 mm diameter pipes, 2.0 km of 1500 mm diameter pipes and 148 m of 2000 mm diameter pipes with a total of 40 ancillary manholes. The proposed DGS is envisaged to be installed via pipejacking method at depths ranging from 15 m – 20 m below the existing ground level at areas near the identified Nature Areas. For areas further from identified Nature Areas, the proposed DGS will be installed at depths ranging from 7 m – 42 m below the existing ground level, which are well below the tree roots hence the trees along the pipejacking alignment will not be affected. Besides, ground movements of pipejacking will also be controlled as per the requirements from Building and Construction Authority (BCA).

Sewer pipes will be laid below ground via the pipejacking method from shaft to shaft (See Figure 3-6). Pipejacking is a non-disruptive technique designed for installing underground pipelines, ducts, and culverts. It is performed with powerful hydraulic jacks used to thrust specially designed pipes through the ground behind a slurry shield with controlled excavation occurring in the shield concurrently. As compared to an open cut excavation method, this produces lesser amount of excavated material that requires removal. Other than reducing excavation works, this method generally requires less overbreak than segmental tunnels. It provides ground support and reduces potential ground movements, lowering the risk of settlement and minimizes surface disruption [13.1]. Thus, this minimizes the long-term damage to existing installed infrastructures above ground. It also prevents groundwater ingress by using pipes with sealed flexible joints. This micro-tunnelling technique will require lesser construction time which potentially reduce the period of noise and air quality disruption from construction activities on the nearby receptors [W-7]. PUB has also applied pipejacking method for the construction of 50 km link sewers as part of the DTSS Phase 2 alignment [W-8].

Before the pipejacking begins, a central control unit will be set up, along with hydraulic unit and slurry tanks at the designated shaft locations. Hydraulic jacks will be installed on the concrete base slab of a completed caisson shaft. At the jacking shaft, slurry shield will first be lowered to the base of the shaft for alignment setting, while the caisson wall will be hacked for pipe entrance. Pumps and slurry pipes will then be connected to the slurry shield before commencing the pipejacking operation.

After driving the slurry shield into a pre-determined location, the cables and pipes on the slurry shield will be disconnected from the pumps and hydraulic jacks. The first jacking pipe is then positioned in between. After that, the pipes and electric cables are reconnected to resume pipejacking operation with the first jacking pipe. Before continuing with laying the next jacking pipe, the cables and pipes are disconnected again, while a spacer is positioned to maintain space in between to support, centre and stabilize the pipes during installation. These steps will be repeated towards the desired jacking direction until the slurry shield reaches the receiving shaft wall, where the caisson wall of the receiving shaft will be hacked for pipe exit. Concrete blocks or I-Beams and steel plate will be provided to guide the removal of slurry shield in the receiving shaft where the pipejacking is completed.

In the case of unforeseen ground condition during pipejacking works where hard rock is encountered or cutterhead worn out, the machine may stop moving forward or become stuck. Rock coring will be applied where micropile machines are mobilized to core out the obstruction before resuming the pipejacking operation as visualized in Figure 3-7.

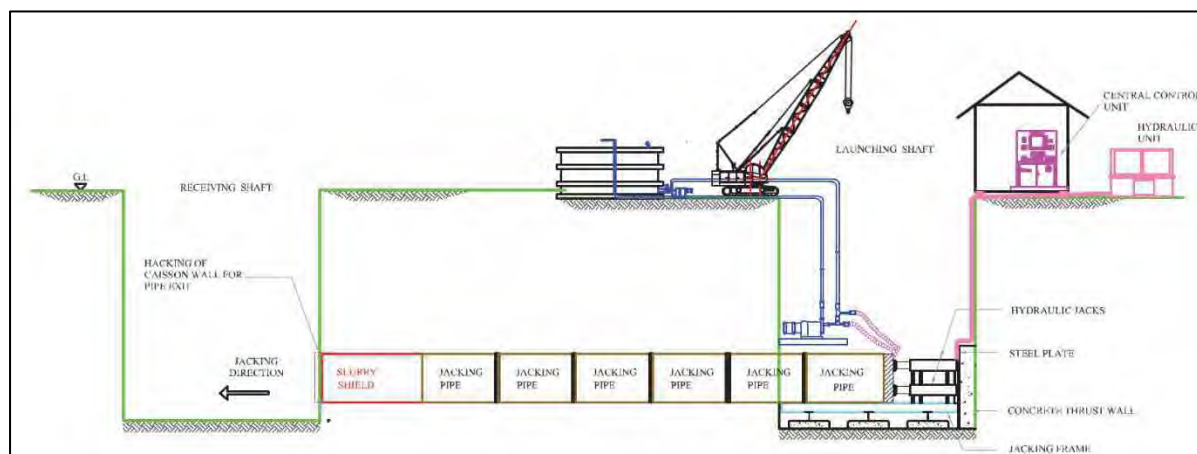


Figure 3-6 Simple Visualization of Pipejacking

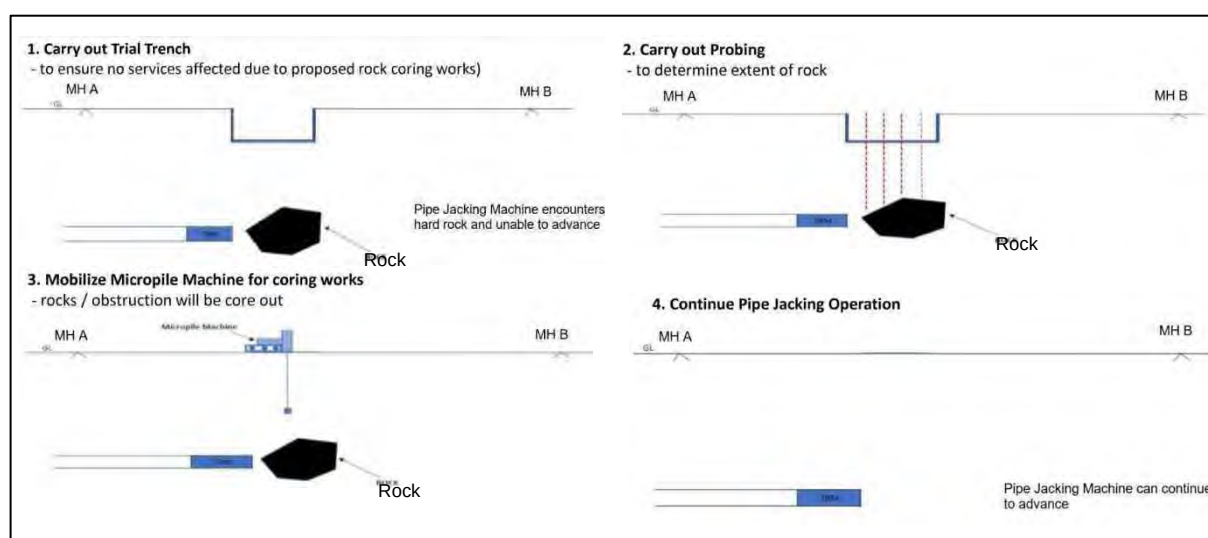


Figure 3-7 Simple Visualization of Rock Coring

Table 3-1 below reflected the tentative plan for jacking and receiving shafts during pipejacking activity of this Project. According to current planning at the time of writing this report, the machines or equipment associated with pipejacking works (refer to Section 3.5.4) could be operating 24 hours during pipejacking period due to safety reasons. As advised by NParks, there should be no night works after 6pm, therefore the Contractor should seek SDC's and Agencies' permission in case of emergency (e.g. when challenging underground geological zone could be detected during pipejacking) or due to other occasions when night work would be necessary to be carried out by human manpower.

Table 3-1 Tentative Plan for Jacking and Receiving Shafts ⁽⁴⁾

Jacking Shafts (JS) ⁽¹⁾ →	Receiving Shafts (RS) ^(1,2)
MH2	MH1, MH3 ⁽¹⁾
MH3	MH4, MH32
MH4a	MH4, MH5
MH5a	MH5, MH6
MH7	MH6, MH7a
MH8	MH7a, MH9
MH9a	MH9, MH10
MH11	MH10, MH12, MH13

Jacking Shafts (JS) ⁽¹⁾ →	Receiving Shafts (RS) ^(1,2)
MH13a	MH13, MH13b ⁽¹⁾
MH13b	MH14, MH15 ⁽¹⁾
MH15	MH16
MH17	MH16, MH18 ⁽¹⁾
MH18	MH19
MH20	MH19, MH21 ⁽¹⁾
MH21	MH22
MH23	MH14, MH25
MH24	L-LS8 ⁽³⁾ , MH23 ⁽¹⁾
MH25a	MH25, MH25b
MH26	MH25b
MH27	MH26 ⁽¹⁾ , MH28
MH29	MH28, MH30
MH31	MH30, MH32
Notes: 1. The primary function of Jacking Shaft is to launch or jack pipes from one worksite to another, while at the same time, it can act as a Receiving Shaft that receives pipes from its neighbouring Jacking Shaft. 2. The function of Receiving Shaft is only to receive pipes launched from a Jacking Shaft. 3. L-LS8 is a proposed sewer link sewer manhole under construction by PUB's appointed contractor for DTSS2. The Project in this report only covers the construction of pipeline from MH24 to L-LS8 via pipejacking. 4. The jacking and receiving of shafts above are not conducted in alphabetical or numerical sequence. The pipejacking activity for each worksite will be subject to changes in the actual construction schedule.	

3.3.2.4 Construction of Sewer Manholes

The pipejacking is completed when it reaches the designated shaft location where a circular caisson shaft (refer to shaft construction in Section 3.3.2.2) is in place. Following that, the construction of sewer manholes will first begin with construction of manhole base or insertion of precast manhole base, which is then fixed with rebar and short pipes that connects to the DGS pipeline. Then benching is casted to allow and maintain smooth flow within the main channel at a desired gradient. Rebars are then fixed and manhole wall will be casted, where the gap between manhole wall and caisson wall will be backfilled with soil. Thereafter, intermediate slab will be casted at the manhole walls. Upon reaching desired depth, a circular in-situ top slab and chamber ring will be erected on top of the manhole wall. The gap between chamber ring and caisson wall will be backfilled subsequently. The top portion of caisson wall will eventually be hacked and removed. Brickwork may be required as support or to regulate the caisson shaft to its required level. Finally, the manhole cover will be installed. The remaining top portion of the caisson shaft will be backfilled and reinstated to ground level. A simple visualization of this process is shown in Figure 3-8.

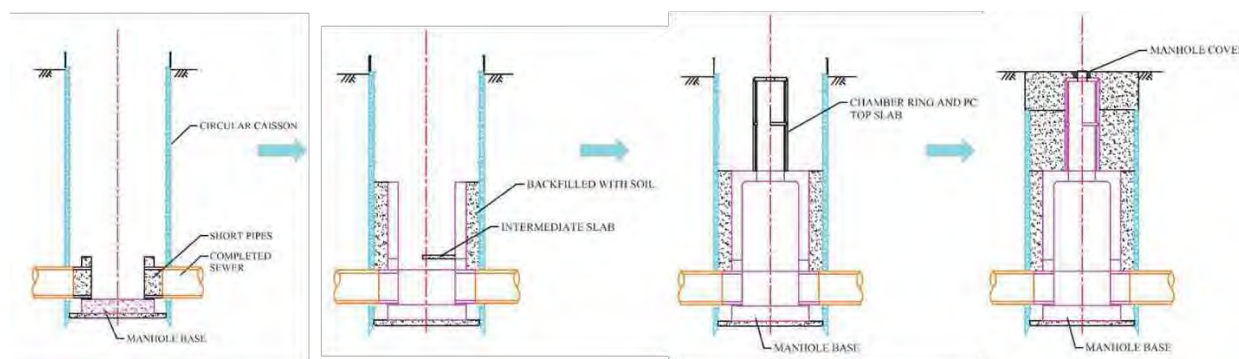


Figure 3-8 Simple Visualization of Manhole Construction

3.3.2.5 General Landscaping and Finishing Works

Upon completion of the construction of manholes, especially where existing topography has been altered, it is mandatory for the finishing works to include reinstatement and stabilisation of the area. General landscaping will be provided to reinstate the original condition of vegetation around the worksite, especially where tree-felling is unavoidable. A separate arboriculture assessment report will be conducted to discuss about the locations and impacts from tree-felling, as well as to propose relevant mitigation measures. Consultation with SDC prior to commencement of both general landscaping and finishing works will be required.

3.3.3 Other Activities (Excluded from this Study)

There are other activities which could be conducted due to the provision of this Project and/or other development planning for Sentosa. These potential works included demolition of existing buildings/ structures before the commencement of this Project, as well as the demolition of pumping stations after the commissioning of the proposed DGS system. However, these activities would be conducted by third parties under separate work packages, therefore were not be assessed in this Environmental Study and excluded from this report. The Environmental Study only assessed the proposed construction works for the DGS system.

3.3.3.1 Demolition of Existing Buildings/ Structures (under separate work package)

At the time of writing this report, it was noted that a few existing buildings or structures will be demolished earlier before the commencement of the construction of proposed DGS system, as listed below:

- Flame Restaurant near MH4a at Siloso Beach Walk; and
- Sentosa Administration Receiving Building near MH13b at Artillery Avenue (**Currently a construction site based on site observations*).

The demolition works of the above-mentioned buildings would be carried out by third party under a separate work package before the commencement of this Project, therefore were not assessed in this Environmental Study.

3.3.3.2 Demolition of Pumping Stations

As mentioned in Section 2, SDC intends to phase out 11 existing pumping stations on Sentosa which will be replaced by the proposed DGS system of this Project. After completion of the proposed DGS works from Year 2023 to 2027, the demolition of the 11 pumping stations was planned to be undertaken for a period of one year under a separate work package. Since no substantial details were available at the time of writing this report, this activity was not assessed at this stage. Shall consultation with authorities require further study on the environmental impacts from demolition of pumping stations at later stage of the planning process, SDC will engage a specialist consultant to carry out an environmental study on this separate work package.

3.4 Project Schedule

The tentative schedule of the construction of proposed DGS system was presented in the following Figure 3-9, subject to future update/review by the Contractor due to potential changes in plan during actual construction stage or at later stage of the Project. The overall construction timeline was expected to commence from the first quarter of Year 2023 and to be completed in the first quarter of Year 2027.

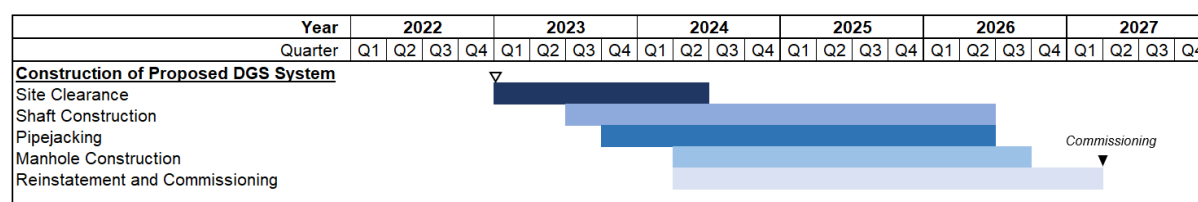


Figure 3-9 Tentative Project Schedule

All works will be carried out in respective group of manholes (about 5 to 6 worksites working concurrently in group) and by phases according to the sequence above. Each manhole worksite will approximately require an average of 12 months to complete the above-mentioned construction works.

3.5 Project Resources

This section discussed about typical resources which might be required in the construction phase of this Project, including electricity and water supply, concrete requirement, and equipment application.

3.5.1 Electricity Supply

During the construction phase, electricity supply is required for lighting and operation of the construction equipment of the Project. According to current planning at the time of writing this report, it was expected that at least one (1) portable generator would be required for electricity supply at each worksite.

3.5.2 Water Supply

In Singapore, water supply is governed under Singapore's National Water Agency PUB with robust and diversified sources known as the "Four National Taps" (comprising of water from the local catchment, imported water, highly-purified reclaimed water known as NEWater and desalinated water) where it reaches the public through water main and taps. [W-4]

Water supply is essential throughout all the phases of the Project, where water will be drawn from the mains for the construction activities (e.g. concreting, dust suppression, wheel washing etc.). In such cases where water supply is not easily accessible from the construction site, temporary water tanks shall be provided on site to support construction activities, as well as potable use and temporary sanitary facilities (e.g. portable toilet on site). Impact from construction and domestic wastewater generated from construction activities are generally discussed in Section 10.

3.5.3 Concrete

Unlike building construction projects, this project comprises only the construction of manholes which does not rely on heavy usage of concrete on site. According to the current planning at the time of writing this report, it was noted that there would be no concrete batching plant on site. The concrete of caisson walls will be cast in-situ concrete prepared using ready-mixed concrete trucks that will transport concrete to site. Other project components such as pipes and manhole covers are of pre-casted or ready-made components that will be transported directly from the production factory to the worksite.

3.5.4 Equipment

Table 3-2 shown an indicative list of equipment and/or facility which might be required during the construction phase of the Project.

Fuel and other chemical materials (e.g. cement additives etc.) are the common inputs to operate the equipment for construction works, which shall be stored at a designated temporary stockpile location or laydown area. For example, diesel fuel for the refuelling of construction equipment and other flammable or non-flammable chemicals required for construction works shall be labelled and stored in accordance with requirements stipulated in the internationally applicable Material Safety Data Sheet (MSDS).

Table 3-2 Indicative Equipment List during Construction Phase of the Project

Activity	Indicative Equipment
Ground Improvement Works	Grout Drilling Rig 6" Pump Lorry Crane Tipper Truck
Site Clearance for Construction	Lorry Crane Handheld Breaker Excavator mounted with Rock Breaker Front end loader Handheld Chainsaw Dump Truck

Activity	Indicative Equipment
Shaft Construction	Silent Piler Dump Truck Excavator Concrete Truck Concrete Pump
Pipejacking	<u>During Normal Operation (with 24-hours machine operation)</u> Generator 2 x 6" Pump Crane (<i>daytime only</i>) Dump Truck (<i>daytime only</i>) <u>During Emergency Case (with machine and human operations at night)</u> Generator 2 x 6" Pump Crane
Manhole Construction	Generator Concrete Truck Concrete Pump Silent Piler Concrete Vibrator Crane

3.6 Project Wastes

Wastes can be defined as unwanted material produced directly and indirectly as a result of construction work. In general, the wastes expected to be generated from construction activities will be hazardous (e.g. toxic industrial wastes, organic wastes), non-hazardous wastes (e.g. general wastes, inorganic waste) and recyclable wastes (e.g. excavated soil).

Typically, hazardous wastes produced from construction activities include oil, grease, sludge, solvents, empty containers of insecticide, paint, solvents, contaminated soil etc. while non-hazardous wastes include paper, cardboard etc. Recyclable wastes generated from construction works will comprise excavated soil, construction debris, plastics, and metals. The project proponent or contractor shall ensure proper handling and disposal of construction waste on site to avoid any potential contamination to nearby water resources, soil, and groundwater.

Construction activities of this Project would generate large amounts of excavated soil which required disposal. An estimated total of 89,200 m³ of soil could be excavated during the Project works. The total excavated soil included the excavation due to construction of caisson shafts at each manhole worksite, as well as during pipejacking activity as shown in Table 3-3. According to current planning, soil excavated from the caisson shafts would be transported to the HDB staging ground for disposal via tipper trucks, while soil from the pipe jacking machine could be mixed with slurry and properly kept on site to be naturally dried before disposal. During rainy events, excavated soil might affect the surface water quality of the nearby waterbodies via surface run-off (in uncontrolled), therefore the water quality impact from liquid effluent generated from worksites of the Project was discussed in Section 10.

Table 3-3 Estimated Spoil Disposal

Project Activity	Volume of Excavated Soil for Disposal (m ³)
Construction of shafts and manholes	70,300
Construction of pipelines via pipejacking	18,900
Total	89,200

4. Description of the Environment

This section described the existing environment in the vicinity of the Project, including the introduction to study areas, current land uses, URA's land zones, historical land uses, heritage trees, topographical and geological conditions, water catchment area and climate.

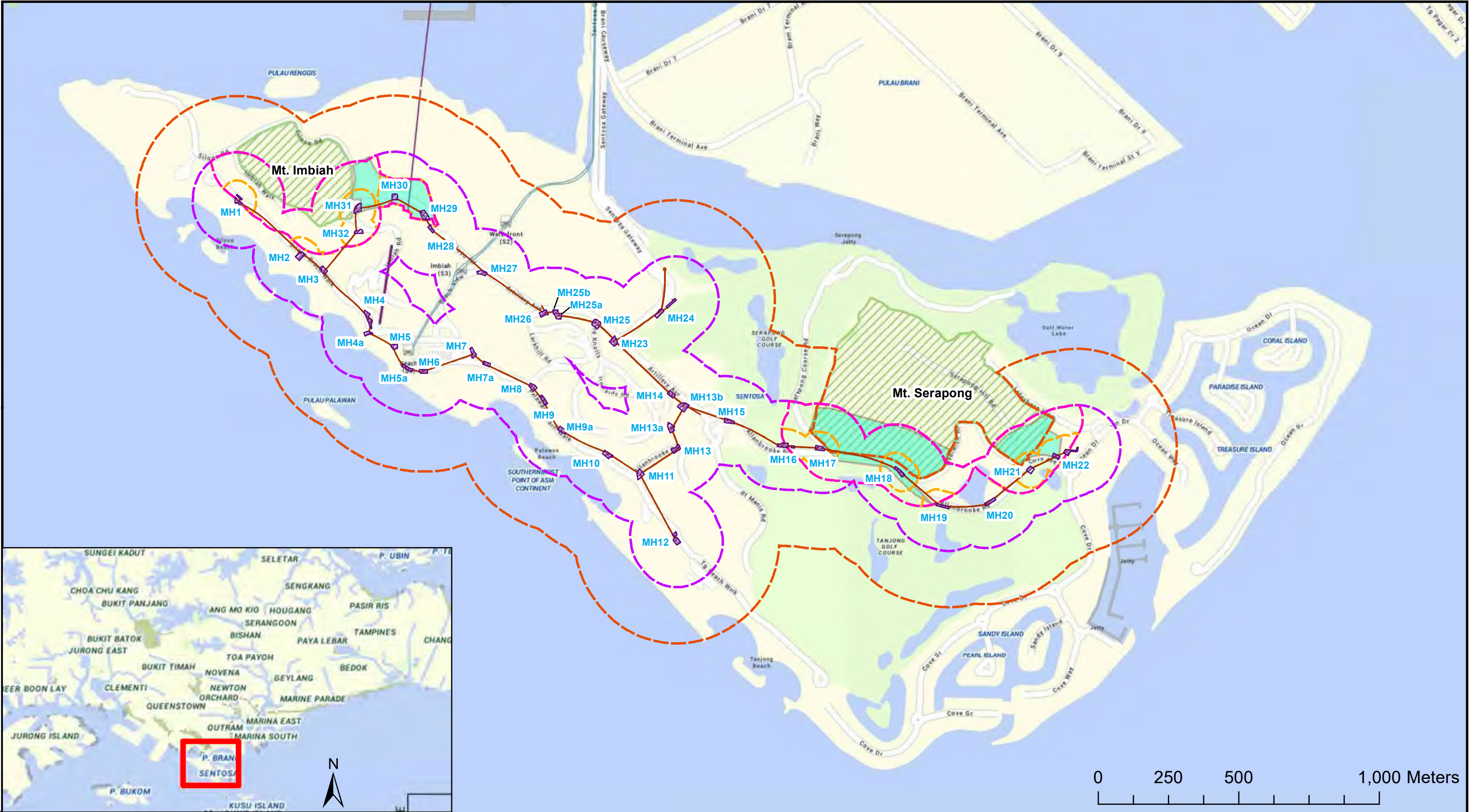
4.1 Study Area

The study area is the area around the worksites of the proposed manholes of this Project defined for the purpose of this Environmental Study.

As documented in the Inception Report [G-1], the environmental parameters to be assessed in this Environmental Study comprised biodiversity, airborne noise, air quality and surface water quality. A varying study area size was defined for each environmental parameter based on legislations or international guidelines and consultation with relevant agencies, as summarized below:

Table 4-1 Study Area

Environmental Parameter	Study Area	Justification	Proposed Manholes That Fall Within Study Area
Biodiversity	Forested areas 150 m from the proposed manhole locations, approximately 3.61 ha within Mt. Imbiah (hereinafter referred to as "Mt. Imbiah Study Area") and 9.91 ha within Mt. Serapong (hereinafter referred to as "Mt. Serapong Study Area").	Mt. Imbiah and Mt. Serapong are ecologically sensitive Nature Areas identified by NParks as closest to where construction activities will be carried out. The Nature Areas are important areas of habitats for flora and fauna.	MH18, MH22, MH29, MH30, MH31.
Airborne Noise	<u>Ecologically Sensitive Receptors</u> 150 m around the above-ground construction worksites for ecologically sensitive receptors located at or in the vicinity of Mt. Imbiah, Mt. Serapong, and the connected forested habitat within biodiversity study area.	- In accordance with Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2008 [R-18], airborne noise impacts will occur from above-ground construction sites only; and - Although the noise impact assessment was applied to its immediate study area, noise contours were provided to the extent that topography was available.	MH1, MH2, MH16, MH17, MH18, MH19, MH20, MH21, MH22, MH28, MH29, MH30, MH31, MH32
	<u>Human Receptors</u> 150 m around the above-ground construction worksites for human receptors.		All manholes.
Air Quality	<u>Ecologically Sensitive Receptors</u> 50 m around the above-ground construction worksites for ecologically sensitive receptors located at or in the vicinity of Mt. Imbiah, Mt. Serapong, and the connected forested habitat within biodiversity study area.	In accordance with UK IAQM Guidance [R-15] adopted for this study for construction phase.	MH17, MH18, MH19, MH21, MH22, MH28, MH29, MH30, MH31
	<u>Human Receptors</u> 350 m around the above-ground construction worksites for human receptors.		All manholes.
Surface Water Quality	Identified natural and non-natural inland waterbodies with potential impact from the construction activities.	During construction phase, above-ground construction activities would result in surface run off with potential to impact water quality of nearby waterbodies/ drainage (if any).	Any manholes with direct impact to identified surface water sensitive receptors.



Legend Base Construction Worksites DGS Manholes & Pipeline Nature Areas Study Area for Airborne Noise Impact Assessment 150m from Proposed Worksites - Ecologically Sensitive Receptors 150m from Proposed Worksites - Human Receptors Study Area for Air Quality Impact Assessment 50m from Proposed Worksites - Ecologically Sensitive Receptors 350m from Proposed Worksites - Human Receptors Study Area for Biodiversity Impact Assessment Biodiversity Study Area for Mt. Imbiah and Mt. Serapong							Qualified Person Endorsement : NA	Consultant : AECOM	Sentosa THE ISLAND OF SINGAPORE Figure Title : Overview of Study Areas					
								Client Endorsement : NA	Project Title : Contract No. SDC/21.8.2/19: Environmental Study For The Proposed Deep Gravity Sewer Project at Sentosa			Figure Title : Overview of Study Areas		
	B	NOV 2021	SYT	Final Report Rev B	JAG/NHT	JAG		Designed SYT	Checked JAG/NHT	Approved JAG	Figure No. : 4-1	Rev. B	Sheet 1 of 1	
	A	JUL 2021	SYT	Final Report Rev A	JAG/NHT	JAG								
	-	MAY 2021	SYT	Final Report	JAG/NHT	JAG								
	Rev.	Date	By	Description	Chk'd	App'd			Drawn SYT	Date NOV 2021	CAD File Name : NA		A3	

4.2 Topography of the Study Area

The topographic survey data within the study area was provided by SDC [G-6] and consolidated with the information available on public domain (e.g. Topography and elevation maps online [O-1, O-2], OneMap SG [O-7]).

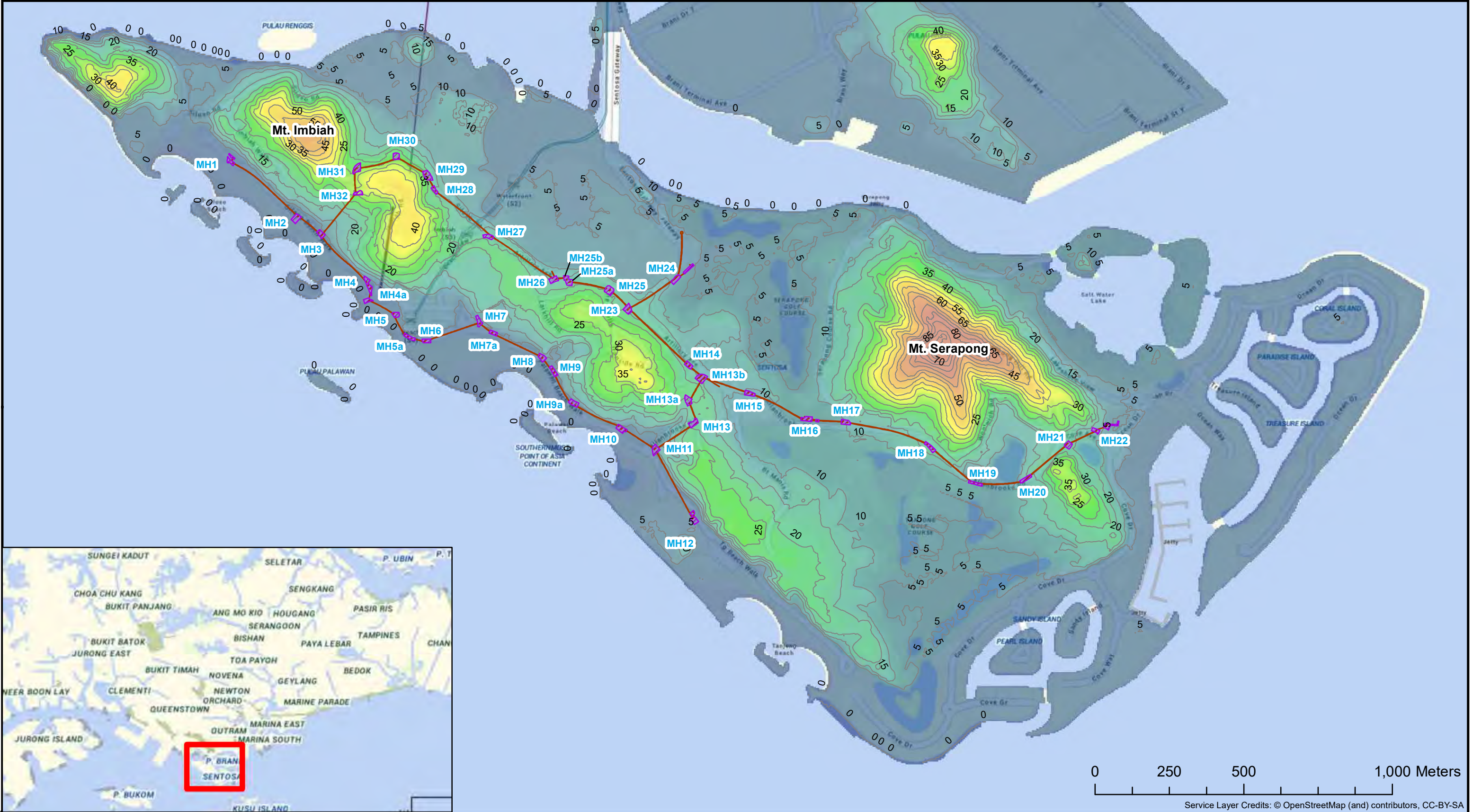
Based on the review of this topographic survey data and observations from site visits, it was noted that the existing topography of the study area comprises of generally gentle sloping low-lying areas with elevation ranging from 0 – 5 mRL particularly along the coastal areas surrounding the island. There also exist pockets of regions with steeper elevation ranging from 0 – 35/40 mRL on the most western end of the Island near Siloso Beach, more inland areas near Palawan Beach and Tanjong Beach, as well as within the Tanjong Golf Course towards the eastern end of the island. There are also two main peaks of elevations, Mt. Imbiah at approximately 55 mRL at the western side of the island, and Mt. Serapong at approximately 85 mRL at the eastern side of the island.

Figure 4-2 reflected the overall topography of the Sentosa Island based on the available topographic data. The topographic characteristics of each of the worksites were described in Table 4-2 below.

Table 4-2 Worksite Topographic Characteristics

Worksite	Topographic Characteristics
MH1	The MH1 worksite is situated near where the current Mega Adventure ticketing booth on Siloso Beach Walk is located. The area has a generally flat terrain and has an elevation of around 14 m above sea level.
MH2	The MH2 worksite is situated in the area between the Rumour's Beach Club and previous Wave House Sentosa was located. The area features low-lying and generally flat elevations of around 12 m above sea level.
MH3	The MH3 worksite is situated near the Eco Alfresco Café, opposite of the Emerald Pavilion on Siloso Beach Walk which is generally gentle sloping with elevation of approximately 15 – 21 m above sea level, with the elevation increasing from the south to the north.
MH4	The MH4 worksite is located on a gentle sloping area near where the Skyline Luge is located on Siloso Beach Walk. It sports an elevation of approximately 19 m above sea level gradually reducing to sea level towards south.
MH4a	The MH4a worksite is currently located on generally flat ground near to sea level.
MH5	MH5 worksite is located on land area that is generally flat, around 11 m above sea level.
MH5a	The MH5a worksite is located near the Wings of Time at Palawan Beach on generally flat terrain near to sea level.
MH6	The MH6 worksite is situated on generally flat terrain with an elevation of around 11 m above sea level.
MH7	The MH7 worksite is located on land with a gentle slope uphill from Palawan Beach Walk into Beach View with an elevation of approximately 11 – 15 m above sea level.
MH7a	The MH7a worksite is situated on generally flat land with an elevation of around 11 m above sea level along Palawan Beach Walk.
MH8	The MH8 worksite is located on generally flat land with an elevation of around 16 m above sea level along Palawan Beach Walk.
MH9	The MH9 worksite is located on a gentle slope with an elevation of around 16 – 24 m above sea level along Palawan Beach Walk.
MH9a	The MH9a worksite is situated on a gentle slope with elevation of around 18 m above sea level gradually decreasing to 8 m above sea level along Palawan Beach Walk, from the inland areas of the island towards the coastal areas near the beach.
MH10	The MH10 worksite is located on gentle slope along Palawan Beach Walk on street level with an elevation of approximately 11 – 21 m above sea level, gradually decreasing from the north to the south.
MH11	The MH11 worksite is situated on a generally flat area with an elevation of around 19 m above sea level.
MH12	The MH12 worksite is located on a generally flat area with elevation of approximately 10 m above sea level.
MH13	The MH13 worksite is located on an area that is generally gentle sloping with elevations of around 27 – 28 m above sea level.
MH13a	The MH13a worksite is located on an area that is generally gentle sloping with elevations of around 28 – 36 m above sea level.

Worksite	Topographic Characteristics
MH13b	The MH13b worksite is located on an area that is generally flat with elevations of around 25 m above sea level.
MH14	The MH14 work site is located on the Artillery Avenue on a generally flat area with elevation approximately 35 m above sea level.
MH15	The MH15 worksite is situated on a gentle sloping area with land that has an approximate elevation of 15 – 20 m above sea level.
MH16	The MH16 worksite is located on gentle sloping area with elevation of around 11 m above sea level.
MH17	The MH17 worksite is located on generally flat ground with an elevation of around 26 m above sea level.
MH18	The MH18 worksite is located along Allanbrooke Road near the entrance to Woolwich with elevation of approximately 28 m above sea level.
MH19	The MH19 worksite is located along Allanbrooke Road on gentle sloping area gentle elevation of approximately 13 – 19 m above sea level, increasing from the east to the southwest.
MH20	The MH20 worksite is located along Allanbrooke Road near the Sentosa Satellite Earth Station and the land area increases in elevation from the west to the east from around 24 – 28 m above sea level.
MH21	The MH21 worksite is located along Cove Avenue on a generally flat land area of around 30 m above sea level.
MH22	The MH22 worksite is situated on near the Lakeshore View @ Sentosa Cove Village residences which presides on a land area which sports an elevation of around 19 – 24 m above sea level from the east to the west of the worksite.
MH23	The MH23 worksite is located near a roundabout along Artillery Avenue near the entrance to The Knolls. This area is generally flat with elevation at approximately 34 m above sea level.
MH24	The MH24 worksite is located along Sentosa Gateway entering the roundabout to Artillery Avenue. This area has an elevation of around 16 – 21 m above sea level from the north to the south.
MH25	The MH25 worksite is located near the entrance into The Knolls from Artillery Avenue on a gentle sloping terrain of around 26 – 34 m above sea level in elevation.
MH25a, MH25b	The MH25a and MH25b share a worksite which is located on a generally flat area with elevation of around 26 m above sea level.
MH26	The MH26 worksite is located on a land area with gentle elevation of around 26 – 31 m above sea level.
MH27	The MH27 worksite is situated at the intersection between Siloso Road, Beach View and Artillery Avenue. This area has a flat elevation of around 25 m above sea level.
MH28	The MH28 worksite is located on a flat area with elevation around 33 m above sea level.
MH29	The MH29 worksite is located on a flat area along Siloso Road with an elevation of approximately 29 m above sea level.
MH30	The MH30 worksite is situated on an elevated spot at the bend of Siloso Road with terrain ranging from 29 – 39 m above sea level with the higher point of elevation from the south and the lower to the north sloping downwards.
MH31	The MH31 worksite is located on a sloping stretch of area along Siloso Road with elevation ranging from 43 – 45 m above sea level.
MH32	The MH32 worksite is located at the bend of the Imbiah Road opposite the Imbiah Lookout Bus Stop. The worksite itself is located on a generally flat area while the elevation to its right, coming from the east, is steeper at approximately 49 m above sea level and decreases downslope to the left, going downwards towards the west at an elevation of approximately 41 m above sea level.



Legend

Base Construction Worksites

DGS Manholes & Pipeline

Contour Lines

Elevation (mRL)

Value

High : 88.1

Low : -0.5

Note: The contour lines are in intervals of 5 m.
Sources: Sentosa Development Corporation (SDC);
Topography Map Singapore (online);
FreeMapTools - Elevation Finder (online).

Rev.

Date

By

Description

Chk'd

App'd

Qualified Person Endorsement :
NA

Client Endorsement :
NA

Consultant :
AECOM

Project Title :
**Contract No. SDC/21.8.2/19:
Environmental Study
For The Proposed Deep Gravity
Sewer Project at Sentosa**

Designed SYT	Checked JAG/NHT	Approved JAG
	Drawn SYT	Date NOV 2021

Figure Title :
Topographic Map of Sentosa Island

Figure No. : 4-2	Rev. B	Sheet 1 of 1
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4.3 Current Land Uses and Land Zoning

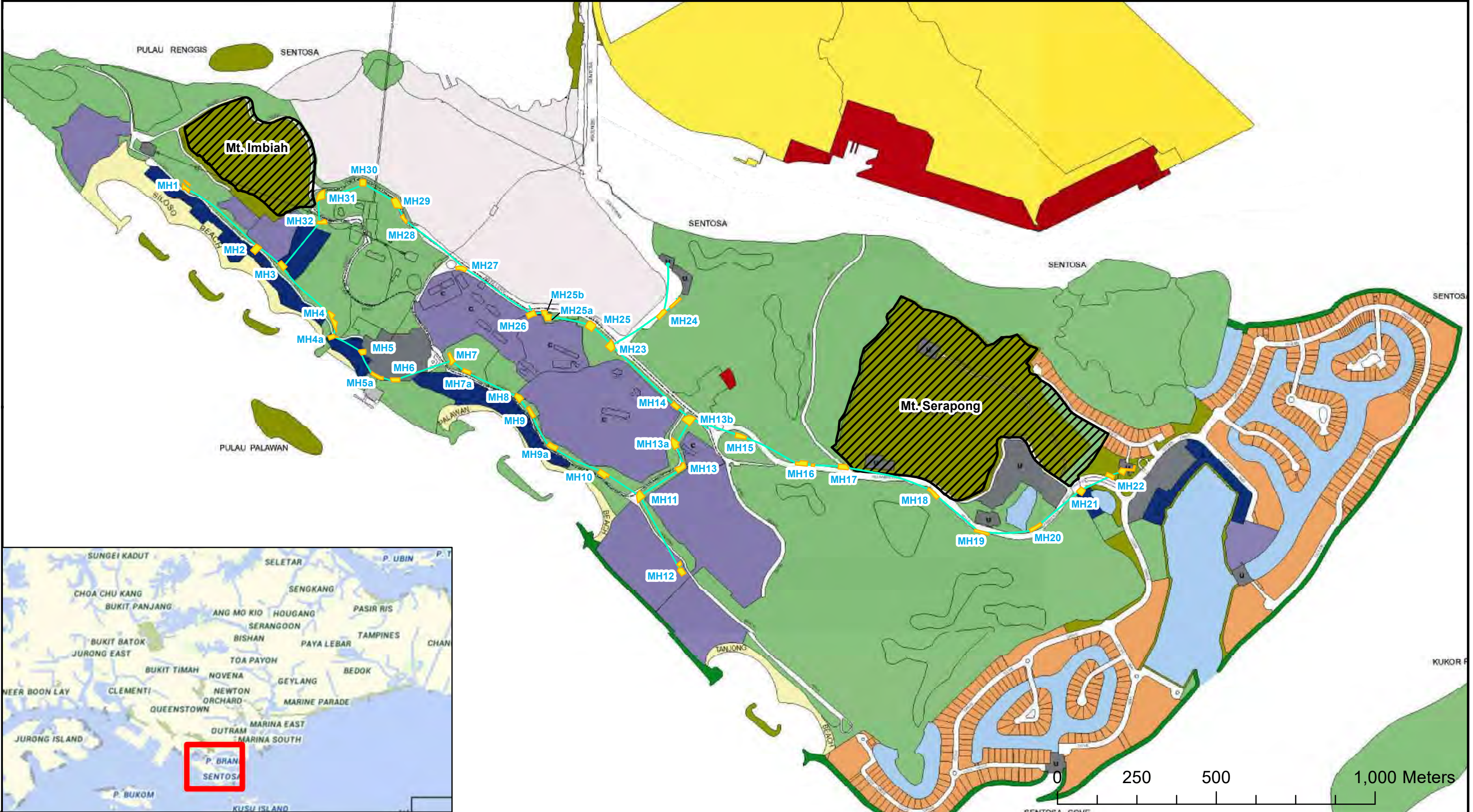
According to the latest Urban Redevelopment Authority of Singapore (URA) Master Plan 2019 [O-3], the pipeline of the deep gravity sewer system would pass through a variety of land zoning such as sports & recreational areas, hotel, commercial area, beach area etc.

The current land uses or buildings situated in and/or across different URA's land use zones within the study area were identified through the Google Map [O-4], Street Directory Map [O-6] and OneMap [O-7]. The summary of land zoning and current land uses were presented in Table 4-3 and Figure 4-3.

Table 4-3 Land Zoning and Uses within the Study Area

URA Master Plan 2019		Street Directory
Land Zones	Description	Current Land Uses within Study Areas
Civic & Community Institution	These are areas used or identified to be used mainly for civic, community or cultural facilities or other similar purposes.	SCDF Sentosa Fire Station.
Conservation Area	These are areas with historical significance to be conserved.	Land area where Sofitel So FIT & So SPA, Capella Singapore, Amara Sanctuary Resort, Mess Hall and previous Le Meridien Hotel (now Oasia Resort Sentosa).
Hotel	These are areas used or intended to be used mainly for hotel development.	Siloso Beach Resort, Siloso Beach Resort Eco Alfresco Café, Village Hotel at Sentosa, The Outpost Hotel, and The Barracks Hotel, Sofitel Sentosa Resort & Spa, Capella Singapore, Shangri-la's Rasa Sentosa Resort & Spa, and Amara Sanctuary Resort.
Open Space	These are areas used or intended to be used as open space.	Mt. Imbiah, Mt. Serapong, and open space beside the entrance to Lakeshore View @ Sentosa Cove Residences along Ocean Drive.
Sports & Recreation	These areas are generally used or intended to be used mainly for sports and recreational purposes.	Serapong Golf Course, Tanjong Golf Course, Skyline Luge, Skyline Luge Refill Station, Imbiah Lookout, Sentosa 4D Magix, Sentosa Nature Discovery, Sentosa CineBlast, Marvel 4D Experience, Imbiah Office, Images of Singapore, Madame Tussauds Singapore, Imbiah LRT Station, iFly Singapore, Animal and Bird Encounters, Palawan Amphitheatre, 3 Larkhill Road Building, abandoned buildings along Artillery Avenue, EtonHouse International Pre-School, EIS International Pre-School, Islander Pre-School, and One° 15 Marina Club and Tennis Court.
Residential	These are areas used or intended to be used mainly for residential development	Lakeshore View @ Sentosa Cove Residences.
Transport Facilities	These are areas used or intended to be used mainly for the parking of vehicles and transport facilities including garages and at-grade structure of underground road tunnel and rapid transit system.	Siloso Point Station, Beach Station, Beach Arrival Plaza, and Sentosa Cove Bus Pickup point.
Commercial	These are areas used or intended to be used mainly for commercial development.	Emerald Pavilion, Ola Beach Club, Bikini Bar, Coastes, Flame, Sand Bar, Nestopia, Gogreen Segway Eco Adventure, Rumour's Beach Club, Baristart Coffee, AJ Hackett Sentosa, AJ's Bar and Beach Dining, Sapphire Pavilion, Wings of Time, Good Old Days Restaurant, Fun Shop Beach Plaza, Ticketing Booth at Beach Plaza, Show Bites at Beach Plaza, The Quayside Isle, Sentosa Cove Village Shops (Cold Storage @ Sentosa Cove etc.).
Utility	These are areas used or intended to be used mainly for public utilities and	Sentosa Satellite Earth Station, PUB Booster Station, pumping station near Lakeshore View

URA Master Plan 2019		Street Directory
Land Zones	Description	Current Land Uses within Study Areas
	telecommunication infrastructure including water works, sewage disposal works and other public installations such as electrical substations.	@ Sentosa Cove Residences, and substation at 84 Allanbrooke Road.
Road	These are areas used or intended to be used for existing and proposed roads.	Allanbrooke Road, Artillery Avenue, Sentosa Gateway, Imbiah Road, Larkhill Road, Palawan Beach Walk, Siloso Beach Walk, Imbiah Walk, Siloso Road, Tanjong Beach Walk, Woolwich Road, Bukit Manis Road, Cove Avenue, Lakeshore View, Ocean Drive, and Cove Drive.
White	These are areas used or intended to be used mainly for commercial, hotel, residential, sports & recreational, and other compatible uses, or a combination of two or more such uses as a mixed development.	Universal Studios Singapore, Hotel Michael, Crockfords Tower, Resorts World Theatre, Resorts World Sentosa Casino, Hard Rock Hotel, Festive Hotel, Equarius Hotel, Adventure Cove Waterpark, Resorts World Sentosa, and TreeTop Loft.
Waterbody	These are areas used or intended to be used or drainage purposes and water areas such as reservoirs, ponds, rivers, and other water channels.	Manmade pond in Sentosa Satellite Earth Station, Yachts' Parking Berths/ Jetty near One° 15 Marina Club.



Legend

Base Construction Worksites

DGS Manholes & Pipeline

Nature Areas

Residential

Civic & Community Institution

Sports & Recreation

Utility

Conservation Area

Hotel

Park

White

Transport Facilities

Road

Open Space

Waterbody

Beach Area

Commercial

Rev.

Date

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Description

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Final Report Rev B

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SYT

Final Report Rev A

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SYT

Final Report

JAG/NHT

JAG

Qualified Person Endorsement :
NA

Client Endorsement :
NA

Consultant :
AECOM

Project Title :
**Contract No. SDC/21.8.2/19:
Environmental Study
For The Proposed Deep Gravity
Sewer Project at Sentosa**

Designed
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Figure Title :
Land Use Map

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4-3

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Source of basemap - OneMap & URA Master Plan 2019 (Extracted in May 2021)

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4.4 Historical Land Uses

By the 1800s, Sentosa had already been inhabited by native Malay villagers, which suggested that the forests could have been disturbed from human activities then to produce charcoal and timber used for building equipment and houses [P-58]. The earliest detailed map of the Sentosa Island was created circa 1860, but the earliest maps of Singapore were produced mainly for navigational purposes and did not provide information about the vegetation. Later in the 19th century, the island was exposed to more human development when it became a site of military installation. Subsequent major changes to Sentosa occurred during the Japanese Occupation from 1942 to 1945, when part of the island turned into a prisoner-of-war camp and base for military training, and also after plans to develop Sentosa as a resort was conceptualized in 1969. Each of these events were likely to have caused additional disturbances to the forests. Information on land use history was primarily gathered from old maps in the online collection of the National Archives of Singapore (NAS) as well as historical maps on the OneMap and the National University of Singapore (NUS) Libraries portals.

4.4.1 Historical Land Use of Mt. Imbiah

The Mt. Imbiah remained as a forested patch in the 1860s (Figure 4-4A). It was adjacent to Imbiah Bay, which might have been a human settlement. By 1914, it was partially cleared to make way for a road, likely to access military installations such as Mount Imbiah Battery located to its east (Figure 4-4B). By 1945, the Mt. Imbiah Study Area was flanked by developed land as a large area to its south had already been deforested (Figure 4-4C). By 1975, the island was further developed and more roads had been built around the study area as the island underwent a makeover to become a resort (Figure 4-4D). Trees were also planted by the Sentosa Development Corporation during the development of the resort, which partially altered the area's floristic composition.



Figure 4-4 Mt. Imbiah Study Area. (A) circa 1860; (B) 1914; (C) 1945; (D) 1975. The Red Polygon Represents the Mt. Imbiah Study Area.

4.4.2 Historical Land Use of Mt. Serapong

The Mt. Serapong Study Area remained as a forested patch in the 1860s (Figure 4-5A). It was adjacent to a road and a coast. Yee et al. (2011) [P-1] showing that the primeval vegetation type of the area was freshwater swamp. By 1914, roads were altered, and one road skirted along the southern boundary of the study area (Figure 4-5B). Fort Serapong was also built as a military installation to its north. The study area appears to have remained largely similar till 1945, but the Japanese Occupation during this period was likely to have caused an increase in disturbance of the forested areas on Sentosa Island (Figure 4-5C). By 1975, the south of the study area appears to have been cleared for the development of the resort (Figure 4-5D).



Figure 4-5 Mt. Serapong Study Area. (A) circa 1860; (B) 1914; (C) 1945; (D) 1975. The Red Polygon Represents the Mt. Serapong Study Area.

4.5 Heritage Trees

Heritage trees are mature trees with a girth of at least 5 m that have a botanical, historical, social, cultural, and/or aesthetic value recognised by the NParks Board Heritage Tree Panel. There are no heritage trees within the Mt. Imbiah Study Area while two reside within the Mt. Serapong Study Area (Figure 4-6) (Section 7.3.2.3). The tree species are *Alstonia angustiloba* and *Litsea elliptica*, both of which are listed as nationally Common [P-2].

Alstonia angustiloba, commonly known as pulai, is a mid-canopy tree species that can be frequently encountered in the secondary forests of Singapore. It can grow up to 40 m in height and attain large sizes. The only specimen within the forested areas of the Mt. Serapong Study Area is of 5.5 m girth and 36 m height [P-22]. Likewise, *Litsea elliptica*, or commonly known as common medang, is also another tree species that can be frequently found in the secondary forests of Singapore. A unique characteristic for specimens of this species is that all living parts of the plants exude a strong aromatic smell. The specimen in the Mt. Serapong Study Area is located near Serapong Course Road, adjacent to the PUB station. It is recorded to be of 3 m girth and 20 m height [P-22].

Atmospheric carbon is sequestered by plants and this aids in mitigating the effects of climate change. Large specimens like the heritage trees store large amounts of biomass in their trunks, roots, and other plant parts over long periods of time, thus retaining them would contribute to conservation efforts. Additionally, they also play an important role in contributing to heterogeneity in forest structures considering how long it takes for plants to grow to sizable statures from seed in forested areas. Complex forest structures are difficult to create or replicate through human intervention, and so plant specimens that make up forested habitats should be retained and left untouched as much as possible. Other ecosystem functions and services of these trees, such as the provision of important sources of food and shelter for faunal communities, are also justification for keeping and protecting the specimens on site.



Legend

Study area

Vegetation

Native-dominated secondary forest

Mixed forest

Scrubland and herbaceous vegetation

Managed vegetation

Waterbody

Others (infrastructure)

Heritage tree

Construction

Manhole

Worksite

N

B	NOV 2021	SHMX	Final Report Rev B	DYCH	DYCH	
A	JUL 2021	SHMX	Final Report Rev A	DYCH	DYCH	
		SHMX	Final Report	DYCH	DYCH	
Rev.	Date	By	Description	Chk'd	App'd	

Qualified Person Endorsement :
NA

Client Endorsement:
NA

Consultant :
AECOM

Project Title :
**Contract No. SDC/21.8.2/19:
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Sewer Project at Sentosa**

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SHMX

Checked
JAG/NHT

Approved
JAG

Drawn
SHMX

Date
NOV 2021

sentosa

Engineering & Construction

Figure Title :
**Locations of Heritage Trees within
the Mt. Serapong Study Area**

Figure No. :
4-6

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1 of 1

CAD File Name : NA

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Note: Source of basemap - Microsoft Bing Map

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4.6 Local Geology

Information relating to the local geology of Sentosa Island was obtained from research publication published by the Journal of Asian Earth Sciences titled *“Ductile And Brittle Deformation In Singapore: A Record Of Mesozoic Orogeny And Amalgamation In Sundaland, And Of Post-Orogenic Faulting”* [P-4] and the *“Paleozoic To Cenozoic Sedimentary Bedrock Geology And Lithostratigraphy Of Singapore”* [P-5, P-6] manuscript retrieved publicly from the National Environment Research Council of the UK Research & Innovation.

The geology of Sentosa Island generally consists of two (2) geological formations, namely the Tanjong Rimau Formation and Fort Siloso Formation. Based on to the geological maps from the Journal of Asian Earth Sciences, the local geological profile of Sentosa Island was reflected in Table 4-4 and Figure 4-7.

Table 4-4 Geological Information in the Vicinity of the Project

Formation	Composition	Occurrence within the alignment of the Sentosa DGS pipeline and its vicinity
Fort Siloso Formation	Interbedded mudstone and sandstone.	This geology underlies the forested area of Mt. Serapong at the east of Sentosa Island, including Sentosa Gateway, parts of Allanbrooke Road, Cove Avenue and Ocean Drive. The geological formation underlies the Project alignment of: Proposed DGS pipelines associated with manholes MH15, MH16, MH17, MH18, MH19, MH20, MH21, MH22 and MH24.
Tanjong Rimau Formation	Interbedded conglomerate, sandstone, and mudstone.	This geology underlies the forested area of Mt. Imbiah at the west of Sentosa Island, including Siloso Beach Walk, Siloso Road, Artillery Avenue, Palawan Beach Road, Tanjong Beach Walk and parts of Allanbrooke Road. The geological formation underlies the Project alignment of: Proposed DGS pipelines associated with manholes MH1 to MH14, MH23, MH25 to MH32.



Base Construction Worksites

DGS Manholes & Pipeline

Nature Areas

Fort Siloso Formation

Tanjong Rimau Formation

N

B	NOV 2021	SYT	Final Report Rev B	JAG/NHT	JAG	
A	JUL 2021	SYT	Final Report Rev A	JAG/NHT	JAG	
-	MAY 2021	SYT	Final Report	JAG/NHT	JAG	
Rev.	Date	By	Description	Chk'd	App'd	

Qualified Person Endorsement :
NA

Client Endorsement :
NA

Consultant :
AECOM

Project Title :
**Contract No. SDC/21.8.2/19:
Environmental Study
For The Proposed Deep Gravity
Sewer Project at Sentosa**

Designed
SYT

Checked
JAG/NHT

Approved
JAG

Figure No. :
4-7

Rev.
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Sheet
1 of 1

CAD File Name :NA

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Source of basemap - OneMap

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4.7 Climate

4.7.1 Rainfall

Rainfall is plentiful in Singapore, as it is situated near the equator and has a typically tropical climate. Singapore's year-to-year rainfall is highly variable. Based on the 30-years long-term climate information (1981 – 2010) by the Meteorological Service Singapore (MSS), it rained an average of 167 days of the year and had an annual rainfall total of 2165.9 mm [W-21]. Nonetheless, the recent findings from MSS demonstrated that the total annual rainfall in Singapore increased at an average rate of 67 mm per decade, and hourly rainfall increased at the rate of 0.8 days per decade for heavy rain (>40 mm) and 0.2 days per decade for very heavy rain (>70 mm) from Year 1980 to 2019 [W-22] as reflected in Figure 4-8 below.

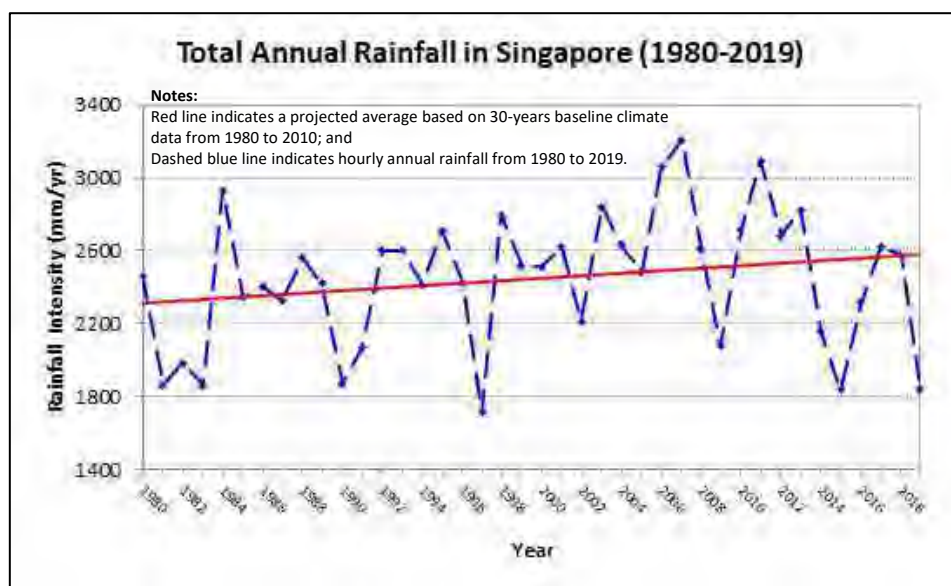


Figure 4-8 Annual Rainfall Total in Singapore from 1980 to 2019 [W-22]

In terms of 30-years long-term average rainfall spatial distribution, rainfall was higher over the central and northern parts of Singapore and decreases towards the eastern and western parts of Singapore (Figure 4-9) [W-21]. For the southern part of Singapore where Sentosa island is located, it has higher rainfall than the eastern and western tips of Singapore, with relatively similar rainfall if compared to the central and northern parts of Singapore. Furthermore, the recent findings from MSS had shown an overall upward trend in total annual rainfall at increased average rates ranging from 3.3 to 12.2 mm/year, during the period from 1980 to 2019 (see Figure 4-10) if compared to the 30-years long-term basis, except for the areas near Changi and Queenstown climate stations at the east and south of Singapore respectively. [W-22]



Figure 4-9 Annual Average Rainfall Spatial Distribution (1981-2010) [W-21]

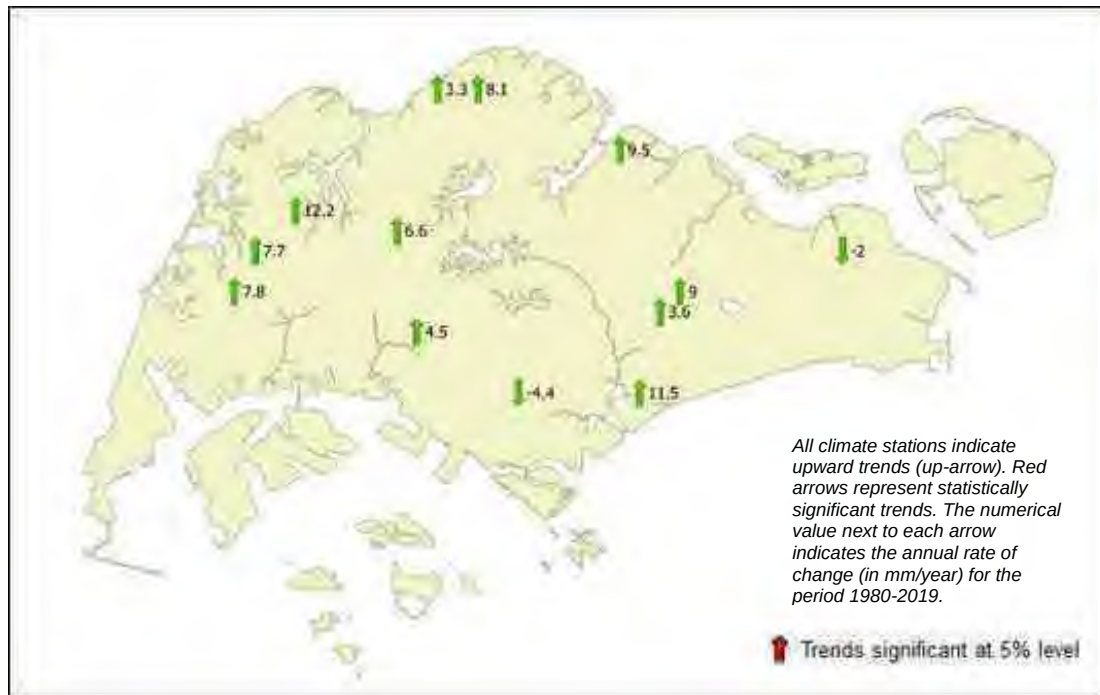


Figure 4-10 Past Trends of Annual Rainfall Total at Individual Stations (1981-2019) [W-22]

Singapore has two monsoon seasons separated by inter-monsoonal periods, where the Northeast Monsoon occurs from December to early March and the Southwest Monsoon from June to September. It also has abundant rainfall all the year round with relatively higher mean rain days (more than 13 days) from November to December every year based on the 30-years (1980 – 2010) long-term monthly average observed by MSS (refer to Figure 4-11).

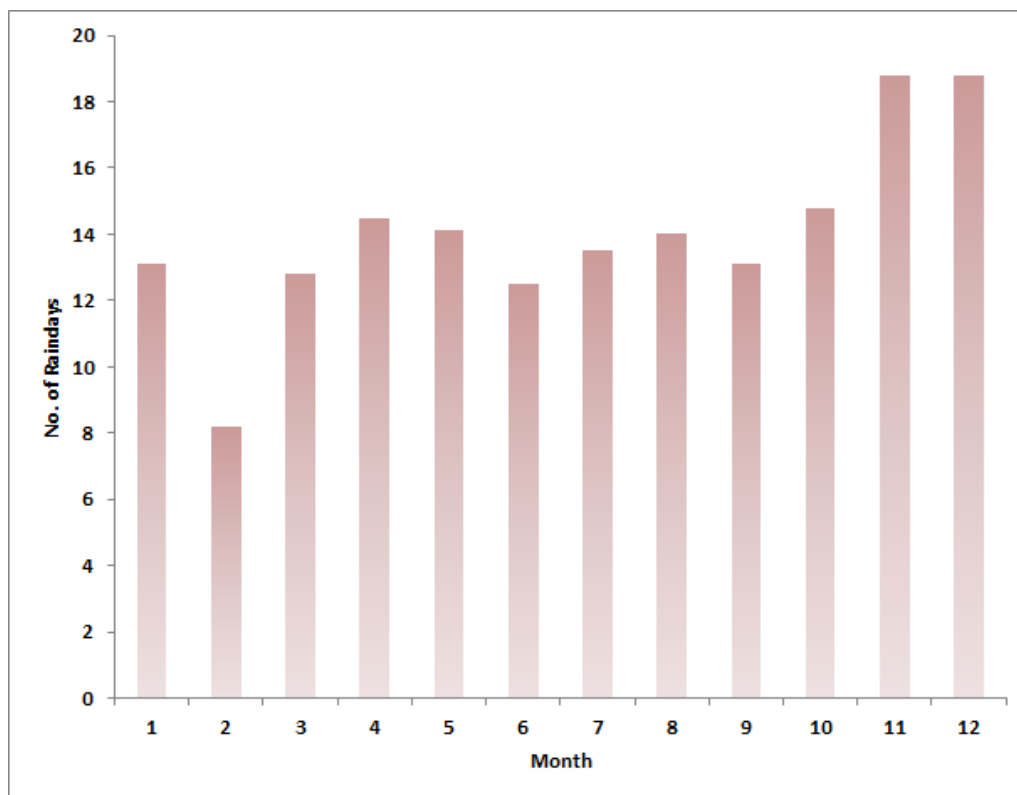


Figure 4-11 Average Number of Rain Days Per Month (1981-2019) [W-21]

During the 30-years long-term climate observation period from Year 1981 to 2010, Singapore had mean rainfall amount of more than 200 mm during the Northeast Monsoon season. Furthermore, the recent findings published by MSS had demonstrated that the annual total rainfall in Year 2019 (refer to Figure 4-12) was mostly below the 30-years long-term average, except for the months of April, June, October and December 2019.

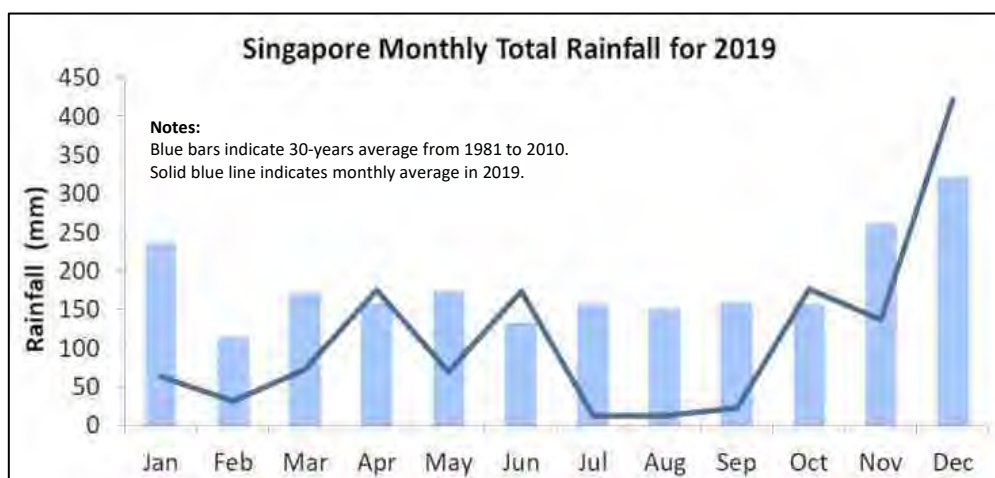


Figure 4-12 Singapore Monthly Total Rainfall for 2019 [W-23]

4.7.2 Temperature

Based on the observations in long-term period from Year 1981 to 2010, Singapore has high and uniform mean temperatures ranging from 26°C to 28°C throughout the year (refer to Figure 4-13). Extreme minimum and maximum temperatures are ranging from 20°C to 36°C.

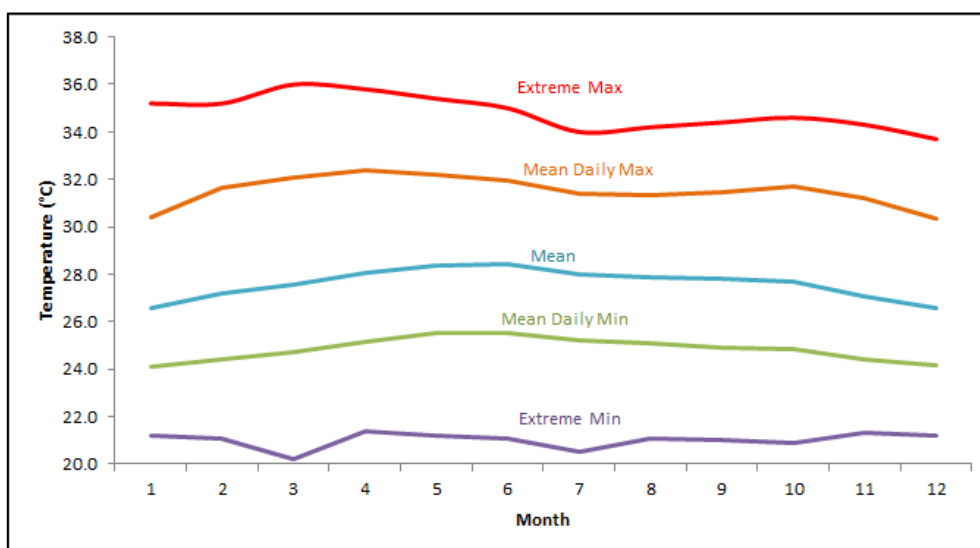


Figure 4-13 Mean Monthly Temperature Variation (1981-2010) [W-21]

As shown in Figure 4-14, Singapore's continuous temperature records since 1948 show that the island has warmed by an average of 0.25°C per decade, with a visible and sudden rapid increase after the mid-1970s. This might have been due to the rapid economic development and urbanization that took place after Singapore's political reformation, as well as due to the influence of anthropogenic climate change effects. Eight of the ten warmest years recorded in Singapore have occurred in the 21st century and all ten occurred after 1997. In Year 2019, the annual mean temperature was observed at 28.4°C, which was 0.9°C higher than the 30-years-long-term average (1981-2010). [W-22]

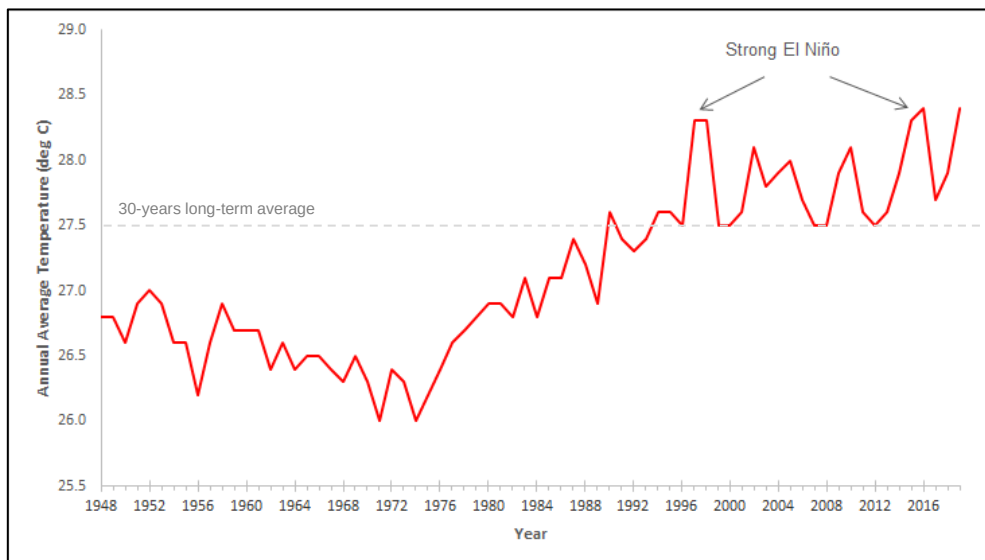


Figure 4-14 Annual Mean Temperature in Singapore from 1948 to 2019 [W-22]

4.7.3 Relative Humidity

Relative humidity shows a fairly uniform pattern throughout the year and does not vary much from month to month. Its daily variation is more marked, varying from more than 90% before sunrise to around 60% in the mid-afternoon on days when there is no rain. While the mean annual relative humidity is 83.9%, the relative humidity frequently reaches 100% during prolonged periods of rain.

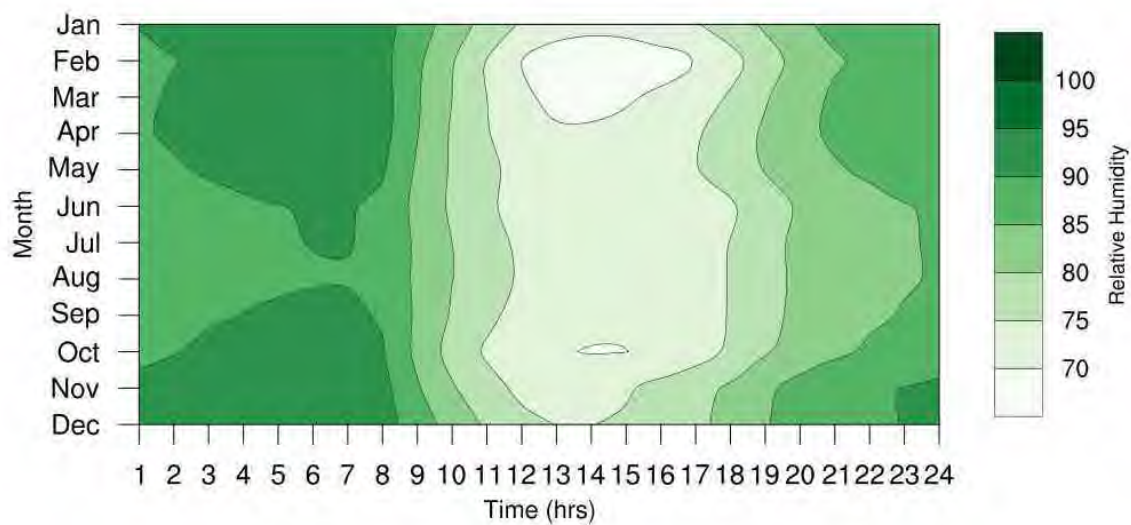


Figure 4-15 Hourly Variation of Relative Humidity for Each Month (1981-2010) [W-21]

4.7.4 Surface Wind

Winds in Singapore are generally light, with the mean surface wind speed normally less than 2.5 m/s. An exception to this is during the presence of a Northeast Monsoon surge, where mean speeds of 10m/s or more have been observed. Strong winds also occur during thunderstorms. Surface wind gusts are produced from thunderstorm downdrafts and from the passage of Sumatra Squall Lines. As shown in Figure 4-16, the most prominent winds in Singapore are from northeast and the south, occurring during the Northeast and Southwest Monsoon, respectively. The mean monthly wind speed ranges from 1.5 to 3 m/s [W-21].

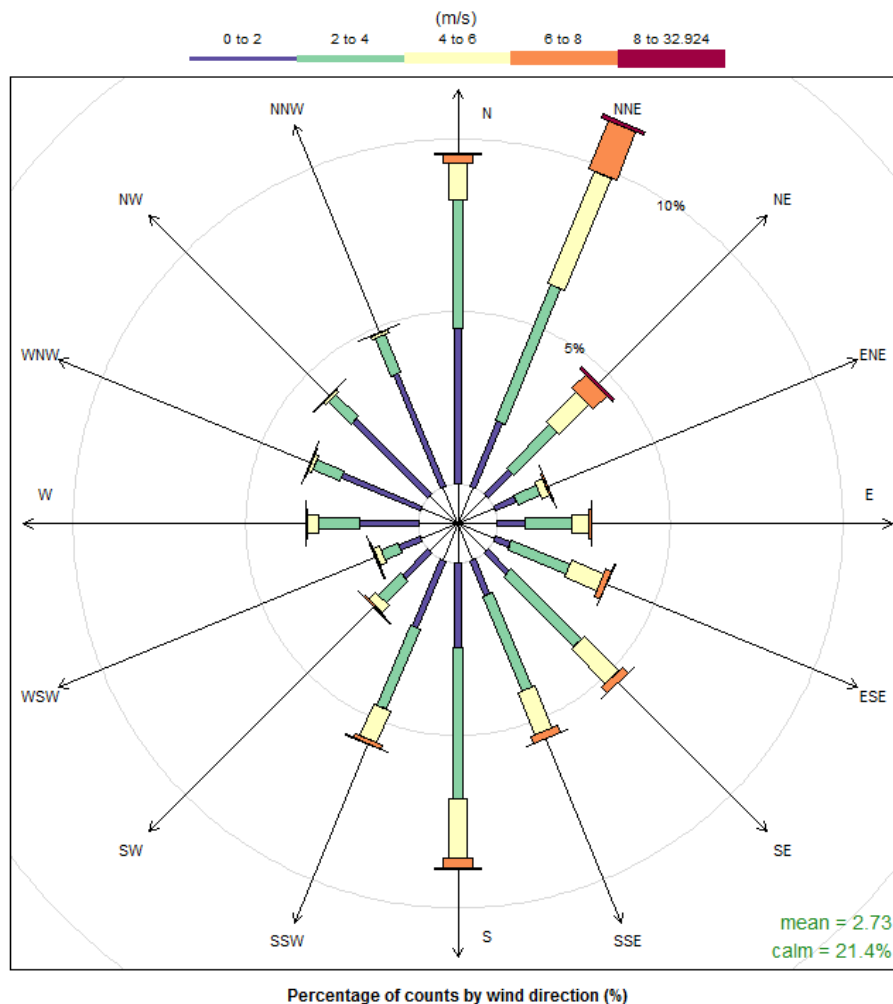


Figure 4-16 Annual Wind Rose of Singapore [W-21]

5. Environmental Legislations, Policies, Guidelines, Plans, Standards and Criteria

An indicative list of relevant environmental legislations, policies, guidelines, plans, standards and criteria applicable for this Project was provided in Table 5-1.

Table 5-1 Applicable Environmental Legislations, Policies, Guidelines, Plans, Standards and Criteria

Environmental Parameter	Legislation/ Policy/ Guideline/ Plan/ Standard/ Criteria	Key Description
Biodiversity	National Parks Board Biodiversity Impact Assessment (BIA) Guidelines, 2020 [R-1]	This document provides a guideline on how to conduct biodiversity impact assessment as an individual study or as the biodiversity component of an environmental study or environmental impact assessment.
	National Biodiversity Strategy and Action Plan [R-2].	This document provides a framework to guide biodiversity conservation efforts in Singapore. It intends to establish both policy frameworks and specific measures to ensure better planning and co-ordination in the sustainable use, management and conservation of biodiversity. A holistic approach has been adopted where the input of various public sector agencies and nature groups have been taken into consideration in the preparation of the document.
	Wildlife Act, Chapter 351, 2000 [R-3].	An Act for the protection, preservation and management of wildlife for the purposes of maintaining a healthy ecosystem and safeguarding public safety and health, and for related matters
	Parks and Trees Act, 2006 [R-4].	- An Act to provide 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, and for matters connected therewith. - No tree with a girth exceeding one meter (when measured 1-m from the ground) should be cut or damaged without the prior approval of the relevant authorities; and - No tree or plant will be cut or damaged if located within the heritage road green buffer.
	Parks and Trees Act (Parks and Trees Regulations), 2006 [R-5].	Prohibitions and regulations on trees and animals within national park, nature reserve or public park.
	Parks and Trees (Heritage Road Green Buffers) Order, 2006 [R-6].	Lists the areas designated as heritage road green buffers.
	Parks and Trees (Preservation of Trees) Order, 1998 [R-7].	Lists the designated tree conservation areas No cutting or damaging of tree having girth of more than one metre.
	The Singapore Red Data Book (SRDB) [R-8].	Lists the endangered plants and animals in Singapore Published by Singapore's Nature Society

Environmental Parameter	Legislation/ Policy/ Guideline/ Plan/ Standard/ Criteria	Key Description
		Provides the scientific name, common name, status, description, habitat, distribution, threats, scientific interest and potential value, as well as conservation measures for each plant and animal listed.
Air Quality	Environmental Protection and Management Act, 2020 [R-11].	Provides standards and regulations on air impurities
	Environmental Protection and Management (Air Impurities) Regulations 2015 [R-12].	Regulates air emissions and impurities in Singapore.
	Singapore Ambient Air Quality Targets (Long Term Targets) [R-13].	Stipulates the recommended limit values for ambient concentrations of NO ₂ , SO ₂ , PM ₁₀ , PM _{2.5} , CO and O ₃ to be applied from the year 2020. Target values are based on World Health Organization (WHO) Limit Values (mixture of Interim and Final values).
	Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations 2012 [R-14].	Stipulates that all off-road diesel engines (including construction equipment with diesel engines) imported for use in Singapore from July 2012 must comply with the EU Stage II, US Tier II or Japan Tier I off-road diesel engine emission standards.
Airborne Noise	SS 593: Code of Practice for Pollution Control (COPPC), 2013 [R-16].	Specifies recommended pollution control requirements and good practices for prevention of impacts to noise.
	SS602:2014 Code of Practice for Noise Control on Construction and Demolition Sites [R-17].	Specifies recommendations and good practices for prevention of noise impacts from construction activities.
	Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2008 [R-18].	- Stipulates a set of maximum allowable noise limits for construction sites for different time periods of the day and for different types of premises affected by construction noise. - Stipulates the correction factor that needs to be applied to the applicable noise criteria based on background noise levels.
Surface Water Quality	Environmental Protection and Management Act, 2020 [R-11].	Regulates the discharge of trade effluent, oil chemical, sewage or other pollution matters into drains.
	SS 593: 2013 – Code of Practice for Pollution Control (COPPC) [R-16].	- Provides guidelines for the appropriate discharge of any effluent into public sewer or watercourse. - Provides guidelines for the appropriate storage and accidental release of oils & chemicals.
	Environmental Protection and Management (Trade Effluent) Regulations, 2008 [R-20].	- Regulates the discharge of trade effluent to public watercourse. - Any discharge into a watercourse must comply with the regulatory standards established in these regulations.
	Sewerage and Drainage Act, 2001 [R-21].	An Act to provide for and regulate the construction, maintenance, improvement, operation and use of sewerage and land

Environmental Parameter	Legislation/ Policy/ Guideline/ Plan/ Standard/ Criteria	Key Description
		drainage systems, and to regulate the discharge of sewage and trade effluent. Regulates the protection, maintenance and provision of stormwater drainage system.
	Sewerage and Drainage (Trade Effluent) Regulations, 2007 [R-22].	Regulates trade effluent discharge into public sewerage system.
	Sewerage and Drainage (Surface Water Drainage) Regulations, 2007 [R-23].	Regulates measures to be implemented to protect the stormwater drainage system.
	PUB Code of Practice on Surface Water Drainage, 2013 [R-24].	Provides guidelines for measures to be implemented to protect the stormwater drainage system and manage surface water drainage (e.g. development and implementation of an Earth Control Measures (ECM) plan).
	NEA Code of Practice for Environmental Control Officers for Construction Sites 2 nd Edition. 26 November 2020 [R-25].	Provides guidelines about earth control measures and other water pollution control measures for the implementation as the best site practices or minimum control measures on site.
	PUB Circular on Preventing Muddy Water from the Construction Site, October 2015 [R-26].	All new construction sites with site area of 0.2ha and above, sites with problematic ECM, and sites within sensitive areas are required to implement CCTV including a Silty Imagery Detection System (SIDS) at the public drain to monitor the surface run-off discharges from the sites.
Chemical Substances (Surface water quality section, where applicable)	Code of Practice for the Storage of Flammable Liquids (SS 532:2007) [R-36].	Provides guidelines for the transport, use and storage of flammable material to prevent occurrence of accidents.
	Environmental Protection and Management (Hazardous Substances) Regulations, 2008 [R-37].	Regulates the transport, use and storage of hazardous substances.
Waste (Surface water quality section, where applicable)	Environmental Public Health, 2002 Act [R-38].	Regulates the storage, handling and disposal of wastes.
	Environmental Public Health (Toxic Industrial Waste) Regulations, 2000 [R-39].	Regulates the storage, collection and disposal of toxic industrial waste.
	Environmental Public Health (General Waste Collection) Regulations, 2000 [R-40].	Regulates general waste (incinerable and non-incinerable waste) disposal.
	Hazardous Waste (Control of Export, Import and Transit) Act 1997 [R-41].	An Act that provides the regulation of the export, import and transit of hazardous and other wastes, and for related purposes.
	Basel Convention on the Control of Transboundary Movements of	Singapore signed the Basel Convention in 1995. Its requirements were transposed into

Environmental Parameter	Legislation/ Policy/ Guideline/ Plan/ Standard/ Criteria	Key Description
	Hazardous Wastes and their Disposal [R-42]	Singaporean law through the Hazardous Waste Act. The Convention obligates parties to provide for the environmentally sound management of hazardous and other wastes, e.g. restrictions on the import, export and trans-boundary movement of hazardous wastes. Appropriate measures must be taken to ensure that the generation of such wastes, as well as the consequences of waste pollution on human health and the environment is minimal. Adequate disposal facilities must be available.
	SS603: 2014 Code of Practice for Hazardous Waste management [R-43].	This code provides guidance on best practice measures for managing hazardous waste on site
	Code of Practice for Licensed General Waste Collector [R-44].	This code provides list of wastes allowed to be collected by various licensed collector types.
	NEA circulars on import and export of waste [R-45].	Several circulars have been rolled out prohibiting certain import / export of waste One of the circulars prohibits import/ export of metal/plastic scrap containing toxic or heavy metals (PCD/BASEL/05-0021)

References were made to other international legislations, policies, guidelines, plans, standards and criteria, where relevant in this report.

Table 5-2 List of Key International References

Environmental Parameter	Legislation/ Policy/ Guideline/ Plan/ Standard/ Criteria	Key Description
Biodiversity	The International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species [R-9].	Provides taxonomic, conservation status and distribution information on plants, fungi and animals that have been globally evaluated.
	The Hong Kong Environmental Impact Assessment Ordinance - Technical Memorandum (HK EIAO TM) [R-10].	Sets out the principles, procedures, guidelines, requirements and criteria for deciding whether a project is environmentally acceptable.
Air Quality	UK Institute of Air Quality Management (IAQM) Guidance on the Assessment of Dust from Demolition and Construction [R-15].	The document provides guidance for developers, their consultants and environmental health practitioners on how to undertake a construction impact assessment.
Airborne Noise	Biodiversity 2020 (UK) [R-19].	"Theme 3: reduce environmental pressures - integrate consideration of biodiversity within the sectors which have the greatest potential for direct influence and reduce direct pressures." The guide does not provide airborne noise criteria for biodiversity impact assessment but only serves as a reference that sets out biodiversity policies and strategies to conserve

Environmental Parameter	Legislation/ Policy/ Guideline/ Plan/ Standard/ Criteria	Key Description
		biodiversity for AECOM to consider and implement in this study.
Surface Water Quality	Standard Statistical Classification of Surface Freshwater Quality for the Maintenance of Aquatic Life, New York and Geneva UNECE (1994) [R-27].	Provides standards for water quality assessment relating to aquatic life for surface waterbodies.
	Water Quality Requirements WHO (n.d.) [R-28].	Provides standards for water quality assessment relating to aquatic life for surface waterbodies.
	Water Quality Standards Handbook USEPA (2017) [R-29].	Provides standards for water quality assessment relating to aquatic life for surface waterbodies.
	Australian & New Zealand Guidelines for Freshwater and Marine Water Quality (2000) [R-30].	Provides standards for water quality assessment relating to aquatic life for surface waterbodies.
	Canadian Water Quality Guidelines for the Protection of Aquatic Life (2007) [R-31].	Provides standards for water quality assessment relating to aquatic life for surface waterbodies.
	Mitigating Impact from Aquaculture in the Philippines (PHILMINAQ) [R-32].	Provides standards for water quality assessment relating to aquatic life for surface waterbodies
	National Water Quality Standards for Malaysia (DOE) [R-33].	Provides standards for water quality assessment relating to aquatic life for surface waterbodies
	ASEAN Marine Water Quality Management Guidelines and Monitoring Manual (2008) [R-34]	Provides marine water quality criteria for the protection of the coastal and marine environment and human health within ASEAN

6. Assessment Methodology

6.1 Approach

The general approach to the Environmental Study was described as follows:

- Scoping of Project, completed through an Inception Report, including:
 - Project definition (Section 3);
 - Identification of study area (Section 6.2.1);
 - Identification of sensitive receptors (Section 6.2.2); and
 - Identification of sample collection locations (Section 6.3.1).
- Impact Assessment and Evaluation, detailed in this report, including:
 - Data collection and analysis (Section 6.3);
 - Prediction of impacts (Section 6.4.1);
 - Evaluation of impacts (Section 6.4.2); and
 - Recommendation of mitigation measures where necessary, and EMMP (Section 11).

6.2 Scoping of Project

Referring to the scoping meeting with NEA and NParks on 25 November 2020, as well as the scope documented in the Sentosa DGS Inception Report [G-1], the potential environmental impacts resulting from the construction activities of this Project were assessed in this Environmental Study as follows:

- Biodiversity;
- Airborne Noise;
- Air Quality; and
- Surface Water Quality.

6.2.1 Identification of Study Area

The study area for this Environmental Study was used to determine any potential environmental impacts to the nearby sensitive receptors due to construction activities in the vicinity of the Project. Study area could vary depending on the technical discipline as summarized in Section 4.1 and was described for each impact in the respective chapters.

6.2.2 Identification and Classification of Sensitive Receptors

Sensitive receptors are those receptors within or in the vicinity of the study area which may potentially be impacted by the construction activities.

Environmentally sensitive receptors were sub-categorised into three categories: Priority 1, Priority 2 and Priority 3 (from the most sensitive to the least) as shown in the following table. The identification of sensitive receptors for each environmental parameter was developed based on the findings of the environmental reconnaissance surveys, baseline surveys and review of the proposed project footprint as reflected in Table 6-1 below.

Table 6-1 Receptor Sensitivity Classification

Environmental Parameter	Receptor Sensitivity		
	Priority 1	Priority 2	Priority 3
Biodiversity	Habitats and species of flora and fauna of high ecological value (i.e., mostly undisturbed forested areas, and nationally and/or globally threatened species of flora and fauna)	Habitats and species of flora and fauna of moderate ecological value (i.e., less disturbed habitats, and largely native species of flora and fauna)	Habitats and species of flora and fauna of low ecological value (i.e., disturbed habitats, and largely exotic or cryptogenic species of flora and fauna)
Airborne Noise¹ (Ecologically Sensitive Receptor)	Fauna species and habitats of high auditory sensitivity to airborne noise.	Fauna species and habitats of moderate auditory sensitivity to airborne noise.	Fauna species and habitats of low auditory sensitivity to airborne noise.
Airborne Noise (Human Receptor)	Schools and Education Buildings, Hospitals and Medical Centres, Nursing Homes.	Residential buildings ²	Other Buildings (Industrial, Commercial, Infrastructure, Sport & Recreation Areas, Religious Buildings, etc.).
Air Quality (Ecologically Sensitive Receptor)	Flora, Fauna Species and Habitats of High Ecological Value within 20 m of worksites.	- Flora, Fauna Species and Habitats of High Ecological Value within 20 m to 50 m of worksites. - Ecological sites having known sensitive communities within 20 m of worksites.	- Ecological sites having known sensitive communities within 20 m to 50 m of worksites. - Any other ecological sites within the study area of 50 m.
Air Quality (Human Receptor)	- Sensitive receptors³ (more than 100 receptors) within 50 m of the worksites. - Sensitive receptors (1-100 receptors) within 20 m of the worksites.	- Sensitive receptors (more than 100 receptors) between 50 m to 100 m of the worksites. - Sensitive receptors (1-100 receptor) between 20 m to 50 m of the worksites. - Office, industrial facilities, or shops (more than 10 receptors) within 20m of the worksites.	- Public footpath, playing fields and parks within 20 m from worksites. - All other buildings within the 350 m study boundary.
Surface Water Quality	Surface waterbodies protected and used for drinking supply ⁴ , or supporting ecosystems of biodiversity conservation significance in consultant with Biodiversity specialist after surveys ⁵	Surface waterbodies used for industrial water supply or for recreational purposes, but not used for drinking water purposes and which do not support ecosystems of biodiversity conservation significance in consultant with Biodiversity specialist after surveys.	Surface waterbodies not used for any purposes and not protected

¹ The fact is that different species are likely to react differently to disturbance and that will be influenced by various other factors such as how percussive the noise is (e.g. from blasting and piling), how far away the receptor is generally, behaviour of the fauna, and other factors such as whether the species is feeding or breeding/nesting and in particular from the complication of visual disturbance (particularly humans on foot nearby).

² Sensitive receptors for residential buildings included both long-term (e.g. residential blocks, landed houses) and short-term stay (e.g. hotels, villas, resorts) as advised by NEA during scoping meeting on 25 November 2020.

³ Sensitive receptors for air impact assessment included residential blocks, hospitals, medical centre, schools and education and residential care home. This was defined according to classification made in the IAQM's guidance. Hawker centres should also be checked.

⁴ Waterbody usage was determined based on the PUB Water Catchment Map [W-5].

⁵ The receptor sensitivity of surface waterbodies was determined based on the biodiversity baseline survey results which identified whether such surface waterbodies were supporting ecosystems of biodiversity conservation significance.

6.3 Data Collection and Analysis

Collection of pre-construction environmental baseline data within the study area was conducted both from primary sources and secondary sources.

6.3.1 Sample Collection Locations and Parameters

The sample collection and survey locations were selected for baseline data collection based on their proximity to the Project and receptor sensitivity. These locations were confirmed after conducted site reconnaissance surveys. Site visits were undertaken as tabulated in the following Table 6-2.

Table 6-2 Site Visits for Data Collection

Environmental Parameter	Site Visits
Biodiversity	<u>Site reconnaissance surveys:</u> 10, 19, and 26 November 2020 <u>Survey period:</u> - Flora: 11 December 2020–21 January 2021 - Fauna: 30 November 2020–18 January 2021 - Camera trapping: 2 December 2020–11 January 2021
Airborne Noise	<u>Site reconnaissance survey:</u> 10 November 2020 2 December 2020 <u>Noise monitoring/ sampling dates:</u> 2 December 2020 11 December 2020 29 December 2020
Air Quality	<u>Site reconnaissance survey:</u> 10 November 2020 2 December 2020 <u>Air monitoring/ sampling dates:</u> 14 December 2020 15 December 2020 22 December 2020 23 December 2020
Surface Water Quality	<u>Site reconnaissance survey:</u> 10 November 2020 with biodiversity site reconnaissance 30 November 2020 with biodiversity survey <u>Water sampling dates:</u> 28 January 2021: S1a, S2a, S3a (dry weather) 5 March 2021: S7, S8 (dry weather) 9 March 2021: S4, S5, S6, S9 (dry weather) 23 March 2021: S1b, S4, S5, S6, S9 (wet weather) 18 May 2021: S2b, S3b, S7, S8 (wet weather)

Further information on sample collection and survey locations and parameters were provided in Section 7 (Biodiversity), Section 8 (Airborne Noise), Section 9 (Air Quality) and Section 10 (Surface Water Quality).

6.3.2 Secondary Data Collection

Additional secondary data was collected from sources including, but not limited to, the following:

- Review of available environmental surveys previously carried out within or in the vicinity of the study area (e.g. tree surveys, ecological surveys, etc);
- Publicly available data, existing literature, books (e.g. Singapore Red Data Book (SRDB) and online sources);
- Singapore ambient air quality available online;
- Historical, current and planned land uses including commercial and recreational activities;
- Online databases (Climate, biodiversity, historical land use, etc);
- Aerial photographs;
- Drainage maps of the catchment area;
- Weather Data (Rainfall, Wind, Evaporation);
- Landscape maps; and
- Commercial and recreational activities.

Further information on sample collection and survey locations and parameters were provided in Section 7 (Biodiversity), Section 8 (Airborne Noise), Section 9 (Air Quality) and Section 10 (Surface Water Quality).

6.4 Assessment Criteria

6.4.1 Prediction of Impacts

The key potential environmental impacts arising from the Project's construction activities were assessed within the project scope. The methodology for the prediction of impacts was given in Table 6-3.

Table 6-3 Methodology for Prediction of Construction Impacts

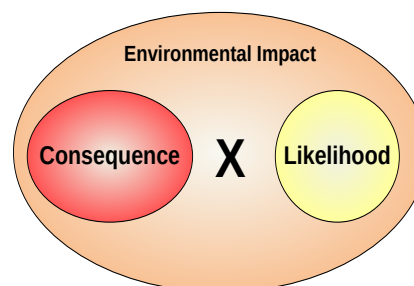
Environmental Parameter	Predictive Methods	Assessment Criteria	Report Section
Biodiversity	Quantitative and Qualitative Assessment to evaluate the impacts of construction activities on key biodiversity sensitive receptors of floral communities, faunal species and habitats within the study area and its immediate surrounding (if any).	Assessment criteria broadly takes guidance from NParks' Biodiversity Impact Assessment (BIA) Guideline [R-1], with considerations from literature review and local biodiversity standards.	Section 7
Airborne Noise	Quantitative Assessment was adopted to assess construction noise to the noise sensitive receptors.	Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2008 [R-18].	Section 8
Air Quality	Qualitative Assessment following dust risk assessment methodology focusing on fugitive particulate emissions (dust) from the construction site.	Assessment broadly follows "Guidance on the Assessment of Dust from Demolition and Construction" which was published by the UK Institute of Air Quality Management (IAQM) in 2014 [R-46].	Section 9
Surface Water Quality	Qualitative Assessment was applied to assess surface water quality impacts arising from the construction phase of the Project on the potential waterbodies within/ surrounding the worksite.	• Environmental Protection and Management (Trade Effluent) regulations [R-20]. • Water Quality Criteria for Aquatic Life from other countries including United Nations Economic	Section 10

Environmental Parameter	Predictive Methods	Assessment Criteria	Report Section
		Commission for Europe [R-27], World Health Organization [R-28], United States Environmental Protection Agency [R-29], Philippines [R-32], Australian and New Zealand Environment and Conservation Council (ANZECC) [R-30], Canadian Council of Ministers of the Environment [R-31], and Department of Environment in Malaysia (DOE) [R-33].	

6.4.2 Evaluation of Impacts

Impacts were evaluated based on their significance, which is a measure of the weight that would be given to each impact in decision making and if it warrants impact management. It was assessed using the following two factors in the Impact Significance Assessment Matrix (refer to Table 6-7) as detailed below and in the following sections:

- **Impact Consequence:** The consequence of an impact is a function of a range of considerations including impact spread, impact duration, impact intensity and nature, legal and guideline compliance (Section 6.4.2.1);
- **Likelihood of Occurrence:** The likelihood of the impact occurring during the project construction periods, which takes into account the probability of the event happening as well as duration of the event (Section 6.4.2.2).



6.4.2.1 Impact Consequence

In evaluating the consequence of environmental impacts, the following aspects was taken into consideration:

- **Receptor Sensitivity:** Categorises receptors according to their susceptibility to adverse impacts from the Project's construction phase (refer to Table 6-1).
- **Impact Intensity:** Defines the magnitude of the impact and the status of the impact in relation to regulations (e.g. discharge limits), standards (e.g. environmental quality criteria) and guidelines. The criteria presented in Table 6-4 was used to categorise the impact intensity.

This Environmental Study proposed minimum controls, or standard practices commonly implemented in Singapore for similar construction activities, that was assumed to be implemented for the purposes of impact consequence assessment.

Table 6-4 Criteria Categorising the Impact Intensity for Construction Phase

Environmental Parameters	Impact Intensity			
	Negligible Intensity	Low Intensity	Medium Intensity	High Intensity
Biodiversity – Habitats	Potential impacts with no detectable changes to viability/function of habitats	Potential impacts with small temporal and spatial (localised) scale changes that could affect part of the habitat but does not cause the loss of viability/function of the habitat	Potential impacts with moderate duration and/or over a considerable spatial scale changes that could affect part of the habitat but does not threaten the long-term viability/function of the habitat	Potential impacts with extensive duration and large spatial scale that affects the entire habitat, or a significant proportion of it, and could affect the long-term viability/function of the habitat
Biodiversity – Flora and Fauna	No expected changes to the ecologically sensitive receptors and/or individuals	Short duration and small-scale localised spatial changes that could cause minimal changes to the ecologically sensitive receptors and/or individuals	Moderate duration and medium-scale spatial changes that could cause moderate effects on the ecologically sensitive receptors but would not threaten long-term viability	Extended duration and large-scale spatial changes that could cause substantial effects on the ecologically sensitive receptors and threaten long-term viability
Airborne Noise	The predicted noise levels are within baseline monitoring results for Ecologically Sensitive Receptors. The predicted noise levels are within regulatory noise limits for Human Receptors.	The exceedance of values compared to baseline monitoring results for Ecologically Sensitive Receptors is within 0-3 dB(A). The exceedance of values compared to regulatory noise limits for Human Receptors is within 0-3 dB(A).	The exceedance of values compared to baseline monitoring results for Ecologically Sensitive Receptors is 3-6 dB(A). The exceedance of values compared to regulatory noise limits for Human Receptors is 3-6 dB(A).	The exceedance of values compared to baseline monitoring results for Ecologically Sensitive Receptors is greater than 6 dB(A). The exceedance of values compared to regulatory noise limits for Human Receptors is greater than 6 dB(A).
Air Quality⁶	-	For Earthworks: • Total site area <2,500 m² • Soil type with large grain size (e.g. sand) • <5 heavy earth moving vehicles active at any one time • Formation of bunds <4 m in height • Total material moved <20,000t • Earthworks during wetter months	For Earthworks: • Total site area 2,500 m² – 10,000 m² • Moderately dusty soil type (e.g. silt) • 5-10 heavy earth moving vehicles active at any one time • Formation of bunds 4 m - 8 m in height • Total material moved 20,000-100,000t	For Earthworks: • Total site area >10,000 m² • Potentially dusty soil type (e.g. clay, which will be prone to suspension when dry due to small particle size) • >10 heavy earth moving vehicles active at any one time • Formation of bunds >8 m in height

⁶ This impact intensity criterion is equivalent to the Emission Magnitude as defined in IAQM's Guidance [R-46].

Environmental Parameters	Impact Intensity			
	Negligible Intensity	Low Intensity	Medium Intensity	High Intensity
				Total material moved >100,000t
	-	For Construction: - Total building volume <25,000 m³ - Construction material with low potential for dust release (e.g. metal cladding or timber)	For Construction: - Total building volume 25,000-100,000 m³ - Potentially dusty construction material (e.g. concrete) - On-site concrete batching	For Construction: - Total building volume >100,000 m³ - On-site concrete batching - Sand blasting
	-	For Trackout: <10 HDV⁷ (>3.5t) outward movements in any one day - Surface material with low potential for dust release - Unpaved road length <50 m	For Trackout: 10-50 HDV⁷ (>3.5t) outward movements in any one day - Moderately dusty surface material (e.g. high clay content) - Unpaved road length 50-100 m	For Trackout: >50 HDV⁷ (>3.5t) outward movements in any one day - Potentially dusty surface material (e.g. high clay content) - Unpaved road length >100 m
Surface Water Quality	No contamination; or Likely to be well within regulatory limits.	Small scale localised contamination within regulatory limits.	Medium scale contamination or just exceed regulatory limits.	Large scale contamination high likely to exceed regulatory limits; or exceeds regulatory limits by hazardous levels for the habitat/ conservation species.

A consequence category was then derived based on receptor sensitivity and impact intensity, as shown in Table 6-5. The air quality impact assessment used matrices specific to the Institute of Air Quality Management (IAQM) *Guidance On The Assessment Of Dust From Demolition And Construction* [R-15] and these were provided in Section 6.4.2.1.

Table 6-5 Impact Consequence Matrix

Sensitivity	Priority 3	Priority 2	Priority 1
Impact Intensity			
Negligible	Imperceptible	Very Low	Very Low
Low	Very Low	Low	Low
Medium	Very Low	Medium	Medium
High	Low	High	High

⁷ Heavy duty vehicles (HDV) defined as vehicles with a gross weight greater than 3.5 tonnes.

6.4.2.2 Likelihood of Occurrence

Likelihood was estimated based on experience and/or evidence that such an outcome had previously occurred. Impacts resulting from routine/planned events (normal operations) was classified under High Likelihood as reflected in Table 6-6 below.

Table 6-6 Likelihood Criteria

Likelihood Criteria	Definition for All Environmental Parameters	Definition for Airborne Noise Quantitative Evaluation (where applicable)
Unlikely/ Remote	Would be unlikely or remotely to occur during construction phase.	Happening < 5% of the construction timeline at the worksite.
Less Likely/ Rare	Would less likely/ rarely occur during construction phase.	Happening 5 - 15% of the construction timeline at the worksite.
Possible/ Occasional	Would possibly/ occasionally occur during construction phase.	Happening 16 - 25% of the construction timeline at the worksite.
Likely/ Regular	Would likely occur or would occur on a regular basis during construction phase.	Happening 26 - 50% of the construction timeline at the worksite.
Certain/ Continuous	Would be certain to occur or would occur continuously during construction phase.	Happening > 50% of the construction timeline at the worksite.

6.4.2.3 Significance of Impact

The significance of each impact was determined by assessing the impact consequence against the likelihood of the impact occurring using the Impact Significance Assessment Matrix. A simple risk-based matrix was used for summation of consequence and likelihood, a sample of which was shown in Table 6-7 below.

Table 6-7 Impact Significance Matrix

Consequence Likelihood	Imperceptible	Very Low	Low	Medium	High
Unlikely/ Remote	Negligible	Negligible	Negligible	Negligible	Negligible
Less Likely/ Rare	Negligible	Negligible	Minor	Minor	Minor
Possible/ Occasional	Negligible	Minor	Minor	Moderate	Moderate
Likely/ Regular	Negligible	Minor	Moderate	Moderate	Major
Certain/ Continuous	Negligible	Minor	Moderate	Major	Major

Impacts assessed as negligible or minor in general would require no additional management or mitigation measures (on the basis that the magnitude of the impact was sufficiently small, or that the receptor was of low sensitivity and/or that adequate controls were already included in the Project design). Negligible and minor impacts were therefore deemed to be "Insignificant". Instances where the impact intensity exceeded the stipulated criteria, however the impact significance was deemed to be minor for high priority receptors due to low likelihood, still strived to mitigate impacts further to as low as reasonably practicable. Impacts evaluated as moderate or major would require the adoption of management or mitigation measures. Major impacts were therefore deemed to be "Significant" and moderate impact as "Relatively Significant". Major impacts always require further management or mitigation measures to minimize or reduce the impact to an acceptable level.

An "acceptable level" is the reduction of a major impact to a moderate/minor/negligible one after mitigation. In seeking to mitigate significant impacts, the emphasis is on demonstrating that the impact has been reduced to a level that is as low as reasonably practicable. It might not always be practical to reduce major/ moderate impacts

to minor/negligible ones in consideration of the cost-ineffectiveness of such an approach (due to the diminishing return of a reduction of impact versus cost). Residual impact assessment was conducted for those parameters where impact from the activity was identified to be significant and additional mitigation measures were recommended. Assessment of residual impact was following similar risk approach as outlined above.

6.5 Mitigation, Monitoring and Management

Where the implementation of minimum controls was insufficient to alleviate any significant environmental construction impacts (moderate to major impacts), Project-specific final mitigation measures, in consultation with SDC, were proposed.

Where applicable and practical, engineering control measures would be accompanied by specifications (product brochures), estimated cost and source of supply. In addition, mitigation measures at receptors' end was also recommended on a case by case basis.

For example, if the unmitigated construction noise levels were found exceeding the relevant criteria, practical direct mitigation measures such as the use of noise barriers, enclosures, quieter powered mechanical equipment (PME) and construction methods, etc. would be recommended. Effective dust control measures would be recommended to minimize dust emission from the site, where necessary.

Mitigation measures were proposed in accordance with the following principles and mitigation hierarchy reflected in Figure 6-1:

- **Elimination/ Avoidance** - Where changes to the Project design and construction methodology could be made to eliminate or avoid an identified impact (e.g. optimisation or reduction of construction footprint, shift or elimination of construction site in critical areas, etc.). If a full elimination is not possible, the next level of mitigation is to minimize the identified impact;
- **Minimisation (Substitution)** - Where changes to the Project design and construction methodology could not affect impact elimination or avoidance, use of alternative construction methodology or any enhancement measures could be adopted to minimize for identified impacts. For e.g. use of silent piling instead of bore or sheet piling where practical, pipejacking instead of tunnel boring, etc.;
- **Minimisation (Engineering controls)** - Where changes to the Project design and construction could not affect impact avoidance and impact minimization via substitution, engineering controls could be adopted to further reduce for identified impacts (and possibly an enhancement measure). For e.g. use of noise barriers to reduce noise, application of silt curtains to curb silt flow into drains, etc.;
- **Minimisation (Administrative controls)** - Where applicable, enhanced mitigation could be achieved by applying administrative controls on top of engineering controls. These controls do not remove environmental hazards, but limit or prevent receptor's exposure to hazards, such as repeated wetting of unpaved roads for dust suppression;
- **Remedy/ Repair/ Restore** – Where residual impacts need to be further reduced, measures should be taken to remedy/ restore/ repair the situation after the impact, e.g. replanting of trees and shrubs in appropriate locations on the impacted site to restore part of the habitat after construction; and
- **Compensation/ Offset** - Where possible, measures should be taken to compensate/ offset the impacts in a different part of the development, wherever technically and financially feasible, e.g. rare shrubs or trees that are important to birds and mammals to be planted elsewhere in consultation with NParks, etc.

The above mitigation approach is in line with the NParks Biodiversity Impact Assessment (BIA) 2020 Guidelines [R-1] adopted for the Biodiversity Impact Assessment of this Environmental Study.

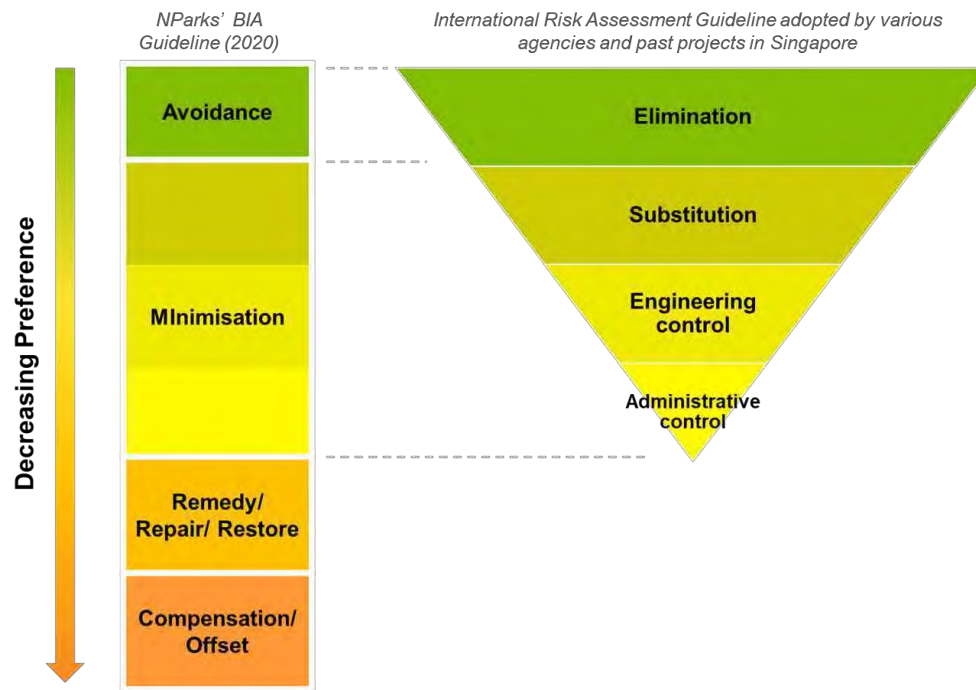


Figure 6-1 Mitigation Hierarchy

Construction Stage EMMP was formulated by specifying mitigation measures, monitoring scope, methodology and location, and triggers to report and escalate the irregularities in the baseline conditions at construction stage. An EMMP was prepared for environmental impacts of the construction phase associated with the project that were assessed in the Environmental Study, namely biodiversity, air quality, airborne noise, and surface water quality. The EMMP detailed how the recommended mitigation measures served in assessing the effectiveness of the mitigation/ minimum control measure of the Project.

The proposed mitigation measures and EMMP in the Environmental Study should be applicable and implemented where appropriate with due diligence during the construction phase. This should be inclusive of worksites outside the defined study areas, to reduce any work-related impacts to the environment.

7. Biodiversity

7.1 Introduction

The Biodiversity Impact Assessment aimed to establish baseline biodiversity information of the study areas and evaluate the impacts of the proposed construction works of the Project on existing flora and fauna. Baseline information was first gathered through reviews of past and present biodiversity records, published literature, and in consultation with taxonomic experts. Actual field surveys were then carried out to verify and supplement the data. Through the desktop and field assessments, important habitats, species of flora and fauna of conservation significance were identified. The information was then used to evaluate the extent of the impacts of construction works. Mitigation measures were then recommended to reduce and/or minimise the impacts. The acceptability of residual impacts was assessed.

7.2 Methodology

The areas for biodiversity assessments were identified as forested sites within 150 m from the proposed manhole locations. They comprise two main areas, i.e., 3.61 ha in the forested site east of the Mt. Imbiah and 9.91 ha within the Mt. Serapong, which add up to 13.52 ha in total (Figure 7-1). The biodiversity study area at Mt. Imbiah excluded the Mt. Imbiah nature area itself as parts of it had been largely developed into a tourist attraction site with facility buildings and infrastructure such as the zipline. The remaining forested areas were too steep to walk and would be unsafe for surveyors to carry out biodiversity surveys. The boundaries of the study areas were finalised after site reconnaissance surveys and discussions with the NParks during the scoping meeting on 25 November 2020.



Study area

Nature area

Manhole

150 m buffer from manhole

N

							Qualified Person Endorsement : NA
							Client Endorsement: NA
B	NOV 2021	SHMX	Final Report Rev B	DYCH	DYCH		
A	JUL 2021	SHMX	Final Report Rev A	DYCH	DYCH		
-		SHMX	Final Report	DYCH	DYCH		
Rev.	Date	By	Description	Chk'd	App'd		

Consultant :
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Project Title :
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For The Proposed Deep Gravity
Sewer Project at Sentosa**

Designed
SHMX

Checked
JAG/NHT

Approved
JAG

Drawn
SHMX

Date
NOV 2021

Figure Title :
Biodiversity Study Areas

Figure No.
7-1

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1 of 1

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7.2.1 Biodiversity Desktop Assessment

7.2.1.1 Land Use History

Historical and present-day land use of the study areas were reviewed. Information on land use history was primarily gathered from old maps in the online collection of the National Archives of Singapore (NAS) as well as historical maps on the OneMap and the National University of Singapore (NUS) Libraries portals. This was presented in Section 4.4.

7.2.1.2 Taxonomy and Nomenclature

Past and present floristic as well as faunistic species composition were examined using relevant key references that included books, scientific publications, unpublished literature, and online databases. Sources of databases included the Biodiversity of Singapore by the Lee Kong Chian Natural History Museum (LKCNCNHM) [W-30], Flora and Fauna Web by the National Parks Board [W-31], and iNaturalist. Other key references included the Singapore Red Data Book [R-8], Biodiversity Records under Nature in Singapore, an online journal of LKCNCNHM [W-35], Singapore Biodiversity Records Archives by LKCNCNHM [W-36], an encyclopaedia on Singapore biodiversity by Ng et al. (2011) [P-59] and the database of flora and fauna records compiled by Camphora Pte Ltd (unpublished).

Local and/or regional references for the various taxonomic groups:

- Plants – Chong et al. (2009) [P-2]; World Checklist of Selected Plant Families [W-27]; Plants of the World Online [W-28]
- Butterflies – Khew (2015) [P-36]; Jain et al. (2018) [P-37]; Theng et al. (2020) [P-38]
- Odonates – Tang et al. (2010) [P-39]; Ngiam & Cheong (2016) [P-40]; Soh et al. (2019) [P-54]
- Herpetofauna – Baker & Lim (2008) [P-8]
- Birds – Gill & Donsker (2021) [W-34]; Nature Society (Singapore) Bird Group Records Committee (2020) [W-37]; Singapore Birds (2021) [W-38]; Singapore Bird Group (2021) [W-39]; Singapore Birds Project (2021) [W-29]
- Mammals (including bats) – Baker & Lim (2008) [P-8]; Corlett (1992) [P-41]; Teo & Rajathurai (1997) [P-42]; Chua & Lim (2011) [P-43]; Brook et al. (2003) [P-61]; Lane et al. (2006) [P-62]
- Freshwater fish – Ng & Lim (1997) [P-44]; Kottelat (2013) [P-45]; Ho et al. (2016) [P-46]; Tan et al. (2020) [P-47]; Giam et al. (2011) [P-60]

7.2.1.3 Preliminary Species Lists

A list of species of fauna that are likely to occur at the study areas (termed thereafter as “species of probable occurrence”) was compiled using information on existing habitat types as well as past records of fauna up to 2 km from the study areas.

7.2.1.4 Species of Conservation Significance

The assessment of whether certain species are of conservation significance is important for highlighting the need and priorities for conservation.

Threatened species of flora—i.e., listed in Chong et al. (2009)) [P-2] as nationally Vulnerable, Endangered, Critically Endangered, or Presumed Extinct (which indicates a rediscovery)—were assessed to determine whether they are of conservation significance. While the national conservation status of threatened species is true of wild populations that originate in an area without direct or indirect human intervention, some populations may be relics that persist from past cultivation or escapees from present-day cultivation that do not belong to native genetic stock. The assessment of whether a threatened species is of conservation significance were based on, but not limited to, information on the following: (1) land use history, (2) presence of large parent tree(s), (3) commercial availability, (4) data from previous environmental impact assessments, (5) reforestation efforts, (6) natural range, and (7) importance for associated fauna. Where the origin of a threatened species population is disputable or difficult to determine, the more conservative approach was adopted, i.e., they were considered of conservation significance, with or without corroborating findings from field surveys of fauna. In carrying out such assessments, conservation needs could then be prioritised, and resources gathered in conserving them.

Faunal species of conservation significance include both non-threatened species regarded as notable records as well as threatened species. Notable non-threatened species are species deemed to be of conservation interest and/or sensitive to the impacts of construction. On the other hand, threatened species of fauna are those listed as nationally or globally Vulnerable, Endangered, Critically Endangered, or Extinct. The national conservation statuses

reference the Singapore Red Data Book [R-8] and other more updated local checklists, where available, such as Soh et al. (2019) [P-54] for odonates and Jain et al. (2018) [P-37] for butterflies. The global conservation status follows the Red List of Threatened Species by the International Union for Conservation of Nature [R-9].

7.2.2 Biodiversity Field Assessment

7.2.2.1 Site Reconnaissance

Site reconnaissance was conducted on 11, 19, and 26 November 2020 to obtain an initial understanding of the existing habitats and biodiversity. Field observations were then used for the planning and execution of actual surveys. The objectives of the site reconnaissance were described as follows:

- Determine site accessibility and terrain;
- Conduct a preliminary assessment to determine the dominant vegetation types;
- Identify locations of existing natural permanent waterbodies, such as streams, ponds, and swampy areas (if any); and
- Mark out survey sampling routes and potential locations for camera traps.

7.2.2.2 Floristic Field Assessment

The field assessment for flora consisted of (1) vegetation mapping, (2) general walking floristic surveys, and (3) ground-truthing. This was carried out from 1 December 2020–21 January 2021.

7.2.2.2.1 Habitat and Vegetation Mapping

A preliminary vegetation map was first prepared based on visual interpretations of satellite images from Google Earth 7.1.2.2041 [O-5]. Preliminary classification of the vegetation types—for example, forests, grasslands, or managed vegetation—was determined using visual features, such as textures and colours, observed in the satellite images. Adjustments were then made to the preliminary map according to actual observations during ground truthing. Ground truthing was conducted throughout the survey area with the aid of a GPS receiver (Garmin GPSMap® 64s). Photographs of the vegetated areas were also taken. The boundaries of each vegetation type were tracked on the GPS receiver and mapped out on Google Earth 9.126.0.3 [O-5]. The classification of vegetation types reference NParks (2020) [R-1].

7.2.2.2.2 General Walking Surveys

All plants observed in the study areas during floristic surveys were identified to species whenever possible. A checklist of all the plant species recorded from the present floristic surveys was compiled and presented in Appendix A. The nomenclature and national conservation status follow that of Chong et al. [P-2], and/or other published papers with updated information. The latter is usually for one or a few individual species. Other information on the plant species was also crosschecked with online databases, namely, the National Parks Board Flora and Fauna Web and Singapore Biodiversity Online.

For plants that could not be immediately identified with certainty in the field, photographs and/or voucher specimens were taken. They were then identified using identification keys, taxonomic descriptions, online plant photo databases, with the help of taxonomic experts, and/or by matching the pressed and dried collected specimens with existing specimens in the Singapore Botanic Gardens' Herbarium (SING).

For very tall unidentifiable trees with leaves that were too high in the canopy to photograph, dried leaves matching these trees were collected from the forest floor and used to aid in species identification.

7.2.2.2.2.1 Species of Conservation Significance

The geographic coordinates of plants of conservation significance, as defined in Section 7.2.1.4, were marked using a Global Positioning System (GPS) receiver (Garmin GPSMap® 64s), which records locations with accuracy of ± 4 m, during floristic surveys. Where there were clusters of plants of conservation significance—i.e., more than one individual occurring within 5 m or less of another individual—the geographic location of the approximated centre of the area was marked using the GPS receiver.

7.2.2.2.2.2 Large Plant Specimens

Similarly, the GPS receiver (Garmin GPSMap® 64s) was used to record locations of all trees of ≥ 3 m girth, as well as bamboo clusters, palm clusters, and strangling Ficus species of ≥ 3 m spread. Individuals were identified to

species whenever possible. The girth (for trees) and spread (for bamboo clusters, palm clusters, and strangling Ficus species) were also measured and/or estimated. The estimated height of the specimens was also recorded.

7.2.2.2.3 Other Plant Specimens of Value

Locations of other plants that were of value but do not meet the minimum size requirement, as detailed in the above sub-section, were also recorded using the GPS receiver (Garmin GPSMap® 64s). Examples of such included bamboo clusters of < 3 m spread that might be important refugia for rare bamboo bats, amongst others.

7.2.2.3 Ground-truthing for Trees Within Worksites

There were 503 trees identified near Imbiah Lookout in the map files provided by the Client on 6 January 2021. Of these specimens, 13 were within the worksite for MH29 while 14 were within that for MH30, both of which were within the Mt. Imbiah Study Area. Ground-truthing was carried out on 21 January 2021 to verify the tree species as well as to assess the specimens for their suitability for transplantation. Only specimens within the worksites were verified and assessed as vegetation within the worksites would most likely be removed completely for construction activities.

7.2.2.4 Faunistic Field Assessment

The field assessment for fauna was carried out for the following taxa: (1) butterflies, (2) odonates (damselflies and dragonflies), (3) herpetofauna (amphibians and reptiles), (4) birds, (5) mammals (including bats), and (6) fish. This was carried out from 30 November 2020–18 January 2021.

The locations and number of sampling units were finalised upon completion of site reconnaissance (Figure 7-2). Table 7-1 summarises all the surveys that were carried out for fauna. Each survey was performed by at least two (maximum three) surveyors. All fauna encountered were identified to species, or to the lowest taxonomic level possible, and the location of each individual was recorded using a handheld GPS (Garmin GPSMAP 64s). The number of individuals observed was also documented.

All observations of notable species from the aforementioned taxa were also recorded when seen outside the stated survey times. A checklist of all species of fauna observed from the surveys was compiled and presented in Appendix G.



Study area

Nature area

Fish trap

Camera trap

Sampling route

Construction

Manhole

Worksite

N

B	NOV 2021	SHMX	Final Report Rev B	DYCH	DYCH
A	JUL 2021	SHMX	Final Report Rev A	DYCH	DYCH
-		SHMX	Final Report	DYCH	DYCH
Rev.	Date	By	Description	Chk'd	App'd

Qualified Person Endorsement :
NA

Client Endorsement:
NA

Consultant :
AECOM

Project Title :
**Contract No. SDC/21.8.2/19:
Environmental Study
For The Proposed Deep Gravity
Sewer Project at Sentosa**

Designed SHMX	Checked JAG/NHT	Approved JAG
	Drawn SHMX	Date NOV 2021

sentosa

Figure Title :
**Sampling Routes and
Locations of Fish and Camera Traps**

Figure No. 7-2	Rev. B	Sheet 1 of 1
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Note: Source of basemap - Microsoft Bing Map

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Table 7-1 Summary of Survey Plans for Fauna

Survey Type	Taxon	Timing (h)	Duration	Sampling Unit	Technique
Diurnal transect surveys	Butterflies	0900–1500	20–30 minutes per transect	200-m continuous transects along a sampling route	Visual only; up to 25 m left, right, and front of surveyor
	Odonates (damselflies and dragonflies)	0900–1500	20–30 minutes per transect	200-m continuous transects along a sampling route	Visual only; up to 25 m left, right, and front of surveyor
Diurnal and nocturnal transect surveys	Herpetofauna (amphibians and reptiles)	0700–1000; 2000–2300	20–30 minutes per transect	200-m continuous transects along a sampling route	Visual and auditory; up to 50 m left, right, and front of surveyor
	Birds	0700–1000; 2000–2300	20–30 minutes per transect	200-m continuous transects along a sampling route	Visual and auditory; up to 50 m left, right, and front of surveyor
	Mammals (non-volant)	0700–1000; 2000–2300	20–30 minutes per transect	200-m continuous transects along a sampling route	Visual and auditory; up to 50 m left, right, and front of surveyor
Camera trapping	Mammals (non-volant)	24 hours a day	40 days	Traps spaced at least 200 m apart	Infrared motion sensing
Bioacoustics surveys	Mammals (bats)	2000–2300	20–30 minutes per transect	200-m continuous transects along a sampling route	Auditory only
Roost emergence surveys	Mammals (bamboo bats only)	1830–2100	–	Bamboo clusters	Visual and auditory
Minnow trapping	Fish	Overnight	Two days one night	Waterbodies	Baited

7.2.2.4.1 Butterflies

Diurnal transect surveys were carried out for adult butterflies along 200-m continuous transects on a sampling route between 0900h and 1500h. Butterfly caterpillars, pupae, eggs, and host plants were also recorded when observed. Adult butterflies were identified visually (with binoculars where necessary), photographed, or caught using insect nets, if required. Captured individuals were released immediately after identification.

7.2.2.4.2 Odonates (Damselflies and Dragonflies)

Diurnal transect surveys were carried out for adult damselflies and dragonflies along 200-m continuous transects on a sampling route between 0900h and 1500h. Owing to difficulties in sampling and identification, aquatic larvae and exuviae were not surveyed. Adult odonates were identified visually (with binoculars where necessary), photographed or caught using insect nets, if required. Captured individuals were released immediately after identification.

7.2.2.4.3 *Herpetofauna (Amphibians and Reptiles)*

Diurnal (0700h–1000h) and nocturnal (2000h–2300h) surveys were carried out for amphibians and reptiles along 200-m continuous transects on a sampling route. As herpetofauna occupy a wide range of habitat types, both the diurnal and nocturnal surveys also involved active searches for individuals on the ground, below rocks, logs, leaf litter and debris, in the water, and/or on vegetation. Torches and/or headlamps were used to elicit eyeshine during nocturnal surveys. Vocalising fauna were also located or identified by call recognition, whenever possible. For species that are capable of quick retreats and escapes, the individuals were captured by hand, or using hooks, tongs, or dip nets for identification. Captured individuals were released immediately after identification.

7.2.2.4.4 *Birds*

Diurnal (0700h–1000h) and nocturnal (2000h–2300h) surveys were carried out for birds along 200-m continuous transects on a sampling route. Birds were identified visually (with binoculars where necessary) and photographed. Torches and/or headlamps were used to elicit eyeshine during nocturnal surveys. Vocalising birds were also located or identified by call recognition, whenever possible.

7.2.2.4.5 *Mammals (Non-Volant)*

Diurnal (0700h–1000h) and nocturnal (2000h–2300h) surveys were carried out for non-volant mammals along 200-m continuous transects on a sampling route. Both the diurnal and nocturnal surveys also involved searches in burrows and tree holes. Tracks and scats were also recorded. Mammals were identified visually (with binoculars where necessary) and photographed. Torches and/or headlamps were used to elicit eyeshine during nocturnal surveys. Vocalising mammals, such as the squirrels, were also located or identified by call recognition, whenever possible.

Mammals were also surveyed via camera trapping. This method is useful for the survey of terrestrial (mostly ground dwelling) mammals because it is non-invasive (i.e., does not require capturing and handling of animals), not labour-intensive, and can be programmed to operate 24 hours a day. This allows for both diurnal and nocturnal species to be recorded, especially if their peak activity periods do not overlap with the timings of transect surveys.

Five terrestrial camera traps were deployed – two at Mt. Imbiah and three at Mt. Serapong. The camera traps were deployed at least 200 m apart within the study areas and kept at least 20 m away from the transects, whenever possible. The locations of two camera traps were specifically placed within the vicinity of manholes 30 and 18 at Mt. Imbiah and Mt. Serapong, respectively (Figure 7-2). This was requested by the NParks during the scoping meeting on 25 November 2020.

Each camera trap was set up at approximately 20–30 cm above ground (Figure 7-3). They were programmed to operate 24 hours a day and to record 10-second footage per motion trigger with a 10-second quiet period following each trigger. Each camera trap was deployed for 40 days. The camera trap model used was Browning Dark Ops HD Pro X BTC-6HDPX.



Figure 7-3 Camera Trap Set Up

7.2.2.4.6 Mammals (Bats Only)

Acoustics surveys were carried out for bats along 200-m continuous transects on a sampling route between 2000h and 2300h. The Echo Meter Touch 2 Pro (Wildlife Acoustics, Inc.) was used to record, stream, and attenuate ultrasonic calls between 6–192 kHz at a sampling frequency of 384 kHz to low frequency signals below 20 kHz, a range that is audible to the human ear.

Roost emergence surveys were also carried out between 1830h and 2100h for bamboo bats, specifically, at bamboo clusters identified during floristic surveys. Bamboo bats were identified visually and photographed, and calls were recorded using the Echo Meter Touch 2 Pro detector. Bamboo slits that were at least 1 cm wide and long and were actively used for entry and exit, as well as the number of bats residing within each internode were recorded.

7.2.2.4.7 Fish

Minnow traps baited with halal meat (e.g., sausage or liver) were deployed at suitable waterbodies with deeper water levels. The traps were left overnight, then checked and removed the following morning. All caught individuals were released immediately the following day.

7.2.2.5 Data Analyses

7.2.2.5.1 Camera Trapping

Camera trap location, species identity, and the number of individuals were recorded for each footage with a positive capture of fauna. An independent detection constitutes footage of one or a group of individuals of the same faunal species occurring within 60 minutes at each camera trap.

7.2.2.5.2 Bat Sound File Analyses

Bat recordings were processed using Kaleidoscope v.4.5.4 (Wildlife Acoustics, Inc.) to distinguish extraneous noise from bat echolocation calls. The signal parameters in recognising bat calls were described as follows: frequency range of 20–200 kHz, duration of 2–500 millisecond (ms), maximum inter-syllable gap of 500 ms and a minimum of two pulses. The files were also examined visually on spectrograms to identify bat species based on call structures, peak frequency, minimum frequency, and call duration. They were identified using Pottie et al. (2005) [P-48] which provided echolocation signatures for bats in Singapore, as well as other relevant references, such as Collen (2012) [P-49].

7.2.2.5.3 Species Distribution Maps

The number of occurrences of fauna sighted during surveys as well as incidental records outside official survey timings were presented as heat maps to show areas where most fauna were seen. Locations of species of conservation significance were weighted ten times more heavily than those not of conservation significance. As such, areas where more species of conservation significance were sighted would generally appear redder on the heat maps, but this was also true for areas with numerous sightings of species not of conservation significance. Areas of hotspot resulting from sightings of species of conservation significance were differentiated from that of other species by an additional point vector layer representing the former on the maps. All maps were prepared and generated using the mapping software QGIS 3.40 [O-8].

7.2.2.5.4 Taxon Sampling Curves

Taxon sampling curves were plotted for the surveys conducted for four taxa: butterflies, odonates, birds, and bats. Only these four taxa were selected because large sample sizes were required for the estimation of sample coverage to be robust [P-51]. As such, only the curves for the aforementioned taxa could be meaningfully plotted and not the rest, such as reptiles with only one and two occurrences at the Mt. Imbiah and Mt. Serapong Study Areas, respectively.

The observed sample of incidence data was used to estimate sample coverage and species richness. Species richness was plotted against sample coverage, as opposed to survey effort, to estimate sample completeness/survey adequacy, i.e., how extensively we had sampled the species in the community.

Sample coverage refers to “the proportion of the total number of individuals in a community that belong to the species represented in the sample” [P-51]. The curve was extrapolated to provide an estimation of species richness and sample coverage if sample size was doubled. The associated standard error and 95% confidence interval were also computed. Standard error represents the range of uncertainty of the estimate, while 95% confidence interval the interval in which there is a 0.95 probability of containing the estimated true species richness.

As some species would always remain undetected, total species richness had to be estimated via extrapolation. This was done using the Chao estimator. All statistical analyses were carried out in the statistical programming environment R version 3.4.3 [O-9] using the “iNEXT” package 2.0.20 [W-32].

7.2.2.6 List of Taxonomic Experts and Field Personnel

The personnel and taxonomic experts involved in the biodiversity surveys for this Project were listed as follows:

Flora

1. Sherry Hung Ming Xuan (flora specialist)
2. Boo Chih Min (flora specialist)
3. Sim Eng Koon (arborist)
4. Derek Yap Chung Hoe (arborist)

Fauna

1. Twang Fang Qi (fauna biologist)
2. Quek Xiao Tong (fauna biologist)
3. Bronwyn Tan Yung Siang (fauna biologist)
4. Henrietta Woo Pui Min (fauna biologist)
5. Chloe Tan Yi Ting (fauna biologist/ butterfly and odonate specialist)
6. Thio Hui Bing (fauna biologist/ butterfly and odonate specialist)
7. Alex Figueroa (reptile specialist)

7.3 Baseline Biodiversity Findings

This section presented biodiversity field findings from surveys conducted from 30 November 2020 to 21 January 2021 at the Mt. Imbiah and Mt. Serapong Study Areas.

7.3.1 Habitat and Vegetation Types

There were five habitat and vegetation types identified to be present at the Mt. Imbiah Study Area (Table 7-2; Figure 7-4). Each occupying about one-third of the site, the slightly larger native-dominated secondary forest (1.2 ha; 33.6%) was situated to the north while mixed forest (1.1 ha; 31.7%) lies to the south and surrounds infrastructure (0.6 ha; 15.9%). Five smaller patches of scrubland and herbaceous vegetation (0.4 ha; 12.5%) were distributed across the site. Managed vegetation (0.2 ha; 6.3%) accounted for the smallest area, bordering the northern edge of the site as well as occupying a small patch in the west adjacent to Siloso Road.

The Mt. Serapong Study Area was observed to be comprising two vegetated areas located on either side of Woolwich Road, collectively including six habitat and vegetation types (Table 7-2; Figure 7-4). Native-dominated forest (4.4 ha; 44.5%) was identified as the largest habitat type, with sizable patches of scrubland and herbaceous vegetation (2.5 ha; 25.5%) primarily located in its interior. Mixed forest (1.7 ha; 16.8%) was largely found at the southern half of both areas and borders infrastructure (1.2 ha; 11.9%) both within and outside of the study area boundary. A strip of managed vegetation (0.1 ha; 1.2%) and two very small waterbodies (0.0022 ha; 0.02%) together occupy the least space in the western area; these two habitat and vegetation types were found to be absent in the eastern area.

Table 7-2 Absolute (ha) and Relative (%) Sizes of Each Habitat and Vegetation Type in the Study Areas

Habitat And Vegetation Types	Mt. Imbiah Study Area		Mt. Serapong Study Area	
	Absolute Size (ha)	Relative Size (%)	Absolute Size (ha)	Relative Size (%)
Native-dominated forest	1.2	33.6	4.4	44.5
Mixed forest	1.1	31.7	1.7	16.8

Habitat And Vegetation Types	Mt. Imbiah Study Area		Mt. Serapong Study Area	
	Absolute Size (ha)	Relative Size (%)	Absolute Size (ha)	Relative Size (%)
Scrubland and herbaceous vegetation	0.4	12.5	2.5	25.5
Managed vegetation	0.2	6.3	0.1	1.2
Others (infrastructure)	0.6	15.9	1.2	11.9
Total	3.6	100.0	9.8	100.0

Note: Waterbodies across the study areas comprised less than 1% of the total area and therefore was omitted from Table 7-2; an in-text description was provided instead



Legend

Study area

Vegetation

Native-dominated secondary forest

Mixed forest

Scrubland and herbaceous vegetation

Managed vegetation

Waterbody

Others (infrastructure)

Construction

Manhole

Worksite

N

North Arrow

B	NOV 2021	SHMX	Final Report Rev B	DYCH	DYCH	
A	JUL 2021	SHMX	Final Report Rev A	DYCH	DYCH	
-	MAY 2021	SHMX	Final Report	DYCH	IDYCH	
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Project Title :
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Environmental Study
For The Proposed Deep Gravity
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Drawn
SHMX

Date
NOV 2021

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Figure Title :
**Habitat and Vegetation Distribution of the
Mt. Imbiah and Mt. Serapong Study Areas**

Figure No.
7-4

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Note: Source of basemap - Microsoft Bing Map

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7.3.1.1 Native-dominated Secondary Forest

Native-dominated secondary forest was identified as the largest habitat type in both study areas (Table 7-2). This forest type dominantly comprises native tree species and can be further classified as early- or late-successional [P-3]. Early-successional forests dominated by fast-growing and light-demanding pioneer species will eventually develop into late-successional forests in which pioneer species are replaced by slower-growing native trees [P-11]. While a clear distinction between these two forest sub-types cannot be identified as they occur along a successional gradient and are part of a floristic continuum [P-11, P-12, P-24], it is still possible to identify the forest sub-types at the extreme ends along the gradient [P-3].

Floristically, the native forest in both study areas appears to be late-successional, native-dominated secondary forest. Although the patches in the Mt. Imbiah Study Area and Mt. Serapong Study Area are about 2 km apart, separated by urbanized spaces with infrastructure and manicured landscaping, they have similar floristic composition. Prior to disturbances and development works in the past, the forest on Sentosa Island was likely to be a single continuous forested patch. Plants within each of the fragmented areas have presumably persisted through past disturbances and hence continue to exist until today. Furthermore, the close proximity of both patches to each other may allow for the exchange of propagules, thus explaining the overlapping floristic assemblages. Two main features observed during field surveys suggest that the forest is at the later stage of forest succession.

Firstly, the floristic composition were observed to be largely comprising rare and common native species (Table 7-3). Many specimens from the genera *Syzygium*, *Garcinia* (Figure 7-6E), and *Alstonia* were found to be widespread throughout the forest. There were comparatively fewer specimens from the genera *Calophyllum* (Figure 7-5C), *Ixonanthes* (Figure 7-5E), and *Elaeocarpus*, but they were nonetheless moderately widespread, especially within certain areas of hotspot within the Mt. Serapong Study Area. These are typically the common genera that make up the canopy layer of late-successional forests in Singapore [P-3]. Aside from some exotic trees that have likely spread from cultivation, the area was found to be otherwise dominated by native species and generally more species-rich than all other vegetation types in the study areas. In addition, common understorey plant species associated with late-successional forests, such as *Anisophyllea disticha* [P-3, P-64] (Figure 7-5A), were also commonly encountered during floristic surveys. Some nationally threatened species were also widespread in the study areas, such as *Archidendron contortum* (Figure 7-5D) and *Gnetum microcarpum* (Figure 7-5B), while others were rarer with fewer specimens, such as *Rourea asplenifolia* (Figure 7-16C) and *Artocarpus lacucha*.

Secondly, a few *Adinandra dumosa* trees were encountered within the Mt. Serapong Study Area. None were encountered in the Mt. Imbiah Study Area. This native tree species dominates very early-successional forests, i.e., *adinandra belukar*. However, elements of an *adinandra belukar* appears to be limited in both study areas; the few *Adinandra dumosa* trees still present could be remnants as forest succession took place. Baseline floristic findings suggested that the forest likely succeeded from an *adinandra belukar* and has now been largely replaced by late-successional secondary forest.

Corlett (1991) [P-11] postulated that some of the late-successional forest could be at least 100 years old. In Singapore, late-successional native forests are mainly found in the Bukit Timah Nature Reserve (BTNR), Central Catchment Nature Reserve (CCNR), and Southern Ridges. However, unlike the typical native forests in the aforementioned localities, those in the present study have elements that resemble coastal forests. For example, large populations of saplings and trees of nationally threatened coastal species, such as *Symplocos adenophylla* (Figure 7-6A), *Streblus elongatus*, *Planchonella obovata* (Figure 7-6C) and *Memecylon edule* (Figure 7-16A) are present in the study areas. Common coastal plants such as *Neolitsea cassia* (Figure 7-6D), *Casuarina equisetifolia* and *Podocarpus polystachyus* (Figure 7-6B) were also found in the Mt. Imbiah Study Area. This floristic assemblage is somewhat similar to that of the southern islands, such as the Sisters' Islands and Pulau Tekukor which host sizable populations of *Memecylon edule* and *Podocarpus polystachyus*, among other coastal species [P-15, P-16].

While the habitat is not considered as coastal forest—defined by Tan et al. (2007) [P-63] as “found along un-reclaimed coasts where the forest is on sandy or rocky substrate. Dominated by hardy plants which can withstand higher temperatures, strong winds and salt sprays”—the close proximity of Sentosa Island to the southern offshore islands of Singapore could provide nearby sources for the arrival of propagules of coastal plants. With constant and steady dispersal rates of propagules, these forested patches may remain as late-stage successional forest with some coastal elements when left undisturbed.



Figure 7-5 Plants in the Native-Dominated Secondary Forest of Both Study Areas. (A) *Anisophyllea disticha*; (B) *Gnetum microcarpum*; (C) *Calophyllum pulcherrimum*; (D) *Archidendron contortum*; (E) *Ixonanthes reticulata*.



Figure 7-6 Coastal Species Recorded in the Study Areas. (A) *Symplocos adenophylla*; (B) *Podocarpus polystachyus*; (C) *Planchonella obovata*; (D) *Neolitsea cassia*; (E) *Garcinia hombroniana*; (F) *Palaquium obovatum*.

7.3.1.2 Mixed Forest

Mixed forest was found to be the second largest habitat type in both study areas, second to native-dominated secondary forest (Table 7-2). This habitat consists of overgrown vegetation from past manicured park spaces with spontaneous native saplings and treelets that are likely the propagules of existing trees. The patches are generally species-poor and comprise a mix of exotic and native species.

Within the Mt. Imbiah Study Area, the largest patch of mixed forest is part of a mini-golf course, south of Siloso Road (Figure 7-4). As the area is no longer regularly maintained, the golf infrastructure is largely overgrown with vegetation (Figure 7-7A–B). Approximately half of the mixed forest is scrubland, while the canopy of the remaining area is covered by planted trees that are relics from cultivation. In this Project, the proposed location of manhole MH30 along Siloso Road is where a row of tall planted hedges is, as shown in Figure 7-7C–D.

Within the Mt. Serapong Study Area, mixed forest is largely south of Allanbrooke Road in the western patch (Figure 7-8) and north of Cove Avenue in the eastern patch (Figure 7-4). The former is a fragmented patch in between the existing Tanjong Golf Course and within which manhole MH18 is proposed to be built. The latter adjacent to Cove Avenue is near the Sentosa Cove residences and appears to a nursery where landscaping plants are stored and maintained.



Figure 7-7 Mixed Forest in the Mt. Imbiah Study Area. (A–B) Overgrown Vegetation in the Abandoned Golf Course; (C–D) Planted Tall Hedges Along Siloso Road When Viewed from inside the Forest and outside along the Road, Respectively



Figure 7-8 Mixed Forest in the Mt. Serapong Study Area When Viewed along Allanbrooke Road (C) and inside the Forest (Red Arrow Points to Allanbrooke Road) (B)

7.3.1.3 Scrubland and Herbaceous Vegetation

Able to withstand high temperatures and light levels, scrubland and herbaceous vegetation typically grows along the edges of forested areas but may also be present as scattered patches in the forest interior where gaps in the canopy have occurred. It is characterised by short vegetation with an open canopy, typically made up of shrubs, climbing/creeping plants, and grasses (Figure 7-9D).

About a tenth of the Mt. Imbiah Study Area is covered by scrubland and herbaceous vegetation (Table 7-2). Distributed across five small patches, this includes the area at the intersection of Siloso and Imbiah Roads where an alteration of microclimatic conditions—that allowed for the spontaneous regrowth of shrubs among planted trees—likely resulted from land clearance (Figure 7-9A–B).

Over a quarter of the Mt. Serapong Study Area, across its two vegetated areas, is covered by scrubland and herbaceous vegetation. Larger contiguous patches of this vegetation type are located mainly within the interior, with smaller ones towards the edges. While land clearance may account for the latter, the former could perhaps have resulted from treefalls that opened gaps in the canopy—this would have created microclimatic conditions conducive for the widespread growth of the sun-loving native climbers observed, such as *Morinda umbellata* and *Fibraurea tinctoria*, that are likely to have dispersed from the surrounding native-dominated forest (Figure 7-9C).



Figure 7-9 Scrubland and Herbaceous Vegetation in Both Study Areas. (A–B) Spontaneous Shrubs and Some Planted Trees at the Intersection of Siloso Road and Imbiah Road at The Mt. Imbiah Study Area; (C) Scrubland Dominated by Native Climbers, *Morinda umbellata* (Yellow Arrow) and *Fibraurea tinctoria* (Red Arrow), at the Mt. Serapong Study Area; (D) Scrubland Characterised by a Single Vegetation Stratum and Open Canopy.

7.3.1.4 Managed Vegetation

Typically composed of landscape and streetscape plantings as well as managed lawns, managed vegetation is mostly located along the edges of forested areas and accounts for only a small percentage of the space across the study areas (Table 7-2; Figure 7-4).

At the Mt. Imbiah Study Area, a narrow strip of managed vegetation borders the northern edge of the site as well as constitutes a small patch adjacent to Siloso Road in the west. The former is seen along Garden Avenue to comprise a maintained *Phyllanthus cochinchinensis* hedge that is edged with shorter *Sphagneticola trilobata* shrubs (Figure 7-10A), whereas the latter patch has been replanted with both native and exotic species (Figure 7-11).

Out of the two areas that comprise the Mt. Serapong Study Area, only the western area has managed vegetation. This thin strip is composed of a section of managed lawn from the adjacent Serapong Golf Course (Figure 7-10B).



Figure 7-10 Managed Vegetation in Both Study Areas. (A) Planted *Phyllanthus cochinchinensis* and *Sphagneticola tribolata* Shrubs Along Garden Avenue in the Mt. Imbiah Study Area; (B) The Serapong Golf Course Next to the Mt. Serapong Study Area



Figure 7-11 Examples of Replanted Native and Exotic Trees and Shrubs within the Mt. Imbiah Study Area

7.3.1.5 Waterbody

Waterbodies occupy the least space across the study areas and only occur within the native-dominated forest in the western area of the Mt. Serapong Study Area (Table 7-2; Figure 7-4). Likely to be a result of waterlogging after heavy rainfall as well as outflow from a broken pipe, the two different-sized waterbodies show a range of conditions with varying depths and waters ranging from being heavily silted to clear (Figure 7-12).

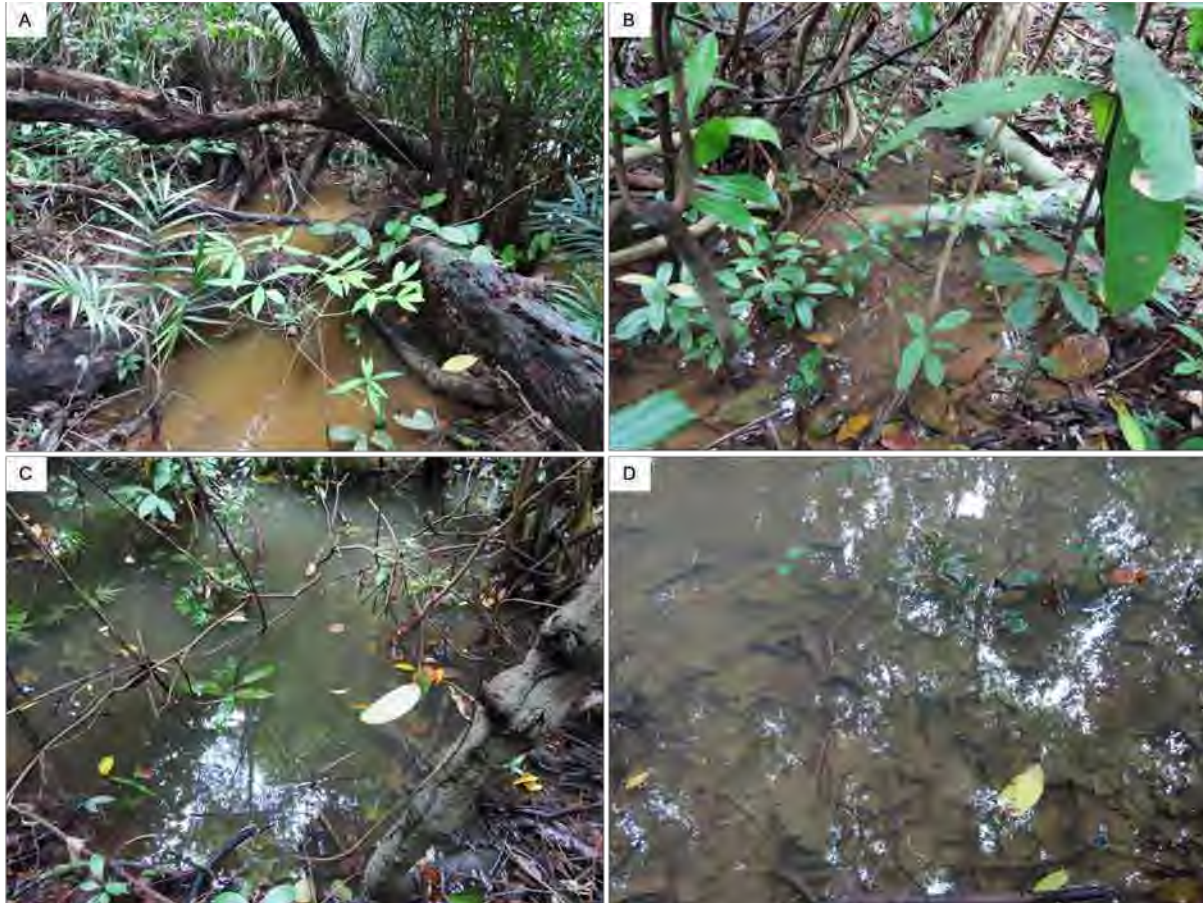


Figure 7-12 Ephemeral Waterbodies in the Mt. Serapong Study Area. (A) Waterlogged and Highly Silted; (B) Broken Pipe from which Water could be Flowing from into the Area; (C) A Larger and Deeper Waterlogged Area; (D) Close Up of the Water from which the Submerged Thick Leaf Litter can be Seen

7.3.1.6 Others (Infrastructure)

Infrastructure constitutes a range of built-up surfaces, covering approximately a tenth of the space across the study areas (Table 7-2; Figure 7-4).

At the Mt. Imbiah Study Area, infrastructure comprises Siloso Road that runs across its length, as well as the north eastern TreeTop Lofts (Figure 7-13A–B).

At the Mt. Serapong Study Area, more types of infrastructure are present across its two areas. These include a facility building, roads (i.e., a portion of Allanbrooke Road), residences (i.e., a part of Sentosa Cove), and a transmission tower (Figure 7-13C–E).



Figure 7-13 Infrastructure in Both Study Areas. (A–B) TreeTop Lofts at the Mt. Imbiah Study Area in the Day and at Night, Respectively; (C–E) Facility Building, Roads and Transmission Tower, Respectively, in the Mt. Serapong Study Area

7.3.2 Floristic Field Findings

7.3.2.1 Overall

A total of 257 plant species and species groups (i.e., plants that could not be identified to species with certainty), belonging to 87 families were collectively recorded from the study areas (Table 7-3; Appendix A). Of these, 172 plant species and species groups represented by 68 families occur at the Mt. Imbiah Study Area. At the Mt. Serapong Study Area, 194 plant species and species groups across 77 families were found.

There are 12 species groups altogether, comprising the following: (1) *Cleistanthus* cf. *maingayi*, (2) *Dalbergia* cf. *rostrata*, (3) *Gnetum* cf. *macrostachyum*, (4) *Gnetum* sp., (5) *Knema* cf. *globularia*, (6) *Ochanostachys* cf. *amentacea*, (7) *Salacia* sp., (8) *Shorea* cf. *ovalis* ssp. *ovalis*, (9) *Shorea* cf. *pauciflora*, (10) *Strombosia* cf. *javanica*, (11) Malvaceae, and (12) Rubiaceae (Appendix A).

Of the 257 species and species groups recorded, 143 are native (55.6%), 101 (39.3%) exotic, 12 (4.7%) cryptogenic (i.e., of unknown or uncertain origin despite it being a known species), and the remaining one (0.4%) of unknown origin owing to it being an unidentified species. The number and percentage of plant species and species groups belonging to each status category at both study areas were summarized in Table 7-3.

Native threatened species comprise species that have been accorded the following statuses: Vulnerable, Endangered, Critically Endangered, Presumed Extinct, and those that were recently rediscovered and not yet assessed. At the Mt. Imbiah Study Area, 47 (27.3%) such species were recorded while 57 (29.4%) were found at the Mt. Serapong Study Area.

For overall findings, however, a distinction was not made as to whether threatened species are from native wild populations or are cultivated locally and/or are relics from past cultivation. Species belonging to the latter category may therefore not be of conservation significance even though they have been accorded with a threatened status. This was discussed in greater detail in 'Species of Conservation Significance' under Sections 7.2.1.4 and 7.3.2.2.

Table 7-3 Number and Percentage of Plant Species Belonging to Each Status Category in the Study Areas

		Mt. Imbiah Study Area		Mt. Serapong Study Area	
Origin	Status	Number Of Species	Percentage (%)	Number Of Species	Percentage (%)
Native		97	56.4	117	60.3
	Common	50	29.1	60	30.9
	Vulnerable	22	12.8	25	12.9
	Endangered	8	4.7	11	5.7
	Critically Endangered	14	8.1	17	8.8
	Presumed Extinct	1	0.6	2	1.0
	Not assessed; recently rediscovered	1	0.6	1	0.5
	Not assessed	1	0.6	1	0.5
Exotic		71	41.3	65	33.5
	Cultivated Only	27	15.7	24	12.4
	Casual	24	14.0	16	8.2
	Naturalised	19	11.0	22	11.3
	Not assessed	1	0.6	2	1.0
	–	0	0	1	0.5
Cryptogenic		4	2.3	11	5.7
Unidentified species (Rubiaceae)		0	0.0	1	0.5
Total		172	100.0	194	100.0

7.3.2.2 Plant Species of Conservation Significance

A total of 31 and 49 plant species were considered of conservation significance in the Mt. Imbiah Study Area and the Mt. Serapong Study Area, respectively (Table 7-4). Some species, though listed as nationally threatened, were not considered of conservation significance in this study because they are most likely escapees from present-day cultivation, relics that had persisted from past cultivation, or were only found in the area with replanted trees (labelled as managed vegetation) in the Mt. Imbiah Study Area. It was challenging to determine whether threatened specimens found within the native or mixed forests were planted and belong to the cultivated genetic stock, or if they have grown spontaneously from native propagules within the forest. There is also another likelihood that the specimens were propagated from local stocks and subsequently planted in the study areas.

The assessment of whether a threatened plant species is of conservation significance was carried out based on the criteria detailed in Section 7.2.1.4. In addition, a list of tree species planted in the vicinity of the Mt. Imbiah Study Area provided by the Client was also used in the assessment. The list for the Mt. Serapong Study Area, however, could not be provided by the Client. Hence, a more conservative approach was adopted by considering the threatened species as of conservation significance.

Altogether, 132 specimens and/or clusters of specimens belonging to these species of conservation significance were recorded in the Mt. Imbiah Study Area, while 694 were recorded in the Mt. Serapong Study Area (Table 7-5). Majority of the specimens are concentrated within the native-dominated secondary forest, followed by the mixed forest.

One nationally Critically Endangered grass species (*Centotheca lappacea*) lie within the worksite for MH30 in the Mt. Imbiah Study Area, while eight individuals and clusters of specimens (seven in the native-dominated forest and one in scrubland and herbaceous vegetation) lie within the worksite for MH18 in the Mt. Serapong Study Area.

The distribution of plant specimens of conservation significance within the study areas was provided in Figure 7-14.

Table 7-4 Number of Plant Species of Conservation Significance in Both Study Areas

		Non-Cultivated Threatened Species	Cultivated Threatened Species	Total Number Of Species Of Conservation Significance
Mt. Imbiah Study Area	VU	14	3	31
	EN	4	1	
	CR	6	1	
	RR	1	0	
	<i>Salacia</i> sp.	1	0	
Mt. Serapong Study Area	VU	23	0	49
	EN	9	0	
	CR	13	1	
	RR	1	0	
	EX	1	0	
	<i>Salacia</i> sp.	1	0	

Note: VU – Vulnerable; EN – Endangered; CR – Critically Endangered; EX – Presumed Extinct; RR – Not assessed/ recently rediscovered

Table 7-5 Number of Plant Specimens of Conservation Significance in Each Vegetation Type. Numbers in Parentheses are those that Fall within the Proposed Worksites.

	Number Of Individuals And Clusters							Number Of Species						
	VU	EN	CR	RR	EX	<i>Salacia</i> sp.	Total	VU	EN	CR	RR	EX	<i>Salacia</i> sp.	Total
Mt. Imbiah Study Area														
Native-dominated secondary forest	59	14	9	0	1	2	85	16	4	5	1	0	–	26
Mixed forest	34	1	4 (1)	0	0	0	39 (1)	9	1	3 (1)	0	0	–	13 (1)
Scrubland and herbaceous vegetation	2	0	2	0	0	0	4	2	0	2	0	0	–	4
Managed vegetation	3	1	0	0	0	0	4	2	1	0	0	0	–	3
Mt. Serapong Study Area														
Native-dominated secondary forest	431 (4)	95 (2)	71 (1)	5	6	6	614 (7)	20 (3)	10 (1)	15 (1)	1	1	–	47 (5)
Mixed forest	32	13	8	0	2	0	55	12	5	5	0	1	–	23
Scrubland and herbaceous vegetation	17	4 (1)	2	1	0	1	25 (1)	8	2 (1)	2	1	0	–	13 (1)
Managed vegetation	0	0	0	0	0	0	0	0	0	0	0	0	–	0



Legend

Study area

Vegetation

Native-dominated secondary forest

Mixed forest

Scrubland and herbaceous vegetation

Managed vegetation

Waterbody

Others (infrastructure)

Construction

Manhole

Worksite

CS specimens

Presumed Extinct

Recently rediscovered

Critically Endangered

Endangered

Vulnerable

Salacia sp

N

B	NOV 2021	SHMX	Final Report Rev B	DYCH	DYCH
A	JUL 2021	SHMX	Final Report Rev A	DYCH	DYCH
-	MAY 2021	SHMX	Final Report	DYCH	DYCH
Rev.	Date	By	Description	Chk'd	App'd

Qualified Person Endorsement :
NA

Client Endorsement:
NA

Consultant :
AECOM

Project Title :
**Contract No. SDC/21.8.2/19:
Environmental Study
For The Proposed Deep Gravity
Sewer Project at Sentosa**

Designed SHMX	Checked JAG/NHT	Approved JAG
Drawn SHMX	Date NOV 2021	

sentosa

Figure Title :
**Distribution of Plant Specimens of
Conservation Significance in the Study Areas**

Figure No. 7-14	Rev. B	Sheet 1 of 1
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Numerous nationally threatened species were found in both study areas. The only species thought to be nationally extinct and whose status was updated to “recently rediscovered” is the native climber *Smilax megacarpa* (Figure 7-16F). Ho et al. (2019) [P-14] state that this species was listed in published records before 2011 but was omitted by Turner and Chua (2011) [P-23]. In their study, the authors recorded this species in the primary forest of the BTNR. The first botanical record of this species catalogued in the Singapore Herbarium date all the way back to the 18th century. Thereafter, various collections have been made through the centuries, with the most recent record in 2016 collected from the Western Catchment. Most other specimens were recorded in the CCNR or offshore islands; none were from the Sentosa Island. During present floristic surveys, however, populations of this climber were observed in the study areas, more so in Mt. Serapong than Mt. Imbiah.

Fifteen nationally Critically Endangered species were recorded in both study areas. Three large *Ficus kerkhovenii* stranglers (Figure 7-19C) of between 3 and 8 m spread and one *Podocarpus polystachyus* tree of 0.8 m girth (Figure 7-6B) were recorded. These are valuable coastal species known to occur in coastal areas, such as the offshore southern islands of Singapore on the Sisters’ Island and Pulau Tekukor (Hung et al., 2017a; 2017b) [P-15, P-16]. Other Critically Endangered species found to be relatively widespread are *Salacia grandiflora* and *Willughbeia flavescens* (Figure 7-15F).

Ten out of 14 species recorded as nationally Endangered were considered of conservation significance in this study (Appendix B). With the exception of *Aphanamixis polystachya*, *Ardisia elliptica*, *Pometia pinnata*, and *Heritiera simplicifolia*, all other species are likely to be of the native genetic stock. Some of the less frequently encountered species include *Artocarpus lacucha* (where only one tree was encountered in each study area), *Dibridsonia conferta* (Figure 7-15C), and *Tristaniaopsis whiteana*. One *Garcinia hombroniana* tree (Figure 7-6E) was found at the edge of the mixed forest in the Mt. Serapong Study Area. This species is known to be slow-growing and it would take a long time for specimens to attain large sizes. Thus, the specimen of 1.6 m girth found must have almost certainly been growing there over an extended period of time. Furthermore, this species is neither known to be planted nor sold locally in commercial markets. Hence, the specimens are of conservation significance.

There were 25 nationally Vulnerable species recorded from both study areas, some of which are commonly encountered in some secondary forests in Singapore, such as *Bridelia stipularis*, *Lygodium longifolium* (Figure 7-16D), and *Oxyceros longiflorus*. In this study, some of the nationally Vulnerable species found to be widespread in the study areas include *Archidendron contortum* (Figure 7-5D), *Oncosperma tigilaria* (Figure 7-19D), *Palaquium obovatum* (Figure 7-6F), *Planchonella obovata* (Figure 7-6C), *Streblus elongatus*, *Syzygium palembanicum* (Figure 7-19A–B), and *Syzygium syzygioides*. There are many specimens of these species with girth ranging between < 0.05 m to 3 m. In particular, a large *Bhesa robusta* tree of 2.4 m girth was found within the Mt. Imbiah Study Area. While this species is known to be planted on Sentosa Island, the tree of this girth size is notable. Several seeds with their aril intact (Figure 7-15C) and clusters of seedlings and saplings were found in the vicinity of the tree. The large tree acts as an important source of seeds, which is important for the viability of the species population. These observations suggest a possibility that the *Bhesa robusta* specimens could belong to the native genetic stock and the specimens have persisted through various stages of disturbances on the island. Likewise, one large *Dracaena maingayi* tree was also found in each study area (Figure 7-19F). Species of this genus are mostly herbaceous and *D. maingayi* is one of those known to be able to attain large sizes like other woody tree species.

Findings of large populations of rare and threatened plant species in the study areas suggest that the latter could serve as an additional refuge for these species in Singapore and would be valuable to conserve as part of the nation’s natural heritage.

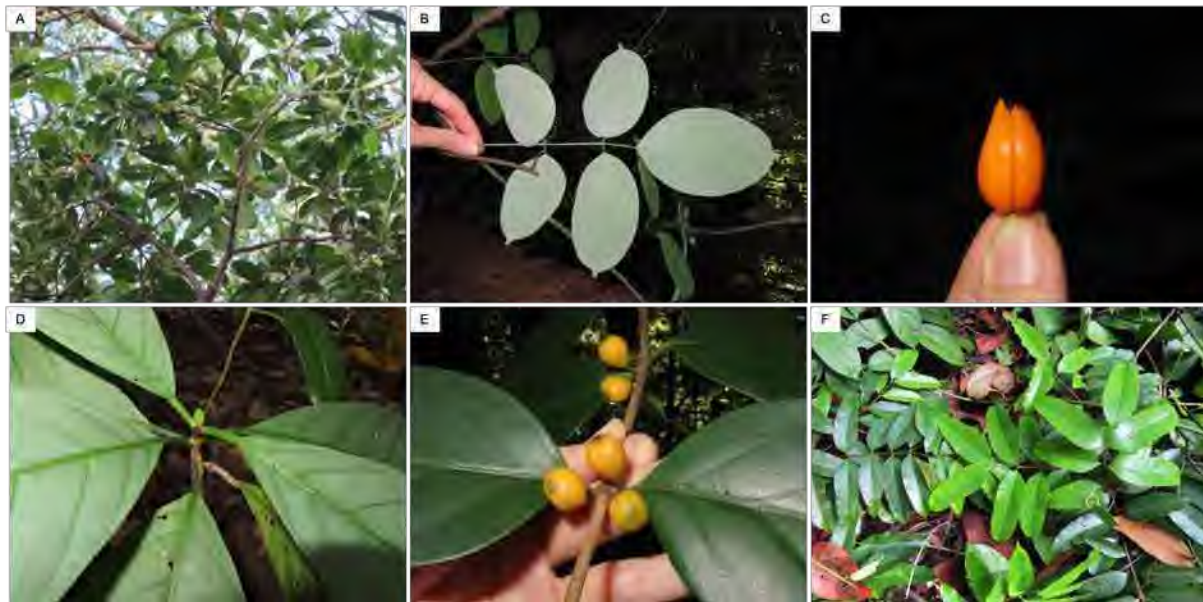


Figure 7-15 Plants of Conservation Significance at the Mt. Imbiah Study Area. (A) *Ficus vasculosa*; (B) *Derris amoena* var. *maingayana*; (C) *Bhesa robusta*; (D) *Nauclea officinalis*; (E) *Dibridsonia conferta*; (F) *Willughbeia flavescens*.



Figure 7-16 Plants of Conservation Significance at the Mt. Serapong Study Area. (A) *Memecylon edule*; (B) *Gynochthodes rigida*; (C) *Rourea asplenifolia*; (D) *Lygodium longifolium*; (E) *Diospyros styraciformis*; (F) *Smilax megacarpa*.

7.3.2.3 Large Plant Specimens

Fifty large plant specimens of native and exotic origin were encountered across both study areas (Table 7-6; Appendix C, Figure 7-17). Of the 23 large specimens recorded at the Mt. Imbiah Study Area, 12 individuals are large trees (3.0–4.7 m girth), two are stranglers (5 m and 8 m spread), and nine are palms (3–6 m spread). At the Mt. Serapong Study Area, the 27 large specimens comprise 17 large trees (3–5 m girth), including two heritage trees, one strangler (3 m spread), two bamboo clusters (3 m and 8 m spread), and seven palms (3–6 m spread).

Exotic large tree species were represented singly at the Mt. Imbiah Study Area and included *Samanea saman*, whereas the more abundant Common native tree species such as *Alstonia angustiloba* and *Syzygium grande* were distributed across both study areas (Figure 7-18).

Native threatened large specimens included the Vulnerable tree species of *Dracaena maingayi*, *Oncosperma tigillaria* (palm species) and *Syzygium palembanicum*, as well as the Critically Endangered strangler *Ficus kerkhovenii* (Figure 7-19). While of exotic origin, the bamboo cluster *Bambusa vulgaris* is a valuable specimen (see Section 7.3.2.4) (Figure 7-19).

Heritage trees were also recorded in the Mt. Serapong Study Area; these comprised a large specimen of *Alstonia angustiloba* and *Litsea elliptica*, the latter of which has failed at the main bifurcation from what appears to be internal decay (Figure 7-20).

The only large plant specimen that lies within the proposed worksite area for MH30 in the Mt. Imbiah Study Area is the exotic species (*Callerya atropurpurea*) of 3 m girth. None of the large specimens lie within the proposed worksite area in the Mt. Serapong Study Area.

Table 7-6 Number of Large Plant Specimens in Both Study Areas

Habit	Species	Mt. Imbiah Study Area	Mt. Serapong Study Area
Tree	<i>Alstonia angustiloba</i>	3	6
	<i>Callerya atropurpurea</i>	1	0
	<i>Cyrtophyllum fragrans</i>	1	1
	<i>Dracaena maingayi</i>	0	1
	<i>Ixonanthes reticulata</i>	0	1
	<i>Litsea elliptica</i>	0	1
	<i>Pterocarpus indicus</i>	1	0
	<i>Samanea saman</i>	1	0
	<i>Syzygium grande</i>	3	4
	<i>Syzygium palembanicum</i>	2	1
	<i>Syzygium syzygioides</i>	0	2
Strangler	<i>Ficus kerkhovenii</i>	2	1
Shrub (Bamboo)	<i>Bambusa vulgaris</i>	0	2
Palm	<i>Oncosperma tigillaria</i>	9	7
Total		23	27



Legend

Study area

Vegetation

Native-dominated secondary forest

Mixed forest

Scrubland and herbaceous vegetation

Managed vegetation

Waterbody

Others (infrastructure)

Construction

Manhole

Worksite

Large specimens

Tree

Heritage tree

Strangler

Bamboo

Palm

N

↑

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Figure Title :
**Distribution of Large Plant Specimens
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Figure 7-18 Common and Exotic Large Plant Specimens Found at Both Study Areas. (A) *Syzygium grande* of 4.7 m Girth; (B) *Samanea saman* of 3 m Girth (Only at Mt. Imbiah Study Area); (C) *Alstonia angustiloba* of 4.5 m Girth.



Figure 7-19 Threatened and Valuable Large Plant Specimens Found at Both Study Areas. (A–B) *Syzygium palembanicum* of 3 m Girth; (C) *Ficus kerkhovenii* of 5 m Spread; (D) *Oncosperma tigilaria* of 6 m Spread; (E) *Bambusa vulgaris* of 8 m Spread; (F) *Dracaena maingayi* of 4 m Girth



Figure 7-20 Large Heritage Trees in the Mt. Serapong Study Area. (A–B) *Litsea elliptica* with Failure at the Main Bifurcation; (C–D) *Alstonia angustiloba* of 5 m Girth.

7.3.2.4 Other Plant Specimens of Value

Two other plant specimens of value were recorded at the study areas, comprising bamboo clusters of two different species (Appendix D). These are a *Thyrsostachys siamensis* cluster (2 m spread) at the Mt. Imbiah Study Area, and a *Bambusa vulgaris* cluster (1 m spread) at the Mt. Serapong Study Area (Figure 7-21, Figure 7-22).

Several bamboo bats were observed to be flying around the bamboo cluster at the Mt. Imbiah Study Area during bat roost emergence surveys. Additionally, bamboo bat calls, which could only be, at best, identified to be that of *Tylonycteris* species, were recorded during nocturnal acoustic surveys along sampling routes in the Mt. Serapong Study Area. Both species of bamboo bats in Singapore are nationally threatened. They are known to enter bamboo internodes via small slits caused by leaf beetle larvae and spend most of the day roosting inside [P-9].

Although small in size, these bamboo clusters are likely to be active roost sites for the bamboo bats and would be valuable to retain in the study areas.

No other plant specimens of value, such as those with bird nests, were recorded from the present surveys.



Figure 7-21 Cluster of *Bambusa vulgaris* of 1 m Spread



Legend

Study area

Vegetation

Native-dominated secondary forest

Mixed forest

Scrubland and herbaceous vegetation

Managed vegetation

Waterbody

Others (infrastructure)

Construction

Manhole

Worksite

Other specimens of value

Bamboo

North Arrow

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-	MAY 2021	SHMX	Final Report	DYCH	DYCH	
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ENVIRONMENTAL STUDY

Figure Title :
**Distribution of Other Plant Specimens of Value
in Both Study Areas**

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7.3.2.5 Trees in Worksites for Manholes 29 and 30

None of the 13 specimens expected to be within the worksite for MH29 were found during ground-truthing. The area appears to be largely cleared (Figure 7-23B), presumably for the mini-golf course, and spontaneous vegetation have grown over (Figure 7-23C).

Similar to what was observed at the worksite for MH29, the trees at MH30 were also largely cleared and the ground covered by concrete. Of the 14 specimens expected to be within the worksite, only one was found during ground-truthing. Three other specimens in close proximity to but outside the worksite were also found (Figure 7-24). All four specimens were tagged with pink flagging tape (Figure 7-23F). The assessment of their suitability for transplantation was shown in Table 7-7.

Following ground-truthing surveys by the biodiversity consultants, an additional site inspection was carried out by a senior arborist from the SDC, who confirmed that all 26 trees (13 at each worksite for MH29 and MH30) were no longer at the former mini golf course. The SDC had postulated that the trees could have been removed many years ago during the development of the mini golf course.

Table 7-7 Tree Specimens within the MH30 Worksite

Species	Conservation status	Girth (m)	Height (m)	Northing (SVY21)	Easting (SVY21)	Assessment
<i>Shorea pauciflora</i>	Vulnerable	0.2	7	26519.45	26220.13	Average health. Poor taper. Poor transplant candidate.
<i>Shorea pauciflora</i>	Vulnerable	0.2	8	26518.57	26224.70	Average health. Poor taper. Poor transplant candidate.
<i>Shorea pauciflora</i>	Vulnerable	0.4	10	26523.10	26223.47	Average health. Poor taper. Poor transplant candidate.
<i>Bhesa paniculata</i>	Common	0.1	3	26516.80	26214.46	Good health and vigour. Good transplant candidate.



Figure 7-23 Worksites for Manhole MH29 (A–C) and Manhole MH30 (D–F)

7.3.3 Faunistic Field Findings

7.3.3.1 Overall

The desktop assessment identified 345 faunal species of probable occurrence at both study areas (Appendix E). The faunal survey and camera trap data were provided in Appendix G and Appendix H, respectively.

At the Mt. Imbiah Study Area, the field assessment recorded 42 species with more than half of the recorded assemblage dominated by bird species (25 species) (Table 7-8). This included one species of mammal, the feral cat (*Felis catus*), that was not listed as a probable species (Appendix E). A total of five species of conservation significance were recorded (Appendix F).

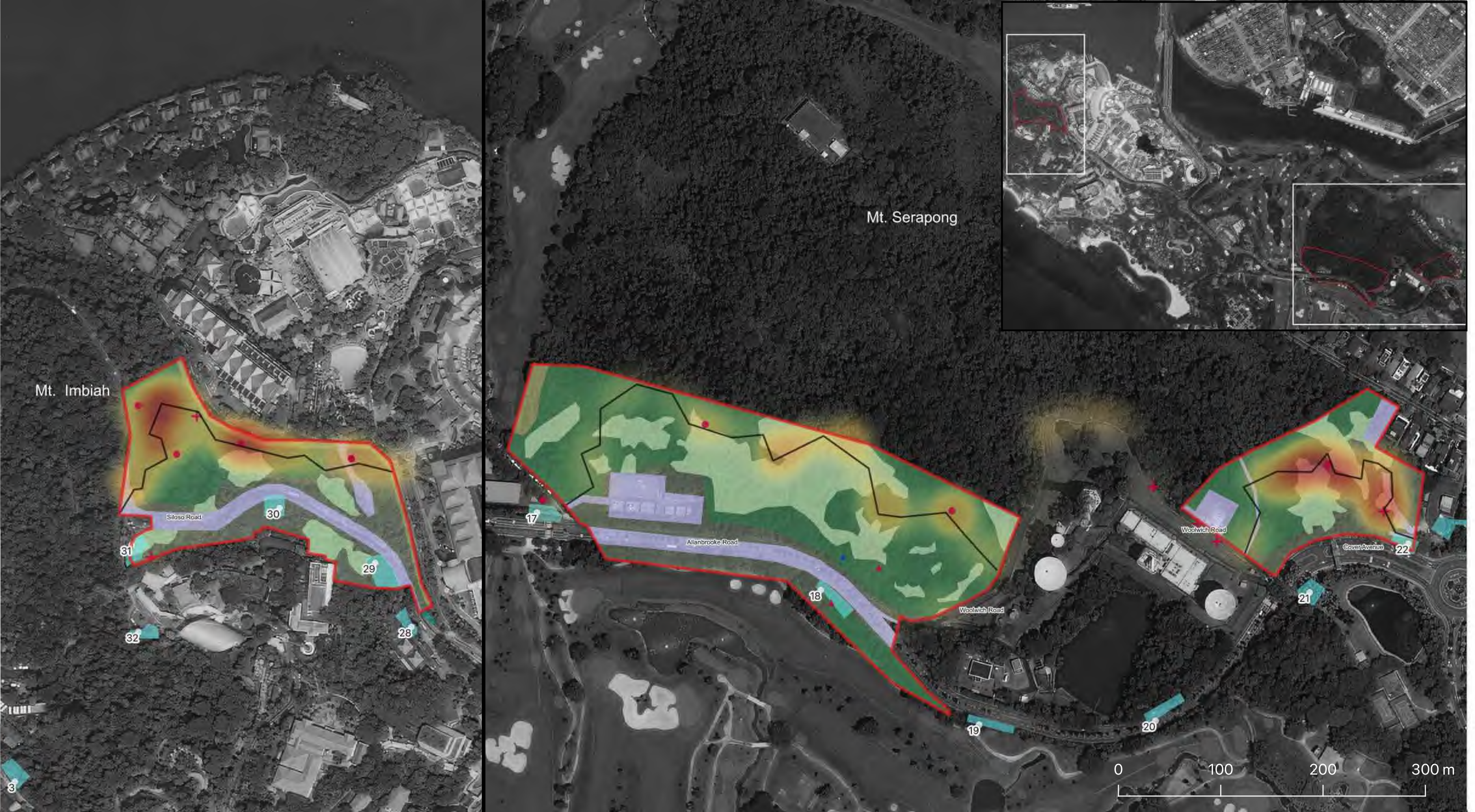
At the Mt. Serapong Study Area, the field assessment recorded 78 species with about a half of the recorded assemblage comprising birds (35 species) (Table 7-8). This included a single species each of odonate (banded skimmer, *Pseudothemis jorina*) and mammal (feral cat, *F. catus*) that were not listed as probable species (Appendix E). A total of six species of conservation significance were recorded (Appendix F).

Table 7-8 Number of Faunal Species Likely to Occur and Recorded at the Study Areas (CS – Species of Conservation Significance)

Taxon	Likely to occur		Recorded			
			Mt. Imbiah Study Area		Mt. Serapong Study Area	
	All species	CS species	All species	CS species	All species	CS species
Butterfly	128	6	5	0	16	0
Odonate	19	0	2	0	8	0
Amphibian	12	0	2	0	3	0
Reptile	24	1	1	0	5	0
Bird	142	17	25	3	35	3
Mammal (non-volant)	10	1	3	0	5	1
Mammal (bat)	10	2	4	2	6	2
Fish	0	0	0	0	0	0
Total	345	27	42	5	78	6

At the Mt. Imbiah Study Area, higher numbers of fauna were recorded in the native-dominated secondary forest and mixed forest, represented by hotspots along the sampling route (Figure 7-25). Records of conservation significant species were evenly distributed along the sampling route (Figure 7-25), consisting of two individuals each of the red junglefowl (*Gallus gallus*) and blue-crowned hanging parrot (*Loriculus galgulus*), as well as sole individuals each of the black-bearded tomb bat (*Taphozous melanopogon*) and an unidentified bamboo bat (*Tylonycteris* sp.). Observed during a roost emergence survey (see Section 7.2.2.4.6), an individual unidentified bamboo bat (*Tylonycteris* sp.) was recorded in the worksite for MH31 within the study area (Figure 7-25).

At the western patch of the Mt. Serapong Study Area, records of fauna were generally low (Figure 7-25). Other records of conservation significant species comprised a troop of the long-tailed macaque (*Macaca fascicularis*), two individuals of the changeable hawk-eagle (*Nisaetus cirrhatus*) along the sampling route, and a single individual of the Oriental pied hornbill (*Anthracoceros albirostris*) just outside the study area (Figure 7-25). Higher numbers of fauna were recorded at the eastern patch of the Mt. Serapong Study Area, including a single individual of the conservation significant red-legged crane (*Rallina fasciata*) that was detected by a camera trap within the mixed forest (Figure 7-25). Other records of conservation significant species comprised an individual unidentified bamboo bat (*Tylonycteris* sp.), in addition to four individuals of the black-bearded tomb bat (*T. melanopogon*) detected at three locations just outside the study area (Figure 7-25).



Legend

Study area

Vegetation

Native-dominated secondary forest

Mixed forest

Scrubland and herbaceous vegetation

Managed vegetation

Waterbody

Others (infrastructure)

Sampling route

CS bird

CS mammal

CS bat

Construction

Manhole

Worksite

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**Heat Map of Faunal Occurrence at the
Mt. Imbiah and Mt. Serapong Study Areas,
Including Species of Conservation Significance**

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7.3.3.2 Taxon Sampling Curves

Across both study areas, the sample coverage of the different fauna groups ranged from moderate to high, reflecting the given proportion of the total number of species in the community that were recorded during field surveys [P-51]. Following extrapolation (i.e., sample sizes were theoretically doubled using the statistical programme), the resulting increases in sample coverage and species richness values were then interpreted accordingly. The sampling curves for butterflies at the Mt. Imbiah Study Area, as well as amphibians, reptiles and non-volant mammals at both study areas were not plotted as the sample sizes were too small for the plots to be meaningful. At the Mt. Imbiah Study Area, two butterfly species, one amphibian species, one reptile species, and three non-volant mammal species were recorded. At the Mt. Serapong Study Area, three amphibian species, five reptile species, and five non-volant mammal species were recorded.

For the Mt. Imbiah Study Area, sample coverage was 66.7% for odonates, 83.3% for birds, and 97.2% for bats (Table 7-9). For odonates, extrapolation increased sample coverage to 96.3% and species richness to 2.44 (95% confidence interval between 1.11 and 3.78) (Table 7-9; Figure 7-26B), implying that even with increased survey effort fewer than two more odonate species would be recorded, likely owing to a lack of aquatic habitats within the study area. On the other hand, for birds, extrapolation increased sample coverage to 93.2% and species richness to 28.9 (confidence interval between 21.2 and 36.6) (Table 7-9; Figure 7-26C), implying that increased survey effort would result in fewer than 28 additional bird species to be recorded. This is possibly because the Mt. Imbiah Study Area is part of a larger, relatively contiguous forest patch that is likely to serve as a refuge for birds. For bats, extrapolation increased sample coverage to 99.6% and species richness to 3.42 (95% confidence interval between 1.22 and 5.62) (Table 7-9; Figure 7-26D). This implies that increased survey effort would result in less than 1% of the bat species in the community remaining undetected in field surveys. Around 4% and 7% of the odonate and bird species, respectively, in the community would remain undetected in the field surveys. Hence, the Chao Richness was used to estimate true species richness in the communities. The estimates were presented in Table 7-10.

For the Mt. Serapong Study Area, sample coverage was 80.3% for butterflies, 62.8% for odonates, 93.0 % for birds, and 97.3% for bats (Table 7-9). For butterflies, extrapolation increased sample coverage to 87.0% and species richness to 12.06 (95% confidence interval between 5.79 and 18.33) (Table 7-9; Figure 7-26A). For odonates, extrapolation increased sample coverage to 81.8% and species richness to 7.76 (95% confidence interval between 3.90 and 11.62) (Table 7-9; Figure 7-26B). A fifth of the odonate species in the community, i.e., around 19%, would remain undetected in the field surveys even with increased survey effort. This is likely owing to the lack of aquatic habitats within the study area. On the other hand, for birds, extrapolation increased sample coverage to 98.9% and species richness to 37.6 (confidence interval between 29.3 and 45.9) (Table 7-9; Figure 7-26C), implying that increased survey effort would result in fewer than 37 additional bird species to be recorded. This is possibly because the Mt. Serapong Study Area is part of a larger, relatively contiguous forest patch that is likely to serve as a refuge for birds. For bats, extrapolation increased sample coverage to 98.6% and species richness increases to 9.18 (95% confidence interval between 4.06 and 14.30) (Table 7-9; Figure 7-26D). The true species richness estimates were shown in Table 7-10.

Table 7-9 Interpolated and Extrapolated Sample Coverage for Both Study Areas

Taxon	Mt. Imbiah Study Area		Mt. Serapong Study Area	
	Interpolated	Extrapolated	Interpolated	Extrapolated
Butterfly	N.A.	N.A.	80.3%	87.0%
Odonate	66.7%	96.3%	62.8%	81.8%
Bird	83.3%	93.2%	93.1%	98.9%
Mammal (Bat)	97.2%	99.6%	97.3%	98.6%

Table 7-10 Observed and Estimated Species Richness (the Standard Error) and 95% Confidence Interval

Taxon	Mt. Imbiah Study Area				Mt. Serapong Study Area			
	Observed	Estimated ± S.E.	95% lower	95% upper	Observed	Estimated ± S.E.	95% lower	95% upper
Butterfly	N.A.	N.A.	N.A.	N.A.	8	20.00 ± 16.47	9.60	98.18
Odonate	2	2.50 ± 1.11	2.04	8.81	3	10.40 ± 6.33	5.87	38.43
Bird	22	32.93 ± 8.86	25.22	67.48	32	38.52 ± 4.59	34.33	55.86
Mammal (Bat)	4	3.49 ± 1.29	3.03	11.23	6	11.46 ± 7.13	7.49	47.57

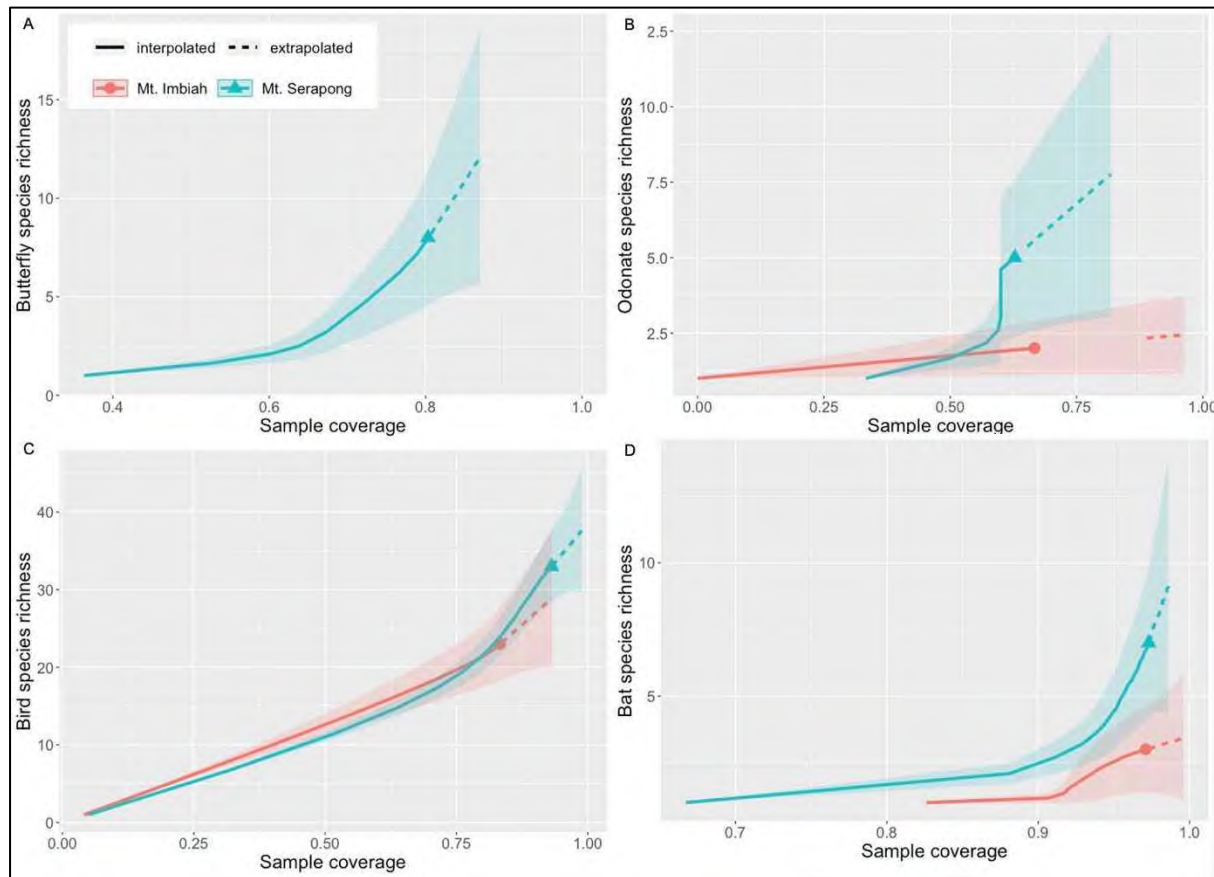


Figure 7-26 Taxon Sampling Curves for (A) Butterflies; (B) Odonates; (C) Birds; (D) Bats

7.3.3.3 Butterflies

According to findings from desktop assessment, a total of 129 species were deemed of probable occurrence within the Mt. Imbiah and Mt. Serapong Study Areas, with six species of conservation significance (Table 7-8; Appendix E). Most are common or moderately common throughout Singapore, while 17 are moderately to very rare.

During field assessment, five species of butterflies were recorded at the Mt. Imbiah Study Area, none of which are of conservation significance (Table 7-8). The recorded species are all common or moderately common. The Malayan plum Judy (*Abisara satura kausambioides*) and the chequered lancer (*Plastingia naga*; Figure 7-26A) are known to be forest-dependent butterflies.

The number of butterfly sightings was generally low along the sampling route in the Mt. Imbiah Study Area with only eight documented, of which four were the sun-loving and urban-adapted common palmfly (*Elymnias hypermnestra agina*). These occurrences were higher at more open areas such as at the edge of the native-dominated secondary forest and near scrubland and herbaceous vegetation patches (Figure 7-27).

At the Mt. Serapong Study Area, 14 species of butterflies were recorded, none of which are of conservation significance (Table 7-8). The recorded species are all common or moderately common, except for the palm king (*Amathusia phidippus*; Figure 7-26D) which is moderately rare. It was seen feeding on a rotting fruit at the Sentosa Pavilion, just adjacent to the study area. This species can be found in a variety of habitats, from parks and gardens to forested areas [P-36]. Its host plant, the coconut palm (*Cocos nucifera*), is widely planted on the island of Sentosa and could explain the presence of the moderately rare butterfly. The forest-dependent chequered lancer (*P. naga*) was also recorded at the Mt. Serapong Study Area.

The eastern patch of the Mt. Serapong Study Area had a markedly higher density of butterfly occurrence (Figure 7-28). Many species recorded there are sun-loving butterflies (see Figure 7-27) such as the grass yellow (*Eurema* sp.), knight (*Lebadea martha parkeri*), painted Jezebel (*Delias hyparete metarete*), and common palmfly (*E. h. agina*). This is likely owed to the more open habitat and what seemed like a private nursery with many potted flowering and landscaping plants. The availability of food sources from the potted plants may have also contributed to the higher number of butterfly sightings in the area.



Figure 7-27 Butterflies Recorded at the Study Areas. (A) Chequered Lancer (*Plastingia naga*); (B) Pale Mottle (*Logania marmorata damis*); (C) Knight (*Lebadea martha parkeri*); (D) Palm King (*Amathusia phidippus phidippus*).

7.3.3.4 Odonates (Damselflies and Dragonflies)

According to findings from desktop assessment, most of the 19 odonate species expected in the Mt. Imbiah and Mt. Serapong Study Areas are widespread and common, except for two which are widespread and uncommon. None of the probable species are of conservation significance (Table 7-8; Appendix E).

During field assessment, only two widespread and common species were recorded at the Mt. Imbiah Study Area. They are the common parasol (*Neurothemis fluctuans*) and the white-barred duskhawk (*Tholymis tillarga*; Figure 7-28A). Both are highly adaptable species that can breed in a variety of habitats, including drains and puddles [P-39].

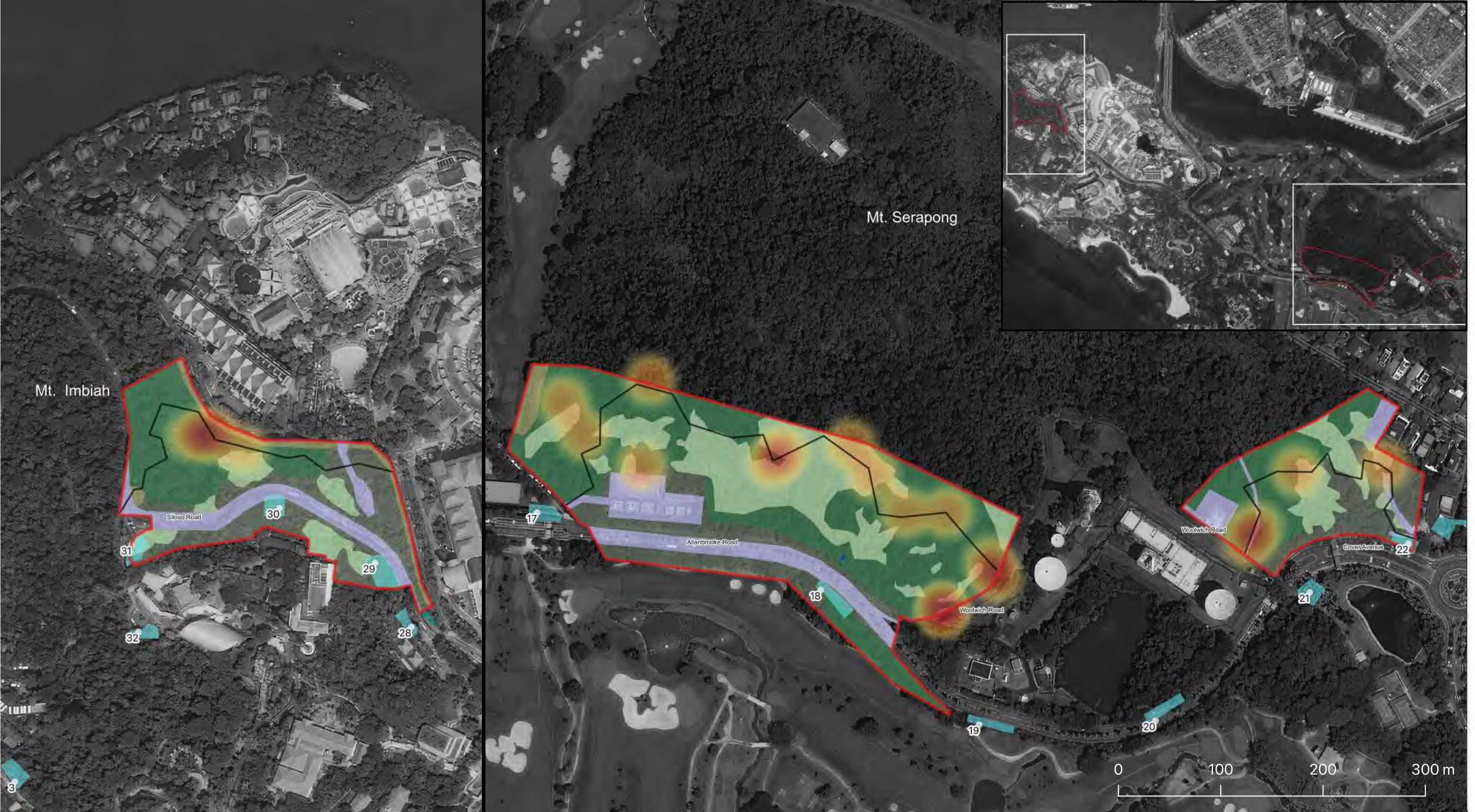
Only two sightings of odonates were documented at the Mt. Imbiah Study Area during transect surveys, both of which were seen near the edge of the native-dominated secondary forest (Figure 7-30).

At the Mt. Serapong Study Area, eight species of odonates were recorded. All of the recorded species are widespread and common, except for two which are widespread and uncommon. The two species are the dingy duskhawker (*Gynacantha subinterrupta*; Figure 7-29C) and the banded skimmer (*Pseudothemis jorina*). The dingy duskhawker inhabits forested areas and can breed in ponds/puddles on the forest floor [P-39]. The banded skimmer was not considered a species of probable occurrence as it prefers large open waterbodies, which are not present within the study area. It is likely that the individual recorded during field assessment inhabits larger waterbodies outside the study area instead, such as the service reservoirs or Serapong Lake.

The number of odonate sightings was generally low along the sampling routes, with only eight documented and of which four were the highly adaptable white-barred duskhawk (*T. tillarga*). These occurrences were relatively evenly distributed along the sampling routes at the Mt. Serapong Study Area (Figure 7-30).



Figure 7-29 Dragonflies Recorded at the Study Areas. (A) White-barred Duskhawk (*Tholymis tillarga*); Common Blue Skimmer (*Orthetrum glaucum*); (C) Dingy Duskhawker (*Gynacantha subinterrupta*).



Legend

Study area

Vegetation

Native-dominated secondary forest

Mixed forest

Scrubland and herbaceous vegetation

Managed vegetation

Waterbody

Others (infrastructure)

Sampling route

Construction

Manhole

Worksite

N

North Arrow

Rev.	Date	By	Description	Chk'd	App'd
B	NOV 2021	SHMX	Final Report Rev B	DYCH	DYCH
A	JUL 2021	SHMX	Final Report Rev A	DYCH	DYCH
-	MAY 2021	SHMX	Final Report	DYCH	DYCH

Qualified Person Endorsement :
NA

Client Endorsement:
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Consultant :
AECOM

Project Title :
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Figure Title :
**Heat Map of Odonate Occurrence at the
Mt. Imbiah and Mt. Serapong Study Areas**

Figure No. 7-30	Rev. B	Sheet 1 of 1
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CAD File Name : NA

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Note: Source of basemap - Microsoft Bing Map

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7.3.3.5 Amphibians

According to findings from the desktop assessment, seven of the 12 amphibian species expected in the study areas are native while the remaining five are non-native. All of these species are widespread and common, except for the restricted and rare East Asian ornate chorus frog (*Microhyla mukhlesuri*) and the widespread but uncommon Guenther's frog (*Sylvirana guentheri*), both of which are non-native. None of the probable species are of conservation significance (Table 7-8; Appendix E).

During the field assessment, only two widespread and common species were recorded at the Mt. Imbiah Study Area. The non-native greenhouse frog (*Eleutherodactylus planirostris*) (Figure 7-31A) was recorded during targeted surveys, while the native Asian toad (*Duttaphrynus melanostictus*) was an incidental observation. Both species are highly tolerant of disturbance and are often found near or in human habitation [P-8].

The number of amphibian sightings was generally low and rather evenly distributed along the sampling route at the Mt. Imbiah Study Area, with two hotspots at the edges of native-dominated secondary forest and mixed forest (Figure 7-32). Out of the 20 individuals recorded, 18 were of the greenhouse frog (*E. planirostris*) (Figure 7-31A).

At the Mt. Serapong Study Area, three species of amphibians were recorded. These comprise the non-native greenhouse frog (*E. planirostris*) and banded bullfrog (*Kaloula pulchra*) that were recorded during targeted surveys, as well as the native four-lined tree frog (*Polypedates leucomystax*) which was an incidental observation. All of the recorded species are widespread and common, being highly tolerant of disturbance and are often found near or in human habitation [P-8].

The number of amphibian sightings was generally low and patchily distributed along the sampling routes at the Mt. Serapong Study Area, with a single hotspot in scrubland and herbaceous vegetation in the western patch of the study area (Figure 7-32). The greenhouse frog (*E. planirostris*) (Figure 7-31A) had the strongest presence, accounting for 14 out of the 20 individuals recorded altogether.



Figure 7-31 Herpetofauna Recorded at the Study Areas. (A) Greenhouse Frog (*Eleutherodactylus planirostris*); (B) Oriental Whip Snake (*Ahaetulla prasina*); (C) Many-lined Sun Skink (*Eutropis multifasciata*).

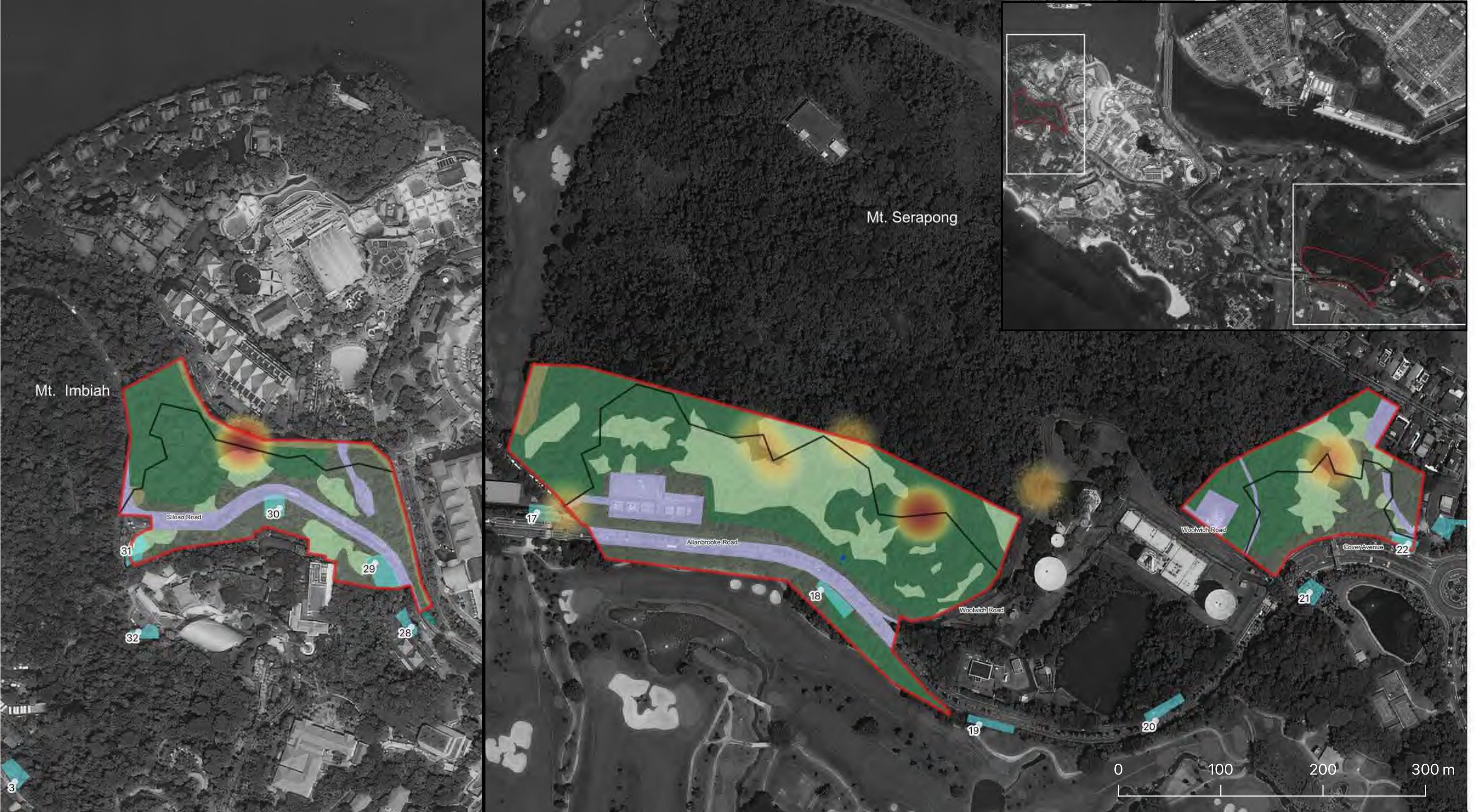
7.3.3.6 Reptiles

According to findings from the desktop assessment, 20 of the 24 reptile species expected in the study areas are native while the remaining four are non-native. All of the native species are widespread and common, except for the widespread but uncommon green-crested lizard (*Bronchocelea cristatella*) as well as the widespread but rare common Malayan racer (*Coelognathus flavolineatus*) and mourning gecko (*Lepidodactylus lugubris*). Out of the species of probable occurrence, only the common Malayan racer (*C. flavolineatus*) is of conservation significance—classified as being nationally Endangered (Table 7-8; Appendix E).

During the field assessment, a sighting of the Oriental whip snake (*Ahaetulla prasina*) (Figure 7-31B) constituted the sole record at the Mt. Imbiah Study Area where it was seen near the edge of the native-dominated secondary forest (Figure 7-33).

At the Mt. Serapong Study Area, five species of reptiles were recorded. These comprise the Oriental whip snake (*A. prasina*) (Figure 7-31B), many-lined sun skink (*Eutropis multifasciata*) (Figure 7-31C), and an unidentified monitor lizard (*Varanus* sp.) that were recorded during targeted surveys, as well as the spotted house gecko (*Gekko monarchus*) and equatorial spitting cobra (*Naja sumatrana*) that were only detected as an incidental observation. All of these species typically inhabit wooded areas, except for the spotted house gecko (*G. monarchus*) and equatorial spitting cobra (*N. sumatrana*) that are also associated with human habitation [P-8].

The number of reptile sightings was generally low and patchily distributed along the sampling routes at the Mt. Serapong Study Area, with a single hotspot in the native-dominated secondary forest in the western patch of the study area (Figure 7-33). The many-lined sun skink (*E. multifasciata*) (Figure 7-31C) accounted for four out of the ten individuals recorded altogether.



Legend

Study area

Vegetation

Native-dominated secondary forest

Mixed forest

Scrubland and herbaceous vegetation

Managed vegetation

Waterbody

Others (infrastructure)

Sampling route

Construction

Manhole

Worksite

N

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B	NOV 2021	SHMX	Final Report Rev B	DYCH	DYCH	
A	JUL 2021	SHMX	Final Report Rev A	DYCH	DYCH	
-	MAY 2021	SHMX	Final Report	DYCH	DYCH	
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sentosa
SENTOSA ISLAND RESORTS

Figure Title :
**Heat Map of Reptile Occurrence at the
Mt. Imbiah and Mt. Serapong Study Areas**

Figure No. 7-33	Rev. B	Sheet 1 of 1
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CAD File Name : NA

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Note: Source of basemap - Microsoft Bing Map

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7.3.3.7 Birds

According to findings from the desktop assessment, out of the 142 bird species expected in the study areas, 88 are resident (12 introduced) and 54 are migrants/visitors. Most of the species are abundant and common, with uncommon and rare species numbering 59 and 15, respectively. Seventeen of the species of probable occurrence are of conservation significance (Table 7-8; Appendix E).

The field assessment recorded 25 species at the Mt. Imbiah Study Area. These comprise abundant, common and uncommon resident species and migrants/visitors such as the common resident Sunda scops owl (*Otus lempiji*) (Figure 7-34A). Three species are of conservation significance: the nationally Endangered red junglefowl (*Gallus gallus*) (Figure 7-34D) and blue-crowned hanging parrot (*Loriculus galgulus*) that were recorded during targeted surveys, as well as the nationally Critically Endangered Oriental pied hornbill (*Anthracoceros albirostris*) (Figure 7-34C) that was an incidental observation. The two migratory species recorded are the Arctic warbler (*Phylloscopus borealis*) and Japanese sparrowhawk (*Accipiter gularis*). Both are common visitors; the former frequents wooded areas and parks, and the latter is often seen thermalling overhead.

The number of birds observed was relatively high and evenly distributed along the sampling route at the Mt. Imbiah Study Area, with two hotspots at the edges of native-dominated secondary forest and mixed forest (Figure 7-35). The 51 individuals recorded were largely represented by one to three individuals from each of the 27 species recorded, with the highest representation by the black-naped oriole (*Oriolus chinensis*) and olive-winged bulbul (*Pycnonotus plumosus*) at five individuals each. Five individuals of the three conservation significant species were distributed evenly along the sampling route (Figure 7-35).

At the Mt. Serapong Study Area, 35 species of birds were recorded. Except for the rare introduced resident Chinese hwamei (*Garrulax canorus*), these comprise abundant, common and uncommon resident species and migrants/visitors such as the uncommon migrant/visitor hooded pitta (*Pitta sordida*) (Figure 7-34B). Three species are of conservation significance: the nationally Vulnerable red-legged crake (*Rallina fasciata*) (Figure 7-34E), the nationally Endangered changeable hawk-eagle (*Nisaetus cirrhatus*) that were recorded during targeted surveys, as well as the nationally Critically Endangered Oriental pied hornbill (*Anthracoceros albirostris*) (Figure 7-34C) that was an incidental observation. The six migratory species recorded are the blue-throated bee-eater (*Merops viridis*), Asian brown flycatcher (*Muscicapa dauurica*), crested honey-buzzard (*Pernis ptilorhynchus*), Arctic warbler (*Phylloscopus borealis*), blue-winged pitta (*Pitta moluccensis*) and hooded pitta (*P. sordida*) (Figure 7-34B). Besides the two pitta species which are uncommon migrants/visitors, the rest are commonly encountered.

The number of birds observed was relatively high and evenly distributed along the sampling route at the Mt. Serapong Study Area (Figure 7-35). Altogether, 144 individuals were recorded across 35 species, with the highest representation by the black-naped oriole (*Oriolus chinensis*), olive-winged bulbul (*Pycnonotus plumosus*) and dark-necked tailorbird (*Orthotomus atrogularis*) at ten individuals each. Four observations of the three conservation significant species were spaced out, including that of the red-legged crake (*R. fasciata*) (Figure 7-34E) that was detected by a camera trap at the eastern patch of the study area as well as an Oriental pied hornbill (*A. albirostris*) just outside the study area (Figure 7-35).

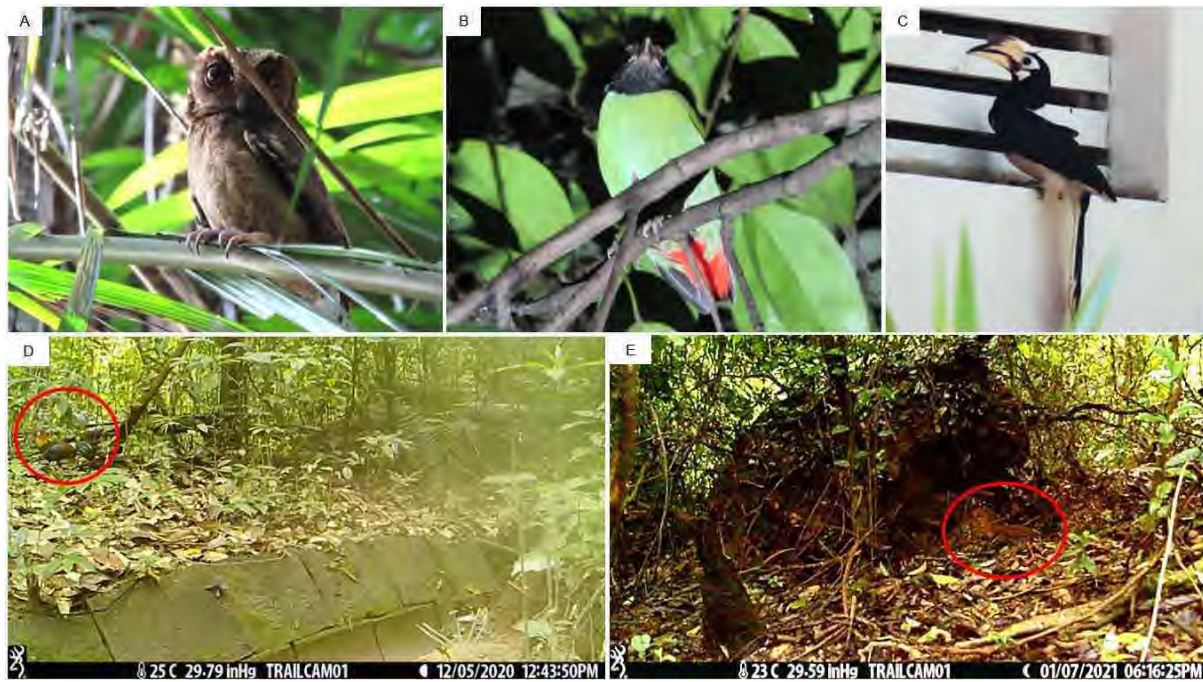
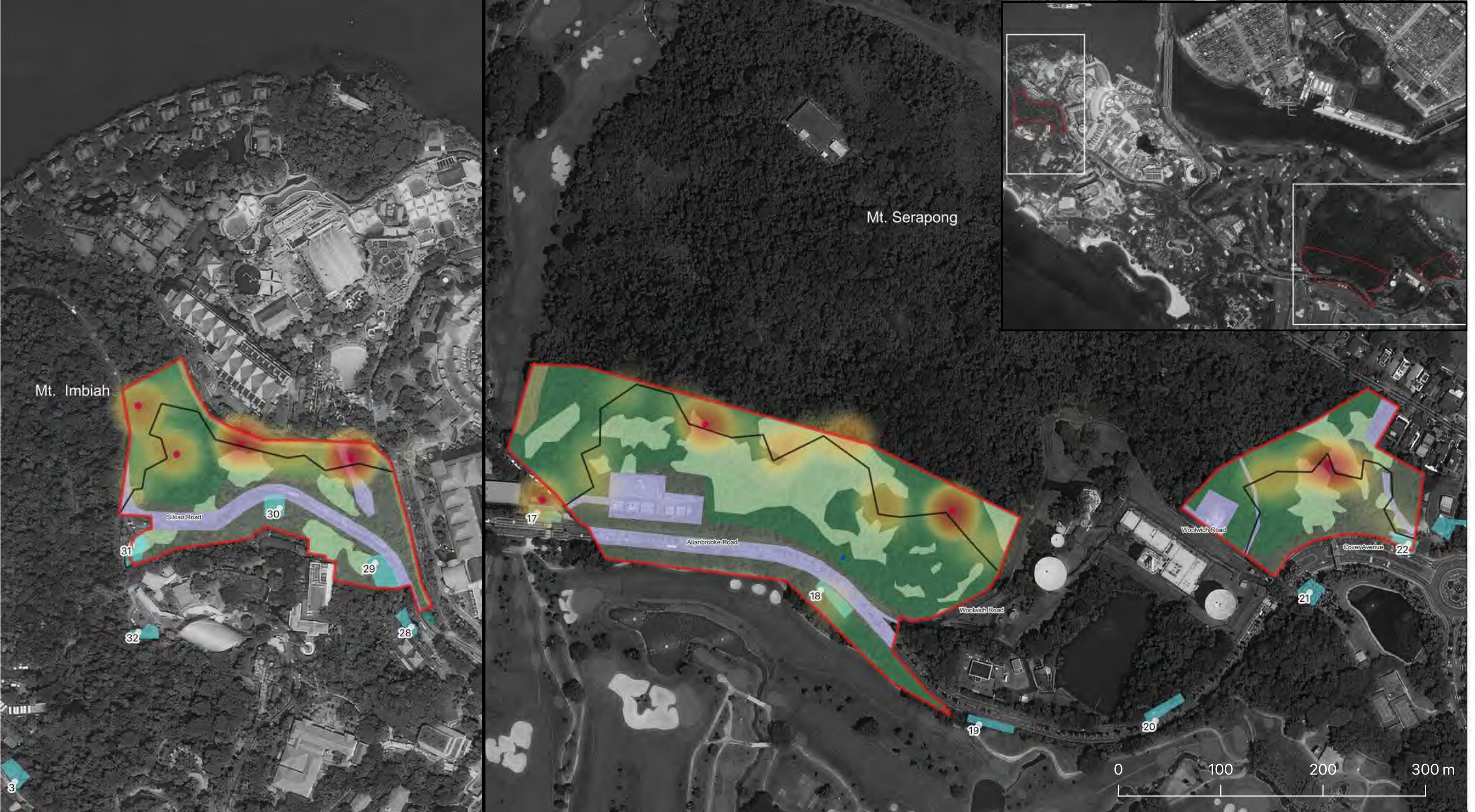


Figure 7-34 Birds Recorded at the Study Areas. (A) Sunda Scops Owl (*Otus lempiji*); (B) Hooded Pitta (*Pitta sordida*); (C) Oriental Pied Hornbil (*Anthracoceros albirostris*); (D) Red Junglefowl (*Gallus gallus*) on the Camera Trap Footage; (E) Red-legged Crake (*Rallina fasciata*) on the Camera Trap Footage.



Legend

Study area

Vegetation

Native-dominated secondary forest

Mixed forest

Scrubland and herbaceous vegetation

Managed vegetation

Waterbody

Others (infrastructure)

Sampling route

CS bird

Construction

Manhole

Worksite

Rev.

Date

By

Description

Chk'd

App'd

B

NOV 2021

SHMX

Final Report Rev B

DYCH

DYCH

A

JUL 2021

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NOV 2021

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Figure Title :
**Heat Map of Bird Occurrence at the
Mt. Imbiah and Mt. Serapong Study Areas**

Figure No.
7-35

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B

Sheet
1 of 1

CAD File Name : NA

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Note: Source of basemap - Microsoft Bing Map

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7.3.3.8 Mammals (Non-Volant)

According to findings from the desktop assessment, nine of the ten non-volant mammal species expected in the study areas are native while the remaining one is non-native. All of the native species are widespread and common, except for the widespread but uncommon Polynesian rat (*Rattus exulans*) and common palm civet (*Paradoxurus musangus*). Out of the species of probable occurrence, only the long-tailed macaque (*Macaca fascicularis*) is of conservation significance—classified as being globally Vulnerable (Table 7-8; Appendix E).

During the field assessment, three species were recorded at the Mt. Imbiah Study Area via camera trap. The plantain squirrel (*Callosciurus notatus*), an unidentified rat species (*Rattus* sp.), and the feral cat (*Felis catus*) were recorded. The feral cat (*F. catus*) was not considered a species of probable occurrence as it is often a house pet with free-roaming individuals largely having been taken off the streets.

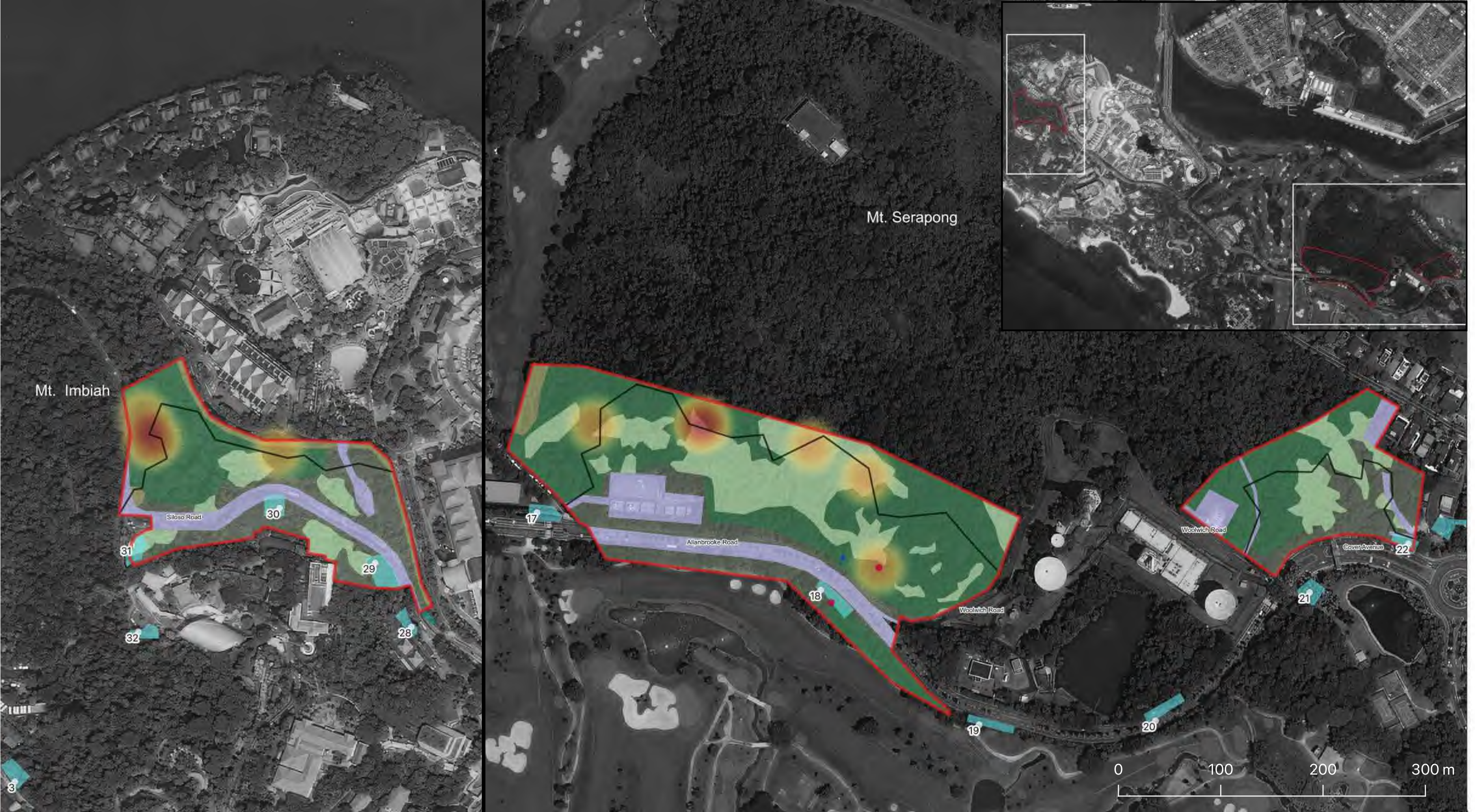
The hotspot along the survey route in the Mt. Imbiah Study Area was contributed by sightings of the plantain squirrel (*C. notatus*), which had the highest representation, and an unidentified rat (Figure 7-37).

At the Mt. Serapong Study Area, five species of non-volant mammals were recorded via camera trap. These comprised of the long-tailed macaque (*M. fascicularis*) (Figure 7-36A), plantain squirrel (*C. notatus*), feral cat (*F. catus*), common palm civet (*P. musangus*) (Figure 7-36B) and Malaysian wood rat (*Rattus tiomanicus*). The nationally widespread and common long-tailed macaque (*M. fascicularis*) was recently up-listed as a globally vulnerable species as a result of human persecution across the rest of Southeast Asia [W-33].

The plantain squirrel (*C. notatus*) had the highest representation, followed by the Malaysian wood rat, both of which contributed to the hotspot in the western patch of the Mt. Serapong Study Area (Figure 7-37). One of these observations constituted a troop of long-tailed macaques (*M. fascicularis*) from an incidental sighting.



Figure 7-36 Footage Recorded on Camera Traps at the Study Areas. (A) Long-tailed Macaque (*Macaca fascicularis*); (B) Common Palm Civet (*Paradoxurus musangus*)



Legend

Study area

Vegetation

Native-dominated secondary forest

Mixed forest

Scrubland and herbaceous vegetation

Managed vegetation

Waterbody

Others (infrastructure)

Sampling route

CS mammal

Construction

Manhole

Worksite

N

↑

B	NOV 2021	SHMX	Final Report Rev B	DYCH	DYCH	
A	JUL 2021	SHMX	Final Report Rev A	DYCH	DYCH	
-	MAY 2021	SHMX	Final Report	DYCH	DYCH	
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Figure Title :
**Heat Map of Mammal Occurrence
(Excluding Bats) at the
Mt. Imbiah and Mt. Serapong Study Areas**

Figure No. 7-37	Rev. B	Sheet 1 of 1
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CAD File Name : NA

A3

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7.3.3.9 Mammals (Bats Only)

According to findings from desktop assessment, only ten species of bats were deemed of probable occurrence at the Mt. Imbiah and Mt. Serapong Study Areas, of which two are of conservation significance (Table 7-8; Appendix E).

During field assessment, four species of bats, all of which are insectivorous, were recorded at the Mt. Imbiah Study Area (Table 7-8). Two of the recorded species are species of conservation significance (Appendix F). They are the nationally Endangered black-bearded tomb bat (*Taphozous melanopogon*; Figure 7-37A) and a bamboo bat which could only be identified to genus (*Tylonycteris* sp.; Figure 7-37B). The black-bearded tomb bat can be found in forested or urban areas and is considered widespread but rare [P-8]. One acoustic recording of the black-bearded tomb bat was obtained near the north-western edge of the Mt. Imbiah Study Area. One bamboo cluster near the proposed MH31 worksite was examined for its (potential) use by bamboo bats (*Tylonycteris* sp.) (Figure 7-39). Bamboo bat activity was detected visually and acoustically around this bamboo cluster during roost emergence survey, indicating that it is likely to be a roosting site for the bats. The acoustic signatures of the nationally Critically Endangered lesser bamboo bat (*T. fulvida*) and the widespread and common greater bamboo bat (*T. malayana*) overlap, thus making it difficult to distinguish the species without handheld specimens. Nevertheless, both species in Singapore are known to roost in bamboo internodes and are especially susceptible to injury or mortality if their roosts are removed/damaged during developments. Hence, both bamboo bat species are regarded as species of conservation significance in this study.

Most of the bat recordings at the Mt. Imbiah Study Area were obtained at the western end of the sampling route (Figure 7-38), but these were contributed only by one species, i.e., the highly urban-adapted Asiatic lesser yellow house bat (*Scotophilus kuhlii*).

Six species of bats, including five insectivorous (*T. melanopogon*; *Tylonycteris* sp.; *M. muricola*; *Saccolaimus*; *S. kuhlii*) and one frugivorous (*Cynopterus brachyotis*), were recorded at the Mt. Serapong Study Area (Table 7-8). The two species of conservation significance recorded at the Mt. Imbiah Study Area were also recorded at the Mt. Serapong Study Area (Appendix F). Three acoustic recordings of the black-bearded tomb bat (*T. melanopogon*) were obtained along Woolwich Road. This bat is adapted to forage in open spaces (Kingston et al., 2009), thus explaining its occurrence along the roads but not within the forested parts of the study area. One acoustic recording of the bamboo bat (*Tylonycteris* sp.) was obtained near the eastern end of the study area during a nocturnal transect survey. Although no bamboo bats were detected during roost emergence surveys at the three bamboo clusters in this study area, its presence in the vicinity (as indicated by the acoustic recordings) and the fact that bamboo bats switch roosts and utilize multiple bamboo clusters [P-52] suggest that the bamboo clusters are potential roosting sites.

Most of the bat records at the Mt. Serapong Study Area were obtained at the eastern part of the study area (Figure 7-38). These records were dominated by the Asiatic lesser yellow house bat (*S. kuhlii*), although the other five recorded species were also recorded in the same area.

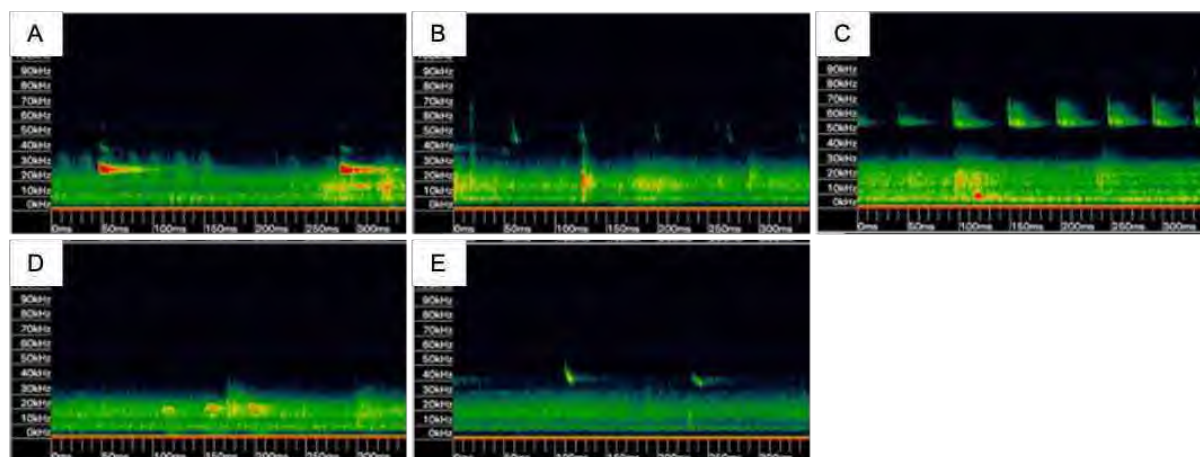
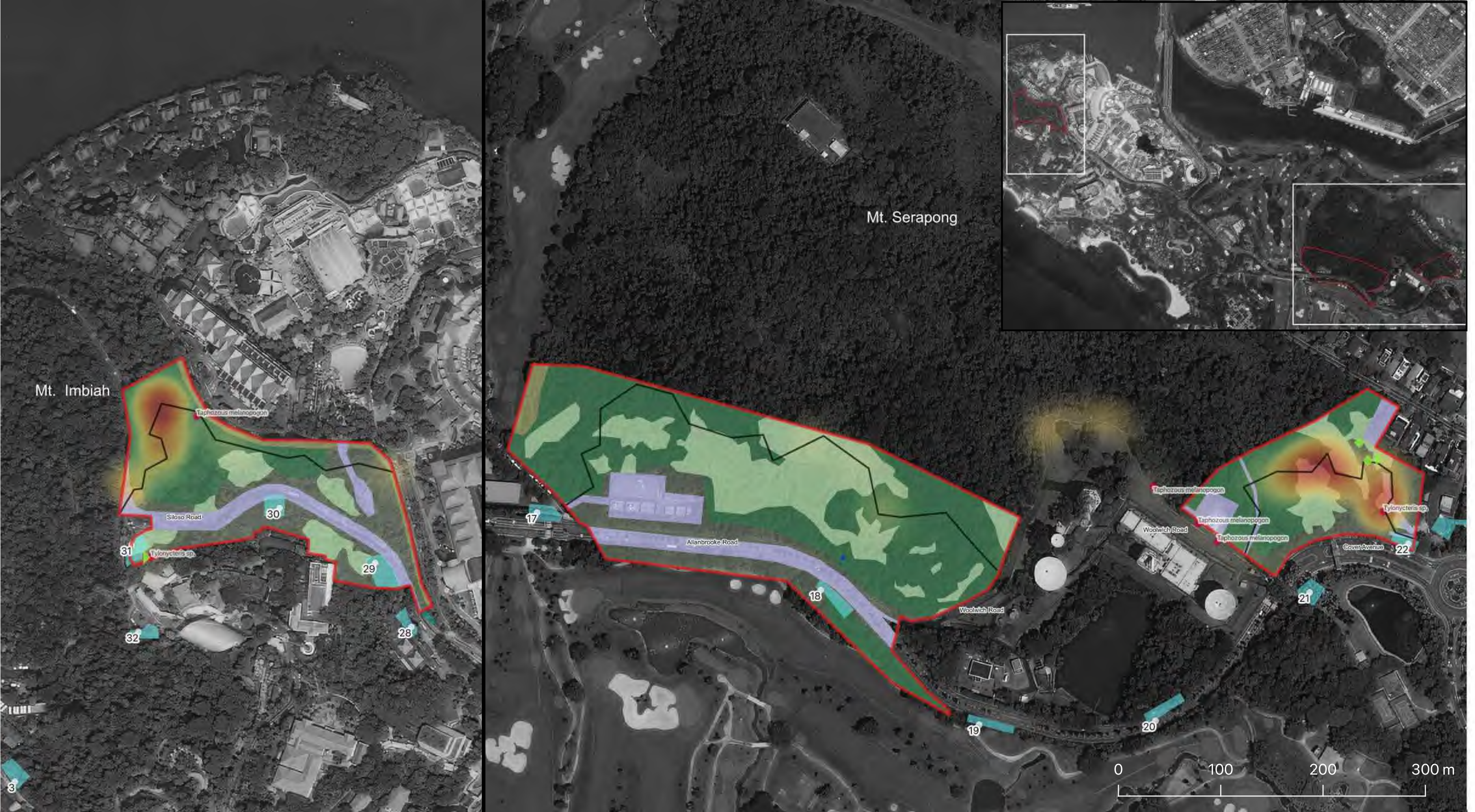


Figure 7-38 Spectrograms of Bat Echolocation Calls. (A) Black-bearded Tomb Bat (*Taphozous melanopogon*); (B) Bamboo Bat (*Tylonycteris* sp.); (C) Whiskered Myotis (*Myotis muricola*); (D) Pouch bearing bat (*Saccolaimus saccolaimus*); (E) Asiatic Lesser Yellow House Bat (*Scotophilus kuhlii*).



Legend

Study area

Vegetation

Native-dominated secondary forest

Mixed forest

Scrubland and herbaceous vegetation

Managed vegetation

Waterbody

Others (infrastructure)

Sampling route

CS bat

Bamboo cluster

> 3 m spread

< 3 m spread

Construction

Manhole

Worksite

N

North Arrow

Rev.	Date	By	Description	Chk'd	App'd
B	NOV 2021	SHMX	Final Report Rev B	DYCH	DYCH
A	JUL 2021	SHMX	Final Report Rev A	DYCH	DYCH
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Figure Title :
**Heat Map of Bat Occurrence at the
Mt. Imbiah and Mt. Serapong Study Areas**

Figure No. : 7-39	Rev. B	Sheet 1 of 1
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CAD File Name : NA

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Note: Source of basemap - Microsoft Bing Map

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7.3.3.10 Fish

No fish were caught in the minnow trap at the Mt. Serapong Study Area.

7.4 Assessment of Ecological Value

Habitats and species were assessed for their ecological value based on the criteria described in Table 7-11 (habitat) and Table 7-12 (plant species) [R-10, P-10]. Those of high ecological value were assigned the Priority 1 sensitivity level, while those of moderate or low ecological value were assigned the Priority 2 or 3 sensitivity levels, respectively.

Habitat and species receptors accorded with higher ecological value were regarded of greater importance for conservation relative to other habitats and species, respectively, within the study areas. This assessment was carried out using biodiversity baseline findings.

Table 7-11 Criteria for Assessing the Ecological Value of Habitats

Criterion	Definition	Classification		
		High	Medium	Low
Size	Area occupied by the habitat relative to the study area or length of a stream	≥ 40%	10–40%	≤ 10%
Naturalness	Degree to which the habitat has been modified or disturbed as a result of human activities	Habitat with minimal human disturbance	Moderately disturbed habitat that has been modified to some extent	Highly disturbed habitat that has been modified to a large extent
Abundance of species of conservation significance	Number of plant specimens and sightings of fauna of conservation significance recorded within the habitat relative to the study area	≥ 40%	10–40%	≤ 10%
Abundance of large and other plant specimens of value	Number of large and other plant specimens of value recorded within the habitat relative to the study area	≥ 40%	10–40%	≤ 10%
Ecological linkage	Connectedness to a highly-valued habitat	Highly connected	Moderately connected	Unconnected/ isolated
Recreatibility	Level of difficulty in re-constructing the habitat through human intervention	Very difficult	Moderately difficult	Easy

All plant species were first accorded with a tentative ecological value, i.e., high, medium, or low, based on the following basic framework:

- High ecological value (Priority 1): Species of conservation significance
- Medium ecological value (Priority 2): All other native species
- Low ecological value (Priority 3): Exotic and cryptogenic species

Species that were tentatively assigned medium (all other native species) or low (exotic and cryptogenic species) ecological value were then evaluated individually based on the criteria listed in Table 7-12. The evaluation of individual species served to either maintain or raise the pre-assigned ecological value. The following paragraphs detail how each criterion was considered in the evaluation.

Association with important fauna (native, exotic, and cryptogenic species): The ecological value of plant species that directly support the growth and survival of important fauna at one or various life cycle stages were raised to high, irrespective of plant species origin, cultivation intensity and effects, as well as national distribution. Examples of such plant species include caterpillar host plants for rare butterfly species and bamboos that are refugia for nationally threatened bamboo bats. The ecological value of plant species without associations with important fauna was maintained at the original level, i.e., medium or low.

Cultivation intensity and effects (native species only): The ecological value of all native species previously or presently cultivated and/or with populations of relics or escapees, respectively, present in the secondary forests of Singapore were maintained at the medium level. Otherwise, those that are associated with important fauna were raised to high ecological value.

National distribution (non-cultivated native species only): The ecological value of non-cultivated native plant species with restricted national distribution—i.e., largely found in certain forest patches in Singapore or offshore islands, such as the primary and old growth secondary forests of the CCNR—were raised from the original medium level to high. On the other hand, that of non-cultivated plant species that are nationally widespread—i.e., occur at several secondary forest patches throughout Singapore—were maintained at the medium level.

There are, however, a few exceptions in which the highest ecological value was automatically assigned to species regardless of the criteria listed below. They are (1) species endemic to Singapore, (2) keystone fig species (*Ficus* sp.) as they fruit all year round and provide a steady source of food for frugivores [P-20] and (3) species planted for reforestation and/or previously thought to be extinct and are planted for species reintroduction. Additionally, the exotic rain tree (*Samanea saman*) was also automatically raised from low to medium ecological value given that it often supports the growth of epiphytes that provide habitats for fauna

Table 7-12 Criteria for Assessing the Ecological Value of Plant Species

Criterion	Definition
Conservation significance	Listed as nationally threatened, i.e., Vulnerable, Endangered, Critically Endangered, or Extinct, and are considered of conservation significance in this study
Cultivation intensity and effects	Cultivated previously or presently—for various purposes such as reforestation, landscaping, species reintroduction, commercial sale, etc—and populations of relics and/or escapees are present/absent in forests
National distribution	Extent of spread and/or occurrence at one or multiple forest patches in Singapore
Association with important fauna	Directly associated with the survival of important fauna at one or various life cycle stages

Similar to the assessment framework for species of fauna, every recorded faunal species were provided an ecological value based on the conservation significance and species origin:

- High ecological value (Priority 1): Species of conservation significance
- Medium ecological value (Priority 2): All other native species
- Low ecological value (Priority 3): Exotic and cryptogenic species

7.4.1 Habitats

The ecological value of four terrestrial habitats in each of the study area were assessed. An additional aquatic habitat in the Mt. Serapong Study Area was also assessed for its ecological value.

Mt. Imbiah Study Area

Of the four habitat types found in the Mt. Imbiah Study Area, one is of high ecological value (native-dominated secondary forest), two are of medium ecological value (mixed forest as well as scrubland and herbaceous vegetation), and the last is of low ecological value (managed vegetation).

The native-dominated secondary forest scored a total of five “high” and one “medium” level in the assessment of ecological value with six criteria (Table 7-13). The only criterion for which this habitat type scored a “medium” level is “size” as the latter occupies less than 40% of the total study area (refer to Table 7-11) for the definitions for each

level). Apart from this criterion, this habitat has minimal human disturbance (high level for “naturalness”) and majority of the recorded plant and faunal species of conservation significance, large plant specimens and other plant specimens of value were found to be located within it (high levels for both abundance criteria). It is also highly connected for ecological linkage as the habitat is in itself, a high-valued habitat. Finally, the complexities of such forests are difficult to reconstruct through human intervention, giving it a “high” score for recreatability as well. Therefore, the ecological value of the native-dominated secondary forest is high, i.e., Priority 1.

Mixed forest scored a total of one “high” and five “medium” levels in the assessment while scrubland and herbaceous vegetation scored a total of three “medium” and “low” levels each. Nonetheless, both were accorded with medium ecological value, i.e., Priority 2. For the mixed forest, it differs from the native-dominated secondary forest in which it is a moderately disturbed habitat with some extent of modification (thus giving a “medium” level of naturalness) and contains fewer plant and faunal species of conservation significance as well as large plant specimens and other plant specimens of value (giving “medium” levels for both abundance criteria too). The ecological linkage is accorded with a “medium” level as well since patches of this habitat is in close proximity to the high-valued native-dominated secondary forest (likewise for all the remaining habitats evaluated in this assessment). The mixed forest is moderately difficult to recreate (“medium” level for recreatability) as it contains both a mix of native as well as planted exotic species that have grown spontaneously into the forested area (refer to Section 7.3.1.2 for the detailed description of this forest type).

For the scrubland and herbaceous vegetation, it contains much fewer plant and faunal species of conservation significance as well as large specimens and other plant specimens of value, giving both abundance criteria “low” levels instead of “medium”. Such habitat with open canopy and little structural heterogeneity would be fairly easy to recreate through human intervention, hence resulting in a “low” score for “recreatability”. While there are equal numbers of “low” and “medium” scores for this habitat type, a more conservative approach was adopted by assigning the ecological value as medium instead of low.

Finally, for managed vegetation, it has majority (five out of six) “low” scores as it is small, highly disturbed and modified to a large extent, very few to no records of plant and faunal species of conservation significance, large specimens and other specimens of value recorded within it, and easy to recreate. The only criterion for which is scored a “medium” level is “ecological linkage” since the managed vegetation patches lie adjacent to the high-valued native-dominated secondary forest.

Table 7-13 Habitat Ecological Assessment Table for the Mt. Imbiah Study Area

Criterion	Native-dominated secondary forest	Mixed forest	Scrubland and herbaceous vegetation	Managed vegetation
Size	33.6% (1.2 ha)	31.7% (1.1 ha)	12.5% (0.4 ha)	6.3% (0.2 ha)
Naturalness	Habitat with minimal human disturbance	Moderately disturbed habitat that has been modified to some extent	Moderately disturbed habitat that has been modified to some extent	Highly disturbed habitat that has been modified to a large extent
Abundance of species of conservation significance	Flora: 61.3% (84) Fauna: 57.1% (4)	Flora: 32.1% (44) Fauna: 42.9% (3)	Flora: 3.6% (5) Fauna: 0.0% (0)	Flora: 2.9% (4) Fauna: 0.0% (0)
Abundance of large and other plant specimens of value	59.1% (13)	36.4% (8)	4.5% (1)	0.0% (0)
Ecological linkage	Highly connected	Moderately connected	Moderately connected	Moderately connected
Recreatability	Very difficult	Moderately difficult	Easy	Easy
Summary of categorisations	Size: medium	Size: medium	Size: medium	Size: low
	Naturalness: high	Naturalness: medium	Naturalness: medium	Naturalness: low
	Abundance of species of conservation significance: high	Abundance of species of conservation significance: high	Abundance of species of conservation significance: low	Abundance of species of conservation significance: low

Criterion	Native-dominated secondary forest	Mixed forest	Scrubland and herbaceous vegetation	Managed vegetation
	Abundance of large specimens and other plant specimens of value: high	Abundance of large specimens and other plant specimens of value: medium	Abundance of large specimens and other plant specimens of value: low	Abundance of large specimens and other plant specimens of value: low
	Ecological linkage: high	Ecological linkage: medium	Ecological linkage: medium	Ecological linkage: medium
	Recreatability: high	Recreatability: medium	Recreatability: low	Recreatability: low
Total	High × 5 (majority) Medium × 1	High × 1 Medium × 5 (majority)	Medium × 3 Low × 3	Medium × 1 Low × 5 (majority)
Sensitivity	Priority 1	Priority 2	Priority 2	Priority 3

Mt. Serapong Study Area

Of the five habitat types found in the Mt. Serapong Study Area, one is of high ecological value (native-dominated secondary forest), two are of medium ecological value (mixed forest as well as scrubland and herbaceous vegetation), and the remaining two are of low ecological value (managed vegetation and waterbody).

The assessment of ecological value of habitats in the Mt. Serapong Study Area is similar to that in the Mt. Imbiah Study Area. The only habitat type found exclusively in the former is the ephemeral waterbodies that make up less than 1% of the total study area (refer to Section 7.3.1.5 for the detailed description of this habitat type). While the waterbodies found here are located within the native-dominated secondary forest, they are mostly small waterlogged ponds that are not connected to any larger water sources. Neither aquatic plants nor fauna were found to inhabit them as well. Therefore, the waterbodies were deemed to be isolated and unconnected, giving it a “low” score for ecological linkage.

Table 7-14 Habitat Ecological Assessment Table for the Mt. Serapong

Criterion	Native-dominated secondary forest	Mixed forest	Scrubland and herbaceous vegetation	Managed vegetation	Waterbody
Size	44.5% (4.4 ha)	16.8% (1.7 ha)	25.5% (2.5 ha)	1.2% (0.1 ha)	< 1% (0.0022 ha)
Naturalness	Habitat with minimal human disturbance	Moderately disturbed habitat that has been modified to some extent	Moderately disturbed habitat that has been modified to some extent	Highly disturbed habitat that has been modified to a large extent	Moderately disturbed habitat that has been modified to some extent
Abundance of species of conservation significance	Flora: 88.5% (615) Fauna: 72.7% (8)	Flora: 7.9% (55) Fauna: 18.2% (2)	Flora: 3.6% (25) Fauna: 9.1% (1)	Flora: 0.0% (0) Fauna: 0.0% (0)	Flora: 0.0% (0) Fauna: 0.0% (0)
Abundance of large and other plant specimens of value	77.8% (21)	18.5% (5)	3.7% (1)	0.0% (0)	0.0% (0)
Ecological linkage	Highly connected	Moderately connected	Moderately connected	Moderately connected	Unconnected/ isolated
Recreatability	Very difficult	Moderately difficult	Easy	Easy	Easy
	Size: high	Size: medium	Size: medium	Size: low	Size: low

Criterion	Native-dominated secondary forest	Mixed forest	Scrubland and herbaceous vegetation	Managed vegetation	Waterbody
Summary of categorisations	Naturalness: high	Naturalness: medium	Naturalness: medium	Naturalness: low	Naturalness: medium
	Abundance of species of conservation significance: high	Abundance of species of conservation significance: medium	Abundance of species of conservation significance: low	Abundance of species of conservation significance: low	Abundance of species of conservation significance: low
	Abundance of large specimens and other plant specimens of value: high	Abundance of large specimens and other plant specimens of value: medium	Abundance of large specimens and other plant specimens of value: low	Abundance of large specimens and other plant specimens of value: low	Abundance of large specimens and other plant specimens of value: low
	Ecological linkage: high	Ecological linkage: medium	Ecological linkage: medium	Ecological linkage: medium	Ecological linkage: low
	Recreatability: high	Recreatability: medium	Recreatability: low	Recreatability: low	Recreatability: low
Total	High × 6 (majority)	Medium × 6 (majority)	Medium × 3 Low × 3	Medium × 1 Low × 5 (majority)	Medium × 1 Low × 5 (majority)
Sensitivity	Priority 1	Priority 2	Priority 2	Priority 3	Priority 3

7.4.2 Flora

The ecological value of 172 and 194 plant species in the Mt. Imbiah and Mt. Serapong study areas, respectively, were assessed. The list of species was made available in Appendix A.

Mt. Imbiah Study Area

Of the 172 plant species assessed for their ecological value at the Mt. Imbiah Study Area, 46 are of high value, 55 of medium value, and 71 of low value. Altogether, 16 species had their ecological value raised after assessment. One species was raised from low to medium ecological value, while that of 15 species were raised to high from low (three species) and from medium (12 species). The former is a rain tree (*Samanea saman*), that while exotic, often supports the growth of various species of epiphytes that create and provide habitats for fauna.

Eight of the species that had their ecological value raised to high comprise fig species. Six of these fig species are Common native species (e.g., *Ficus fistulosa* and *F. heteropleura*) and were therefore accorded an initial level of medium, while the remaining two species of *F. benjamina* and *F. religiosa* are respectively cryptogenic and of exotic origin and thus originally accorded low ecological value. The ecological value of these fig species was raised as they are keystone species important for the health of entire ecosystems; they produce figs year-round that provide a steady source of food for frugivores [P-20].

The sole bamboo species present was raised from low to high ecological value. Albeit exotic, *Thyrsostachys siamensis* may be inhabited by bamboo bats that are known to reside within the bamboo internodes, where they roost for long hours. Bamboo bats were found to be in the vicinity of the cluster during bat roost emergence surveys. Such bamboo clusters play an important role in the survival of these nationally threatened bat species. Therefore, retaining bamboo clusters in the study area is essential to safeguarding local populations that continually face the threat of habitat loss.

The remaining six species raised to high ecological value from an initial medium level are native species. Even though five of these are nationally threatened, such as *Cyathocalyx ridleyi* and *Dipterocarpus kunstleri*, they were not considered to be of conservation significance as they were planted within the Mt. Imbiah Study Area. Instead, they were accorded high ecological value as they were cultivated for the purpose of reforestation (see Section 7.4.2). The final species is the non-cultivated *Alyxia reinwardtii*, that although listed as locally Common, has a restricted distribution nationally where it more often occurs in later-stage successional secondary forests or forest

reserves in the CCNR. The Mt. Imbiah Study Area may therefore serve as an additional refuge for this species outside the CCNR.

Mt. Serapong Study Area

In the Mt. Serapong Study Area, 60 plant species were assessed to be of high ecological value, 60 of medium value, and 72 of low value. Altogether, 11 species had their ecological value raised after assessment. Three species were raised from low to high ecological value, and eight from medium to high.

Seven of the species that had their ecological value raised to high comprise fig species, for the same reasons discussed above for the Mt. Imbiah Study Area. Five of these fig species are Common native species (e.g., *F. fistulosa* and *F. punctata*) and were therefore accorded an initial level of medium, while the remaining two species of *F. benjamina* and *F. barteri* are respectively cryptogenic and of exotic origin and thus originally accorded low ecological value.

The exotic *Bambusa vulgaris* was the only bamboo species present in the Mt. Serapong Study Area and was raised from low to high ecological value for the same reasons discussed above for the Mt. Imbiah Study Area. Acoustic sampling along the terrestrial sampling route at the Mt. Serapong Study Area revealed the presence of bamboo bats (see Section 7.3.3.8).

The remaining three species raised to high ecological value from an initial medium level are native species. Although Common, *Alyxia reinwardtii*, *Bromheadia finlaysoniana* and *Campylospermum serratum* have a restricted distribution nationally where they more often occur in later-stage successional secondary forests or forest reserves in the CCNR. The Mt. Serapong Study Area may therefore serve as an additional refuge for these species outside the CCNR.

Across both study areas, all other species assessed to be of high ecological value are nationally threatened species of conservation significance.

7.4.3 Fauna

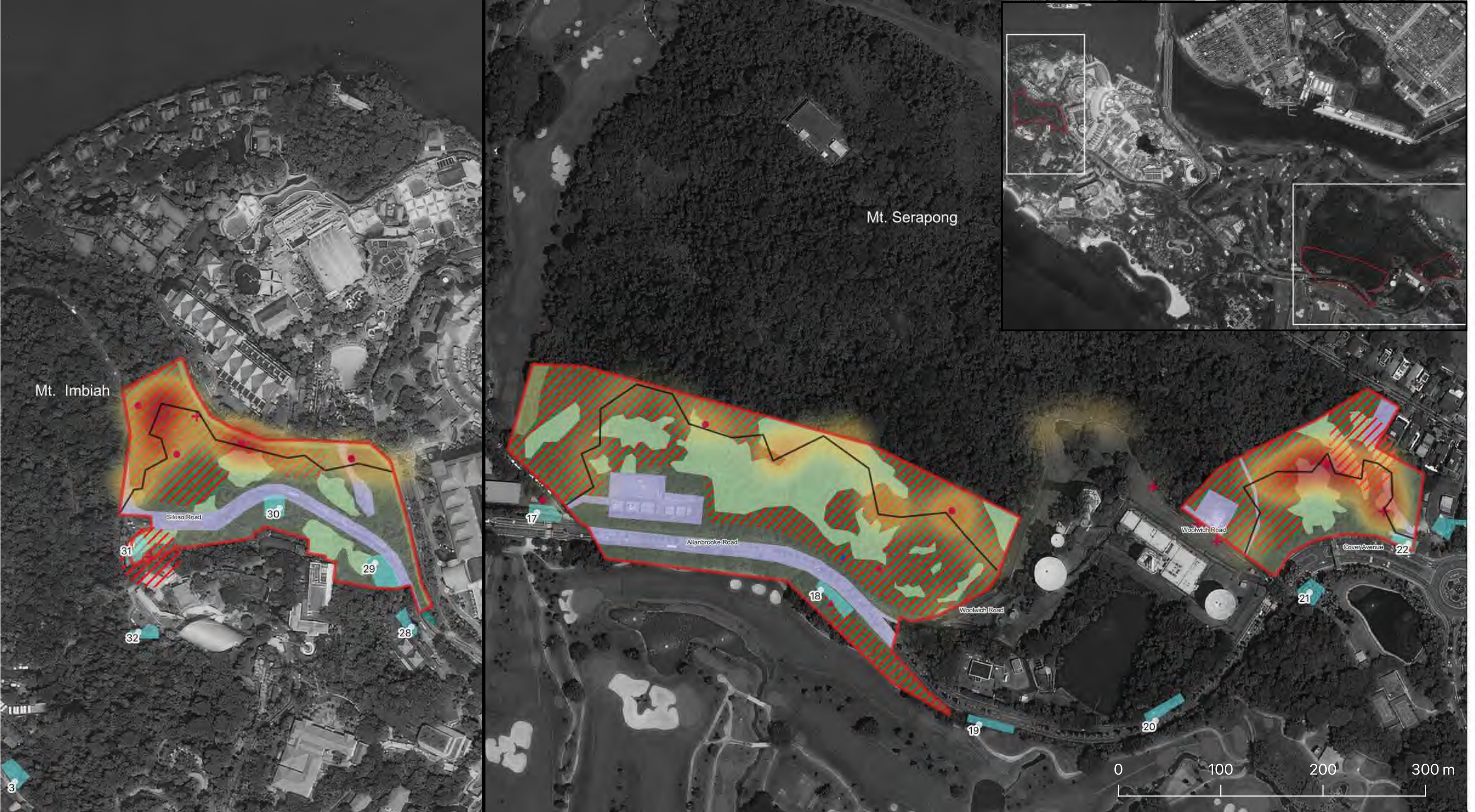
The ecological value of 42 and 78 species of fauna recorded in the Mt. Imbiah and Mt. Serapong study areas, respectively, were assessed. In the Mt. Imbiah Study Area, five faunal species were assessed to be of high ecological value while in the Mt. Serapong Study Area, six fauna species were assessed to be of high ecological value (Table 7-15).

Table 7-15 List of Faunal Species of High Ecological Value Recorded in the Study Area

Taxon	Species	Common Name	Global Status	Local Status	Mt. Imbiah	Mt. Serapong
Bird	<i>Anthracoceros albirostris</i>	Oriental pied hornbill	Least Concern	Critically Endangered	Y	Y
	<i>Gallus gallus</i>	Red junglefowl	Least Concern	Endangered	Y	
	<i>Loriculus galgulus</i>	Blue-crowned hanging-parrot	Least Concern	Endangered	Y	
	<i>Nisaetus cirrhatus</i>	Changeable hawk-eagle	Least Concern	Endangered		Y
	<i>Rallina fasciata</i>	Red-legged crane	Least Concern	Vulnerable		Y
Mammal (non-volant)	<i>Macaca fascicularis</i>	Long-tailed macaque	Vulnerable	Not assessed		Y
Mammal (bat)	<i>Taphozous melanopogon</i>	Black-bearded tomb bat	Least Concern	Endangered	Y	Y
	<i>Tylonycteris</i> sp.	Unidentified bamboo bat	Least Concern	Critically Endangered (<i>T. fulvida</i>) or Not Assessed (<i>T. malayana</i>)	Y	Y

7.5 Areas of High Conservation Value

The assessment of habitat and species ecological value was used to identify areas of high conservation value (Figure 7-40). In this study, all habitats with Priority 1 sensitivity level as well as areas within 30 m from all identified bamboo clusters were classified as areas of high conservation value. All such areas are of the highest priority for conservation and should be left untouched as far as possible. Any developments or construction activities within them are likely to result in **Moderate** to **Major** impacts. It is important to note that while certain areas have to be prioritised over others, those accorded with medium or low conservation value are also important and contribute to the ecological integrity of the entire site.



Legend

Study area

Vegetation

Native-dominated secondary forest

Mixed forest

Scrubland and herbaceous vegetation

Managed vegetation

Waterbody

Others (infrastructure)

Conservation area

CS bird

CS mammal

CS bat

Construction

Manhole

Worksite

N

							Qualified Person Endorsement : NA	Consultant : AECOM	sentosa				
							Client Endorsement: NA	Project Title : Contract No. SDC/21.8.2/19: Environmental Study For The Proposed Deep Gravity Sewer Project at Sentosa			Figure Title : Map of Areas of High Conservation Value		
B	NOV 2021	SHMX	Final Report Rev B	DYCH	DYCH			Designed SHMX	Checked JAG/NHT	Approved JAG	Figure No. 7-40	Rev. B	Sheet 1 of 1
A	JUL 2021	SHMX	Final Report Rev A	DYCH	DYCH								
-	MAY 2021	SHMX	Final Report	DYCH	DYCH								
Rev.	Date	By	Description	Chk'd	App'd			Drawn SHMX	Date NOV 2021	CAD File Name : NA			A3

7.6 Identification of Sensitive Receptors

7.6.1 Habitats

All habitats of Priority 1 and 2 sensitivity levels were identified as the sensitive receptors for habitats.

7.6.2 Flora

Following the assessment of ecological value for all plant species (Section 7.4.2), some were selected for the assessment of ecological impacts. The selection was based on the following: (1) species with specimens of conservation significance, large specimens, and/or other specimens of value found inside and within 30 m from the proposed worksite area, (2) keystone species, which are only the *Ficus* species in this study, (3) species associated with important fauna, and (4) species that make up $\leq 1\%$ of the total number of specimens of conservation significance.

7.6.3 Fauna

All species of fauna of conservation significance in this study were identified as the sensitive receptors for faunal species.

7.7 Potential Sources of Biodiversity Impacts

Potential impacts to biodiversity arising from construction activities were identified in this section (Table 7-16). The main construction activities are, in sequence, site clearance, shaft construction, pipejacking, manhole construction and reinstatement works. Construction works will be carried out concurrently for groups of manholes (about 5–6 worksites per group), and across phases until construction at all the manholes are completed. This is expected to take place from the first quarter of 2023 to the first quarter of 2027 (see Figure 3-9). The estimated time required to complete construction works at each worksite averages around 12 months.

Machines would operate 24 hours a day for pipejacking works, during which the main form of disturbance for fauna was identified to be light. In the event of an emergency, human operators could be deployed to the worksite, even if it is night-time. For the latter, the main form of disturbance to fauna would be human disturbance.

There are two main categories in which the impacts fall into, namely, (1) direct, i.e., impacts to habitats and species within the worksites and (2) indirect, i.e., impacts to habitats and species outside the worksites but within the impact zone. Impact zones for habitat and species receptors were defined as areas within 30 m from worksites of the proposed development, even though there are some studies that found edge effects affecting vegetation up to 150 m from forest boundaries [P-13, P-19, P-25, P-53]. The 30-m impact zone was defined based on the assumption that edge effects in the forests adjacent to worksites are the greatest within 30 m from the worksites.

Table 7-16 List of Potential Ecological Impacts during Construction

Receptor	Impact type	Description	Impact category
Habitats	Loss of vegetation	Direct removal of vegetation (with extensive underground root systems that protect against soil erosion) to create space for construction activities	Direct
	Habitat degradation	Improper disposal of construction waste, accidental release of hazardous materials (such as construction slurry, paint, and/or solvents), increase in dust, noise, and light levels, changes in forest hydrology	Indirect
	Change in species composition	Formation of forest edge habitats that favour the growth of certain exotic plants and fauna, and accidental introduction of exotic species from construction materials (such as soil with seeds or bio-degradable erosion blankets with insect eggs)	Indirect
Plant species	Mortality	Direct removal of vegetation to create space for construction activities	Direct

Receptor	Impact type	Description	Impact category
	Impediment to seedling recruitment	Pollution of habitats from improper disposal of construction waste and accidental release of hazardous materials (such as construction slurry, paint, and/or solvents)	Indirect
	Competition from exotic plant species	Formation of forest edge habitats that favour the growth of certain exotic plants and accidental introduction of exotic species from construction materials (such as soil with seeds)	Indirect
	Decline in plant health and survival	Changes in microclimatic conditions (i.e., dust, noise, and light, temperature, and humidity) and hydrology	Indirect
Faunal species	Loss of/ reduction in habitats and food sources	Direct removal of vegetation to create space for construction activities	Direct
	Injury or mortality	Collisions with machineries, entrapments in construction materials (such as non-biodegradable erosion control blankets) and structures (such as exposed pits or drains), and accidental kills by construction personnel	Direct
	Loss of ecological connectivity for faunal movement	Habitat fragmentation from the removal of vegetation	Indirect
	Light disturbances	Increase in light levels from construction activities	Indirect
	Human disturbances	Increase in human traffic flow, such as workers and site personnel	Indirect

7.8 Minimum Control for Potential Biodiversity Impacts

This section listed biodiversity-specific minimum controls commonly implemented in Singapore for similar construction activities. These were assumed to be implemented for the purpose of the impact assessment. Minimum controls for each potential impact occurring from the construction phase were listed in Table 7-17. Since work activities/methods are similar across both study areas, all minimum control measures proposed are applicable to all worksites. These measures should be proposed in tandem with other environmental receptors (e.g., air and noise). The main construction activities that would likely occur at all worksites include vegetation clearance for worksite and excavation for levelling ground, followed by above and below ground construction.

Table 7-17 Minimum Control Measures during Construction

Work activities	Minimum controls	Worksite
Vegetation clearance	- Set up Tree Protection Zones (TPZs) around trees or other plant specimens to be retained within the worksites, within which no construction works should be carried out. This should be executed by certified arborists and in accordance with the guidelines set up by the NParks. - Conduct inspections of fauna prior to felling or removal of vegetation. This should be done by an ecologist who is able to identify wildlife and/or active nesting structures, such as bird nests, tree hollows and/or burrows. - Execute wildlife response plan - Implement soil erosion control measures as soon as vegetation has been removed and soil is exposed (refer to Section 10 on Surface Water Quality)	All
Excavation	- Implement soil erosion control measures (refer to Section 10 on Surface Water Quality) - Implement dust control measures (refer to Section 9 on Air Quality)	All
Above and below ground construction	Ensure proper storage of machineries likely to leech harmful chemicals and fuel-powered equipment	All

Work activities	Minimum controls	Worksite
	- Ensure noise levels are within approved limits or as low as reasonably practicable as described in Section 8 under Airborne Noise - Store the aforementioned equipment away from waterbodies and/or sensitive habitats (refer to Section 10 on Surface Water Quality)	
General	- Avoid carrying out works at night (especially at worksites near Nature Areas, i.e. MH17, MH18, MH22, MH29, MH30, MH31) to prevent disturbance to nocturnal fauna - Direct artificial lighting away from forested and nature areas (if the lights are required)	All

7.9 Prediction and Evaluation of Biodiversity Impacts

In this section, the identified key ecologically sensitive receptors were evaluated based on impact intensity (Table 6-5) and likelihood (Table 6-6), which eventually gives the impact significance.

The various levels of impact intensity and likelihood for each impact type during construction were specifically defined for the ecologically sensitive receptors. Some assumptions were made in defining the levels of impact intensity.

The two assumptions made in defining the levels of impact intensity (Table 7-18) and likelihood (Table 7-19) for habitat receptor were:

- Habitats within 30 m from the worksites were assumed to experience the greatest extent of edge effects, though some studies have shown that edge effects could be up to 150 m (refer to Section 7.6.3 for the definition of the impact zone)
- The likelihood of habit degradation [i.e., improper disposal of construction waste, accidental release of hazardous materials (such as construction slurry, paint, and/or solvents), increase in dust, noise, and light levels, changes in forest hydrology; refer to Table 7-16] was presumed to be “less likely” for all habitat receptors, based on the assumption that all minimum controls (Section 7.8) are adequately and properly implemented.

Table 7-18 Definitions of Each Level of Impact Intensity for All Three Impact Types during Construction for Habitat Receptors

Impact Type	Negligible	Low	Medium	High
Loss of vegetation	The habitat does not overlap with the worksites	≤ 10% of the habitat overlaps with the worksites	10–40% of the habitat overlaps with the worksites	≥ 40% of the habitat overlaps with the worksites
Habitat degradation	The habitat does overlap with areas 30 m from the worksites	≤ 10% of the habitat overlaps with areas 30 m from the worksites	10–40% of the habitat overlaps with areas 30 m from the worksites	≥ 40% of the habitat overlaps with areas 30 m from the worksites
Change in species composition				

Table 7-19 Definitions of Each Level of Likelihood for All Three Impact Types during Construction for Habitat Receptors

	Loss of vegetation	Habitat degradation	Change in species composition
Unlikely/Remote	The habitat does not overlap with the worksites	N.A.	No formation of forest edges (i.e., construction activities are fully underground and/or in existing built-up areas outside the forest)
Less Likely/ Rare	N.A.	N.A. (see assumption above)	Formation of scrubland edges in scrubland areas only

	Loss of vegetation	Habitat degradation	Change in species composition
Possible/ Occasional	N.A.	N.A.	Formation of some forest and scrubland edges in a mix of managed vegetation, scrubland and forested areas
Likely/ Regular	N.A.	N.A.	Formation of new forest edges (i.e., complete clearance within forested areas)
Almost Certain/ Continuous	The habitat overlaps with the worksites	N.A.	N.A.

Assumptions made in defining the levels of impact intensity (Table 7-20) for plant species receptors:

1. Habitats within 30 m from the worksites were assumed to experience the greatest extent of edge effects, though some studies have shown that edge effects could be up to 150 m (refer to Section 7.6.3 for the definition of the impact zone). The effects of forest edges may be experienced by species more sensitive to microclimatic changes more than 30 m away from the worksites; these were considered during species-specific impact evaluations.
2. For tree/strangler species that are not bamboos or of conservation significance (i.e., native common or exotic species), and hence do not have count data, it was assumed that the intensity of impacts of work activities to be **Negligible**. The impacts, however, were still considered specifically for each species during the evaluation.
3. For native common or exotic climbing fig species/species associated with important fauna that also do not have count data from floristic surveys, it was assumed that the intensity of impacts of work activities on them to be **Negligible** since most of these species were expected to be widespread. The impacts, however, would still be considered specifically for each species during evaluation (e.g., *Ficus heteropleura* and *Ficus punctata*).

The definitions for likelihood for plant species receptors were presented in Table 7-21.

Table 7-20 Definitions of Each Level of Impact Intensity for All Four Impact Types during Construction for Plant Species Receptors

Impact Type	Negligible	Low	Medium	High
Mortality	No plant specimens of this species are within the worksites	Less than 50% of all plant specimens of this species are within the worksites	More than or exactly 50% of all plant specimens of this species are within the worksites	All plant specimens of this species are within the worksites
Impediment to seedling recruitment	No specimens of this species are within 30 m from the worksites	Less than 50% of all plant specimens of this species are within 30 m from the worksites	More than or exactly 50% of all plant specimens of this species are within 30 m from the worksites	All specimens of this species are within 30 m from the worksites
Competition from exotic species				
Decline in plant health and survival				

Table 7-21 Definitions of Each Level of Likelihood for All Four Impact Types during Construction for Plant Species Receptors

	Mortality	Impediment To Seedling Recruitment	Competition From Exotic Species	Decline In Plant Health And Survival
Unlikely/Remote	No plant specimens of this species are within the worksites	Plants are epiphytes and/or do not grow on soil	No formation of forest edges (i.e., construction activities are fully underground and/or in existing built-up areas outside the forest)	

	Mortality	Impediment To Seedling Recruitment	Competition From Exotic Species	Decline In Plant Health And Survival
Less Likely/ Rare	N.A.	N.A.	N.A.	
Possible/ Occasional	No count data/locations of specimens of this species is available, but specimens could possibly be within the worksites	Plants that grow on soil and whose dispersals are not restricted, i.e., they disperse via wind, water, and/or terrestrial fauna	Formation of scrubland edges in scrubland areas only	
Likely/ Regular	N.A.	N.A.	Formation of some forest and scrubland edges in a mix of managed vegetation, scrubland and forested areas	
Almost Certain/ Continuous	Plant specimens of this species are within the worksite	Plants that grow on soil whose dispersals are restricted owing to environmental factors and/or growth strategies (e.g., bamboos that propagate via underground rhizomes and ground orchids)	Formation of new forest edges (i.e., complete clearance within forested areas)	

The definitions for impact intensity and likelihood for faunal species were presented in Table 7-22 and Table 7-23, respectively.

Table 7-22 Definitions of Each Level of Impact Intensity for All Five Impact Types during Construction for Faunal Species Receptors

Impact Type	Negligible	Low	Medium	High
Loss of/ reduction in habitats and food sources	No loss of original habitat	– Loss of <10% of original habitat; – Retention of >90% of original habitat	– Loss of 10–40% of original habitat; – Retention of >60% of original habitat	– Loss of >40% of original habitat; – Retention of <60% of original habitat
Injury or mortality	Negligible susceptibility to roadkills	Species with low susceptibility to injury/mortality: – Volant species (e.g., odonates, butterflies, birds and bats) – Low susceptibility to roadkills	Species that are mobile but possibly susceptible to injury/mortality: – Amphibious aquatic species – All amphibians – Mammals: squirrels, shrews – Possibly susceptible to roadkills	Species with high susceptibility to collisions with buildings (birds only) and vehicles: – All birds, including migratory species – All amphibians – All reptiles – Mammals: Long-tailed macaque – Has small population size
Loss of ecological connectivity for faunal movement	– Not dependent on connected and forested habitats for dispersal and able to traverse urban infrastructures (i.e. high dispersal ability);	– Slightly dependent on connected and forested habitats for dispersal and adaptable to traverse urban infrastructures if needed;	– Dependent on connected and forested habitats for dispersal (i.e. intermediate dispersal ability);	– Highly dependent on connected and forested habitats for dispersal (i.e. low dispersal ability); – Susceptible to roadkills;

Impact Type	Negligible	Low	Medium	High
	– Negligible susceptibility to roadkills;	– Low susceptibility to roadkills; – Has small home range	– Possibly susceptible to roadkills; – Has moderate home range	– Has large home range
Light disturbances	Species that are not susceptible to changes in light levels: aculeate hymenopterans, aquatic species	Species that are slightly susceptible to changes in light levels: odonates, butterflies	Species that are susceptible to changes in light levels: diurnal birds, reptiles and mammals	Species that are highly susceptible to changes in light levels: nocturnal and crepuscular fauna
Human disturbances	Species that are not sensitive to human presence: commonly observed in urban environments	Species that are slightly sensitive to human presence: sometimes observed in urban environments	Species that are possibly sensitive to human presence: occasionally observed in urban environments	Species that are sensitive to human presence: rarely observed in urban environments

Table 7-23 Definitions of Each Level of Likelihood for All Five Impact Types during Construction for Faunal Species Receptors

	Loss of/ reduction in habitats and food sources	Injury or mortality	Loss of ecological connectivity for faunal movement	Light disturbances	Human disturbances
Unlikely/Remote	The habitats and locations of food sources does not overlap with the worksites	No fauna of this species utilizes the areas that are within the worksites	Fauna species have a small home range and rarely utilize connecting vegetation to travel between patches.	No human activities (e.g. construction) within the habitat that the species utilize	
Less Likely/ Rare	N.A.	N.A.	N.A.	N.A.	
Possible/ Occasional	N.A.	No records of this fauna species are available, but individuals could possibly be within the worksites	Fauna species have a medium home range and sometimes utilize connecting vegetation to travel between vegetated patches.	Some human activities (e.g. construction) within the habitat that the species utilize	
Likely/ Regular	N.A.	N.A.	N.A.	N.A.	
Almost Certain/ Continuous	The habitats and locations of food sources overlap with the worksites	Fauna species is recorded within the worksite	Fauna species have a large home range and often utilize connecting vegetation to travel between vegetated patches.	Complete overlap of human activities (e.g. construction) within the habitat that the species utilize	

7.9.1 Habitats

In the assessment of the four types of impact for the Priority 1 and 2 habitat receptors during the construction phase—(1) loss of vegetation, (2) habitat degradation, and (3) change in species composition—the impact

significance was negligible, low, moderate, or major. Only the most severe impact for each species from the assessment of all three impact types was presented for both study areas.

Mt. Imbiah Study Area

In the assessment of ecological impacts for the selected sensitive habitat receptors, the impact significance was evaluated to be **Moderate** for both the mixed forest as well as scrubland and herbaceous vegetation, and **Minor** for the native-dominated secondary forest.

Both the mixed forest as well as scrubland and herbaceous vegetation would be likely to experience **Moderate** impacts as a result of loss of vegetation. Approximately 10% of both habitats—0.1 ha (9%) of mixed forest and 0.04 ha (10%) of scrubland and herbaceous vegetation—overlapped with the areas for worksites, which gave an impact intensity of **Low**. Both vegetation types were evaluated to be **Priority 2**, which resulted in an impact consequence of **Low**. Since vegetation clearance would take place within the worksites, the likelihood of loss of vegetation was **Almost Certain**. Therefore, this gave an overall impact significance of **Moderate**.

The most severe impact significance for native-dominated secondary forest was evaluated to be **Minor** as a result of habitat degradation and change in species composition. Only 3% of the habitat (0.03 ha) overlapped with areas 30m from the worksites, thus resulting in an impact intensity of **Low** for both impact types. The native-dominated secondary forest was assessed to be **Priority 1**, which resulting in an impact consequence of **Low**. The likelihood of habitat degradation was **Less Likely** (see Table 7-18), while that of change in species composition was **Possible** but both gave an overall impact significance of **Minor**.

Mt. Serapong Study Area

In the Mt. Serapong Study Area, the impact significance for mixed forest was evaluated to be **Moderate**, while that for native-dominated secondary forest as well as scrubland and herbaceous vegetation was **Minor**.

Similar to the assessment for the Mt. Imbiah Study Area, the mixed forest in the Mt. Serapong Study Area would be likely to experience **Moderate** impacts as a result of loss in vegetation. Only 3% (0.05 ha) of this habitat type overlapped with the areas for worksites, thus giving an impact intensity of **Low**. Considering that the mixed forest was **Priority 2**, it gave an impact consequence of **Low**. With the likelihood as **Almost Certain**, the resulting impact significance was **Moderate**.

The most severe impact significance for native-dominated secondary forest was **Minor** as a result of habitat degradation and change in species composition, while that for scrubland and herbaceous vegetation was **Minor** as a result of change in species composition only. The assessment for both habitat types in the Mt. Serapong Study Area was observed to be similar to that in the Mt. Imbiah Study Area.

7.9.2 Flora

In the assessment of the four types of impact for individual species during the construction phase—(1) mortality, (2) impediment to seedling recruitment, (3) competition from exotic species, and (4) decline in plant health and survival—the impact significance was negligible, low, moderate, or major. Only the most severe impact for each species from the assessment of all four impact types was presented for both study areas.

Mt. Imbiah Study Area

A total of 30 sensitive plant species receptors recorded in the Mt. Imbiah Study Area were selected for the assessment of ecological impacts (refer to Section 7.6.2 on how the sensitive receptors were selected). The significance of the impacts was **Major** for two species, **Moderate** for nine species, and **Minor** for the remaining 19 species (Appendix I).

The two species likely to experience major impacts were (1) the nationally Critically Endangered *Centotheca lappacea*, and (2) the exotic *Thyrsostachys siamensis*, for the following reasons:

- 1) *Centotheca lappacea* would be likely to experience **Major** impacts owing to mortality given that 50% of all specimens (one out of two) were found to be locating within the proposed worksite for MH30, in addition to it having high ecological value (**Priority 1**) as it is a species of conservation significance. The resulting impact intensity and impact consequence were both **Medium**, and it was **Almost Certain** that these specimens would be removed for construction activities. Hence, the impact significance was assessed to be **Major**.

- 2) *Thyrsostachys siamensis* would be likely to experience **Major** impacts owing to mortality given that the sole specimen, i.e., 100% of all specimens, of this species was found to be locating within the proposed worksite for MH31, in addition to it having high ecological value (**Priority 1**) in spite of its exotic origin (see Section 7.4.2). The resulting impact intensity and impact consequence were both **High**, and it was **Almost Certain** that the sole specimen would be affected by construction activities. Hence, the impact significance was evaluated to be **Major**.

The nine species likely to experience **Moderate** impacts comprised (1) the exotic *Callerya atropurpurea*, (2) the nationally Vulnerable *Derris amoena* var. *maingayana*, (3) the nationally Critically Endangered *Ficus kerkhovenii*, (4) the Endangered *Ficus vasculosa*, (5) the nationally Vulnerable *Planchonella obovata*, (6) the exotic *Samanea saman*, (7) the Critically Endangered *Sterculia parvifolia*, (8) the nationally Vulnerable *Streblus elongatus*, and (9) the nationally Common *Syzygium grande*.

- 1) *Callerya atropurpurea* would be likely to experience **Moderate** impacts owing to mortality given that the sole specimen, i.e., 100% of all specimens, of this species was found to be locating within the proposed worksite for MH30 but is of low ecological value (**Priority 3**) since it is an exotic species. The resulting impact intensity and impact consequence were **High** and **Low** respectively. It was **Almost Certain** (likelihood) that the sole specimen would be removed by construction activities. Hence, the impact significance was **Moderate**.
- 2) The other eight species would be likely to experience **Moderate** impacts owing to impediment to seedling recruitment, competition from exotic species, and a decline in plant health and survival given that 50–67% of all specimens of these species was found to be locating within 30m from the proposed worksites (MH28, MH29, MH30 and MH31) and all are of high ecological value (**Priority 1**), except for *Syzygium grande* which has medium ecological value (**Priority 2**). The resulting impact intensities and impact consequences were predicted to be **Medium**. As all flowering seed plants that grow on soil and whose dispersal modes are not restricted, there was a possibility (likelihood was assessed to be **Possible**) that seedling recruitment for the 50–67% of specimens found within 30 m from the proposed worksite might still be somewhat impeded as a result of construction activities, such as pollution from improper disposals and/or accidental release of construction waste. It was also **Possible** (likelihood) that forest edges would be formed following the expected vegetation clearance for construction activities. Assuming that forest edge effects are the greatest in habitats within 30 m from the cleared areas, the specimens would experience competition from exotic species as the formation of forest edge habitats favours the growth of certain exotic plants. Additionally, changes in microclimatic conditions at forest edges might also cause a decline in plant health and survival of these specimens. Hence, the impact significance was **Moderate**.

The remaining 19 species would be likely to experience **Minor** impacts owing to all impact types on eight of these species, while three of these impact types (impediment to seedling recruitment, competition from exotic species, as well as a decline in plant health and survival) affect 11 species. All species are of high ecological value (**Priority 1**) but given that none of the specimens were found to be locating in and within 30 m from the proposed worksite, the resulting impact intensities were **Negligible** and the resulting impact consequences were **Very Low** throughout. Hence, the impact significance was assessed to be **Minor**.

Mt. Serapong Study Area

A total of 45 sensitive plant species receptors recorded in the Mt. Serapong Study Area were selected for the assessment of ecological impacts (refer to Section 7.6.2 on how the sensitive receptors were selected). The significance of the impacts was **Major** for one species, **Moderate** for six species, and **Minor** for the remaining 38 species (Appendix I).

The only species likely to experience **Major** impacts, owing to mortality, was the nationally Critically Endangered *Garcinia atroviridis* given that 50% of all specimens were found to be locating within the proposed worksite for MH18, in addition to it having high ecological value (**Priority 1**) as it is a species of conservation significance (see Section 7.4.2). The resulting impact intensity and impact consequence were both **Medium**, and it was **Almost Certain** that these specimens would be affected by construction activities. Hence, the impact significance was **Major**.

The six species likely to experience **Moderate** impacts comprised (1) the Endangered *Ficus vasculosa*, (2) the nationally Vulnerable *Glochidion zeylanicum* var. *zeylanicum*, (3) the nationally Endangered *Memecylon edule*, (4) the nationally Vulnerable *Oncosperma tigillaria*, (5) the nationally Vulnerable *Palaquium obovatum*, and (6) the nationally Vulnerable *Planchonella obovata*.

- 1) *Ficus vasculosa*, *Memecylon edule*, *Oncosperma tigillaria*, *Palaquium obovatum*, and *Planchonella obovata* would be likely to experience **Moderate** impacts owing to mortality given that less than 50% of all specimens of these species were found to be locating in and within the proposed worksites (MH17, MH18, and MH22), in addition to all having high ecological value (**Priority 1**) as they are species of conservation significance (see Section 7.4.2). The resulting impact intensities and impact consequences were **Low**, and it was **Almost Certain** that the specimens would be removed by construction activities given their distribution relative to the proposed worksites. Hence, the impact significance was assessed to be **Moderate**.
- 2) *Glochidion zeylanicum* var. *zeylanicum* would be likely to experience **Moderate** impacts owing to impediment to seedling recruitment, competition from exotic species, and a decline in plant health and survival given that the sole specimen, i.e., 100% of all specimens, of this species was found to be locating located within 30 m from the proposed worksite for MH18, in addition to it having high ecological value (**Priority 1**) as it is a species of conservation significance (see Section 7.4.2). The resulting impact intensities and impact consequences were **High**. As a flowering seed plant that grows on soil and whose dispersal modes are not restricted, there was a possibility that seedling recruitment for the sole specimen found within 30 m from the proposed worksite might still be somewhat impeded as a result of construction activities, such as pollution from improper disposals and/or accidental release of construction waste. It was also likely that forest edges would be formed following the expected land clearance for construction activities. Assuming that forest edge effects are the greatest in habitats within 30 m from the cleared areas, the sole specimen would experience competition from exotic species as the formation of forest edge habitats favours the growth of certain exotic plants. Additionally, changes in microclimatic conditions at forest edges might also cause a decline in plant health and survival of this specimen. Hence, the impact significance was assessed to be **Moderate**.

The remaining 38 species would be likely to experience **Minor** impacts owing to all impact types on seven of these species, while three of these impact types (impediment to seedling recruitment, competition from exotic species, as well as a decline in plant health and survival) affect 31 species. All species were of high ecological value (**Priority 1**) except for *Ardisia elliptica* which was of medium ecological value (**Priority 2**). However, given that none of the specimens of the majority of the species were found to be locating in and within 30 m from the proposed worksite (likelihood was **Negligible**), and that less than 50% of the specimens of the rest of the species were located within 30 m from the proposed worksites (MH17, MH18, and MH22) (likelihood was **Low**), the resulting impact intensities and impact consequences were **Negligible** and **Low**, respectively. Hence, the impact significance was **Minor**.

7.9.3 Fauna

Please refer to Appendix I for the full list of Priority level, impact intensity, impact consequence, impact likelihood, as well as the resulting impact significance for each faunal species receptor.

Mt. Imbiah Study Area

Birds

Minor impacts were expected to all bird species in the Mt. Imbiah Study Area. This is because there is little direct loss of habitat for the birds and they are likely still able to use alternative habitats around the construction areas. Moreover, the three bird species of high ecological value (**Priority 1**) are highly volant, disturbance tolerant and have adapted to parkland habitats, **Minor** impacts were expected for these species for the loss of connectivity, injury or mortality, light and human disturbances.

Bats

The bamboo bat recorded during our surveys could only be narrowed down to the genus *Tylonycteris*. There are two species of bamboo bats present in Singapore. The lesser bamboo bat (*Tylonycteris fulvida*) is nationally Critically Endangered while the greater bamboo bat (*Tylonycteris malayana*) is not assessed. Bamboo bats were not identified to species level due to difficulty in field identification. They were recorded visually or acoustically around one bamboo cluster at the Mt. Imbiah Study Area. This bamboo cluster at the Mt. Imbiah Study Area lie within construction site. As the habitat for bamboo bats are cleared, there would be **Major** impacts during the construction phase. During construction phase, generation of noise, and dust were expected at a distance from daytime activities. However, moderate levels of increase in noise, and dust generation were expected (refer to the Section 8 and Section 9 on Airborne Noise and Air Quality respectively). The bamboo bats may also be susceptible to noise and light disturbance as it is nocturnal, the disturbance may cause them to abandon their roost site. Thus,

the impact significance from habitat loss and injury or mortality were regarded as **Major**. While **Moderate** impacts from impediment to faunal movement, light, noise and human disturbances were expected for the bamboo bats (refer to Section 8 on Airborne Noise).

The other species of bat that is of high ecological value (**Priority 1**) is the nationally Endangered black-bearded tomb bat (*Taphozous melanopogon*). As this species is adaptable to urban areas, they are not as sensitive to loss of habitats, loss of connectivity and human disturbances. Thus, **Minor** impacts were expected for this bat species.

Mt. Serapong Study Area

Birds

Similar to the Mt. Imbiah Study Area, there is little loss of habitat due to the construction works. Thus, **Minor** impacts were expected for all bird species within the study area. Amongst all the birds of high ecological value, the red-legged crane (*Rallina fasciata*) found in the Mt. Serapong Study Area is shy, hence **Moderate** impact was expected for this species for the loss of connectivity, light and human disturbances. It is also more ground-dwelling in habitats, making them more susceptible to roadkills and injury or mortality from construction activities. Thus, the **Moderate** impact was expected for injury or mortality for the red-legged crane. The remaining two species of high ecological value (**Priority 1**) are highly volant, disturbance tolerant and have adapted to parkland habitats, **Minor** impacts were expected for these species for the loss of connectivity, injury or mortality, light and human disturbances.

Mammals (non-volant)

The long-tailed macaque (*Macaca fascicularis*) is globally Vulnerable. This species was recorded within the Mt. Serapong study area and locally common. This species was considered susceptible to roadkills and injury or mortality from construction activities. Impact significance was expected to be **Major** for injury or mortality. However, as they highly adaptable to urban environment and human presence, the impact significance was expected to be **Minor** or **Negligible** for loss of habitats and food sources, loss of ecological connectivity for faunal movement, light and human disturbances.

Mammals (bats only)

The same two bat species of high ecological value recorded in the Mt. Imbiah Study Area were recorded at the Mt. Serapong Study Area as well. However, the bamboo bats (*Tylonycteris* sp.) were detected acoustically along the transect in the latter. There were three bamboo clusters along the Mt. Serapong Study Area that were identified as potential roosting sites for the bamboo bats, but they were not recorded around these bamboo clusters. Moreover, these three bamboo clusters are not within the construction sites. Thus, for the Mt. Serapong Study Area, the impact for loss of habitat was assessed to be **Negligible**. However, moderate levels of increase in noise, and dust generation were still expected (refer to the Section 8 and Section 9 on Airborne Noise and Air Quality respectively).. The bamboo bats may also be susceptible to noise and light disturbance as it is nocturnal, the disturbance may cause them to abandon their roost site in seek of a new roost. Thus, the impact significance impediment to faunal movement, light, noise and human disturbances were expected to be **Moderate** for the bamboo bats (refer to Section 8 on Airborne Noise).

Similarly, the nationally Endangered black-bearded tomb bat (*Taphozous melanopogon*) was recorded multiple times along the road at the Mt. Serapong Study Area. This species is adaptable to urban areas, such as roads where they were recorded during the survey. Thus, there were **Minor** impacts expected for loss of habitats, loss of connectivity and human disturbances for this species.

7.10 Recommended Mitigation Measures

Mitigation measures stated here should be relevant for both study areas and enforced if applicable. Most of the mitigation measures stated have overlapping and cascading effects on other impacts. For example, reviewing the construction footprint primarily reduces working space and the need for vegetation removal. Subsequently, this would also reduce the effects of other potential impacts such as habitat degradation, mortality of flora and fauna, and decline in species fitness and survival etc. Therefore, the relevant mitigation measures proposed should be implemented as good practice even if the impacts were evaluated as insignificant (i.e., **Negligible** or **Minor**). The following mitigation measures were recommended for both the design and construction phases.

7.10.1 Design Optimization of the MH31 Worksite

Following the important finding of a bamboo cluster (*Thyrsostachys siamensis*) within the worksite for MH31 in the Mt. Imbiah Study Area which likely to be a roost site for bamboo bats, the footprint for the worksite at MH31 was reduced (Figure 3-2). The updated optimised worksite footprint was smaller than that of the original and aided in reducing the impacts of mortality on both the bamboo cluster as well as the associated bamboo bats.

7.10.2 Habitats

Elimination/ Avoidance (Design Phase)

- Shift or reduce the areas of worksites to avoid overlaps with habitats of high and moderate ecological value, such as the native-dominated secondary forest and mixed forest, onto concrete roads/pavements or roadside turf.
- Enhance the areas with landscaping as much as possible during the stage for reinstatement to increase connectivity and facilitate movement of fauna among the green patches. The following recommendations for landscaping could be adopted:
 1. Plant keystone species such as fig trees. Fig plants have uncoordinated fruiting periods but fruit abundantly when in season. Thus, they are important food sources for avian fauna and small mammals.
 2. Increase vertical vegetation structures (i.e., ground cover, shrub, understorey and canopy layers) and forms (e.g., epiphytes, shrubs, ferns, trees).
 3. Use a native plant palette.
 4. Select a diversity of flowering and fruiting plant species, including butterfly- and bird-attracting plant species. The palette selected species should preferably flower or fruit throughout the year so as to continuously attract pollinators such as butterflies, bees, and wasps, which contribute to the forest ecosystems and services.
 5. Prioritise intensive greening along streets or in areas with low disturbances (e.g., low traffic volumes and speeds, low human activities).

Elimination/ Avoidance (Construction Phase)

- Ensure there are no works and disturbances to areas outside of the worksites, especially into areas of high conservation value as shown in Section 7.10.
- Ensure any associated slope stabilisation and grading works will not impact topography of areas outside the worksites as well as water quality and hydrology of the waterbodies within the study areas.

7.10.3 Flora

Elimination/ Avoidance (Design Phase)

- Shift or reduce the areas of worksites in which plant specimens of high ecological value were found (refer to Section 7.10.1).

Elimination/ Avoidance (Construction Phase)

- Consider engaging arborists, and flora and fauna specialists to clearly mark out areas and plants of conservation value before the start of works. This would minimise working space, reduce disturbance to adjacent forested areas, and eliminate the need to remove specimens of value as much as possible.
- Establish proper TPZs around bamboo clusters to ensure they are adequately protected. This would eliminate the need to remove them as they are potential roosting sites for the nationally threatened bamboo bats (*Tylonycteris* sp.).

Minimisation (Substitution) (Construction Phase)

- Transplant or harvest trees/saplings of conservation significance if they are to be removed within the worksites.
- Erect TPZs to prevent encroachment of construction activities and excessive vegetation clearance around trees to be retained (if any).

Minimisation (Engineering Controls) (Construction Phase)

- Conduct regular inspections to ensure compliance on part of the contractors and identify any potential/ on-going impacts to the adjacent forested areas.

7.10.4 Fauna

Elimination/ Avoidance (Construction Phase)

- Avoid felling trees and clearing vegetation during the peak bird breeding season (March to July).
- Restrict working hours to between 0800–1800h (recommended for worksites near Nature Areas, i.e. MH17, MH18, MH22, MH29, MH30, MH31). Any level of artificial light above that of moonlight masks the natural rhythms of lunar sky brightness and may disrupt patterns of foraging, mating, as well as the circadian rhythm [P-56]. Artificial lighting at night (ALAN) could disorient birds, bats, and insects, altering their behaviours that cause them to become more vulnerable to predation and other risks [P-57]. For example, ALAN may repel light-adverse bats from lit areas and restrict their use of commuting or feeding space.

Minimisation (Substitution) (Construction Phase)

- Carry out wildlife shepherding via directional clearing as opposed to the usual site clearance. This entails clearing the site from built-up areas towards forested refuge areas so as to prevent ground-dwelling mammals from getting trapped in isolated forest patches. This should be planned and overseen by an ecologist.
- Conduct pre-felling inspections of fauna, active nests (with or without eggs), etc. before felling any trees or removing any vegetation. This should be planned and overseen by an ecologist.
- Use quieter construction machinery/equipment as opposed to loud and noisy machinery/equipment whenever possible.
- Restrict food consumption near and within the worksite for MH18 to specified rest areas to minimise potential human-wildlife conflicts, especially with the troop of long-tailed macaques in the area.

Minimisation (Engineering Controls) (Construction Phase)

- Erect hoardings along the roads at work sites to minimise roadkill accidents.
- Adopt road calming measures such as speed bumps, and other mitigation measures such as restriction on speed of vehicles and working time, to minimise roadkill accidents.
- Retain ground cover for as long as possible before removal. When ground cover is removed, earth control measures (ECM) are to be in place. Use only fully biodegradable erosion control blankets (ECB) to avoid trapping fossorial fauna, such as snakes.
- Train site personnel on biodiversity awareness and actions to take when encountering wildlife.
- Execute the fauna response and rescue protocol if any fauna is found on-site.
- Monitor the water quality and aquatic faunal community in retained streams and streams adjacent to the construction areas (if any).
- Ensure silt fences or other silt control measures along the site hoarding are installed and properly maintained.
- Practise due diligence in proper storage and handling of machinery to prevent leaching of oil or harmful materials, such as bentonite slurry, especially into waterbodies.
- Engage a Qualified Erosion Control Professional (QECP) to formulate and implement the ECM plans in accordance with the requirements slated by the PUB.
- Implement dust control measures, such as installing dust screens and water suppression systems.
- Implement acoustic barriers to reduce noise pollution outside worksites.
- Use low vibration equipment and construction techniques.
- Conduct regular site inspections to ensure contractor compliance and to identify potential fauna entrapments.
- Adopt the following framework if night works cannot be avoided:
 1. Prevent areas from being artificially lit; lighting should be installed only when necessary;
 2. Limit the duration of lighting and minimise the overlap with periods with peak nocturnal faunal activities;

3. Reduce the trespass of lighting by using minimal number of luminaires, positioning the light sources at low positions relative to the ground, directing and shielding the area to minimise light spills into the adjacent habitats while having the necessary lighting levels for working safely (Figure 7-41). Accessories such as baffles, hoods or louvres can be used to reduce light spill and direct light only to where it is needed;
4. Use warm colour temperature light sources, preferably at < 2,700 K;
5. Set dark buffers, zonation and illuminance limits of < 100 lux to minimise effects on animal behaviour due to light pollution [R-1];
6. Employ species-specific strategy; and
7. Minimise noise levels at night (see Section 8).



Figure 7-41 (A) Low Level Bollards Directed downwards and Shielded to Limit Lighting to Only the Area Intended; (B) Combined Effects of Shielded Luminaires and Short Poles on Reducing Light Trespass (Top: Unshielded Luminaires; Middle: Luminaires with Shield; Bottom: Shielded Luminaires on Short Poles which Cut-Off Light Trespass and Keep Adjacent Areas Dark)

7.11 Residual Impacts

7.11.1 Habitats

In the assessment of ecological impacts for the selected sensitive habitat receptors, the impact significance was evaluated to be **Moderate** for both the mixed forest as well as scrubland and herbaceous vegetation in the Mt. Imbiah Study Area and **Moderate** for the mixed forest in the Mt. Serapong Study Area before mitigation measures were theoretically implemented.

As the moderate level impacts were a result of loss of vegetation, the appropriate mitigation measure to implement would be to reduce or shift the areas of worksites such that they do not overlap with the high-valued habitats (refer to Section 7.10.2 for the detailed recommended mitigation measures) at the design phase. This can be done by utilising the space where there are concrete roads/pavements or roadside turf, as opposed to forested areas.

Following the implementation of these measures, the impact intensity of loss of vegetation would be reduced to **Negligible** and the impact consequences would be reduced to **Very Low** while the likelihood would be reduced to **Unlikely** (assuming there were no overlaps between the worksites and habitats). This would result in an overall residual impact significance of **Negligible** for all three habitat types across both study areas (Appendix I).

7.11.2 Flora

In the ideal situation where the worksites could be shifted to be along concrete roads/pavements or roadside turf areas, the residual impacts for all flora and fauna were likely to be reduced to **Negligible** or **Minor**. Following the mitigation hierarchy, however, the next level of recommended mitigation measures have to be implemented if the assumption of the previous cannot be held true. In the assessment of residual impacts for both flora and fauna, the evaluation was carried out based on the next level of recommended mitigation measures in the mitigation hierarchy. This was applied for both plant and faunal species receptors in the two study areas.

Mt. Imbiah Study Area

For the 30 plant species recorded from the Mt. Imbiah Study Area and selected for the assessment of ecological impacts, the most severe impacts during the construction phase before mitigation measures were theoretically implemented were **Major** for two species and **Moderate** for nine species (Appendix I).

Following the implementation of mitigation measures, the impacts on these 11 plant species would, theoretically, be reduced to **Minor** for eight species and **Negligible** for three species.

Prior to the implementation of mitigation measures, the three species likely to experience **Moderate – Major** impacts owing to mortality comprised *Callerya atropurpurea* (**Moderate**), *Centotheca lappacea* and *Thyrsostachys siamensis* (**Major**). Erection of TPZs for the *C. atropurpurea* tree and *T. siamensis* bamboo, and transplantation of the herbaceous *C. lappacea*, were expected to result in **Negligible** residual impact intensities as the specimens would be shielded from construction activities or moved out of the worksite, respectively. Mortality is therefore unlikely to occur but is still a possibility given that the specimens may be unable to cope with the change in microclimatic conditions inside the TPZs if the surrounding plants are removed; or if transplanted, may be unable to withstand the transplant shock. With the impact intensity reduced to '**Negligible**' and likelihood to '**Less Likely**', the impact significance was therefore **Negligible**.

Prior to the implementation of mitigation measures, the eight species likely to experience **Moderate** impacts owing to impediment to seedling recruitment, competition from exotic species, and decline in plant health and survival comprised *Derris amoena* var. *maingayana*, *Ficus kerkhovenii*, *Ficus vasculosa*, *Planchonella obovata*, *Samanea saman*, *Sterculia parvifolia*, *Streblus elongatus* and *Syzygium grande*. Monitoring for any decline in plant health as well as the introduction of exotic species should be carried out with the following courses of action: retention onsite if they appear to be coping well, or transplantation if otherwise. These measures were expected to keep residual impact intensities unchanged at medium or high, but the likelihood was reduced to '**Less Likely**' as monitoring was being carried out and with intervention measures in place. The impact significance of the three aforementioned impact types was therefore reduced to **Minor**.

Mt. Serapong Study Area

For the 45 plant species recorded from the Mt. Serapong Study Area and selected for the assessment of ecological impacts, the most severe impacts during the construction phase before mitigation measures were theoretically implemented are **Major** for one species and **Moderate** for six species (Appendix I).

Following the implementation of mitigation measures, the impacts on these seven species would, theoretically, be reduced to **Minor** for one species and **Negligible** for six species.

Prior to the implementation of mitigation measures, the six species likely to experience **Moderate – Major** impacts owing to mortality comprised *Garcinia atroviridis* (**Major**), *Ficus vasculosa*, *Memecylon edule*, *Oncosperma tigilaria*, *Palaquium obovatum*, and *Planchonella obovata* (**Moderate**). With the appropriate mitigation measures discussed above for the Mt. Imbiah Study Area, i.e., set up TPZs (for trees) or transplant where suitable, the impact intensity would be reduced to '**Negligible**' and likelihood to '**Less Likely**'. This resulted in a **Negligible** impact significance for all six species.

Prior to the implementation of mitigation measures, the only species likely to experience **Moderate** impacts owing to impediment to seedling recruitment, competition from exotic species, and decline in plant health and survival was found to be *Glochidion zeylanicum* var. *zeylanicum*. Similar to what was discussed above for the Mt. Imbiah

Study Area, the impact significance of the three impact types would be reduced from **Moderate** to **Minor** if the recommended mitigation measures could be implemented.

7.11.3 Fauna

Mt. Imbiah Study Area

The most severe impact significance during the construction phase before mitigation measures were the impacts on the bamboo bat (*Tylonycteris* sp.). It was expected to have **Major** impact significance due to habitat loss and injury or mortality, and **Moderate** impact significance due to loss of ecological connectivity for faunal movement, light, noise and human disturbances. With the implementation of mitigation measures such as retaining the bamboo cluster through TPZs, the **Major** impact significance due to habitat loss and injury or mortality could be reduced to **Negligible** impact significance. On the other hand, despite the implementation of mitigation measures such as sound and dust controls, the impact significance from impediment to faunal movement, light, noise and human disturbances remained as **Moderate**. This is because there is limited information on how sensitive the bamboo bats (*Tylonycteris* sp.) are in response to disturbances in their surrounding environment; thus, they may still be affected even after the mitigation measures are implemented.

Mt. Serapong Study Area

Birds

The most severe impact significance during construction phase before mitigation measures were **Moderate** impacts on the red-legged crane (*Rallina fasciata*) for injury or mortality, loss of connectivity, light and human disturbances. With the implementation of mitigation measures (such as regular inspections and control measures), the **Moderate** impact significance could be reduced to **Minor**.

Mammals (non-volant)

The **Major** impact for injury or mortality of the long-tailed macaque (*Macaca fascicularis*) could be reduced to **Moderate** impact with the implementation of suitable mitigation measures, such as training site personnel on biodiversity awareness and adopt traffic calming measures.

Mammals (bats only)

The most severe impact significance during the construction phase before mitigation measures were the impacts on the bamboo bat (*Tylonycteris* sp.). It was expected to have **Moderate** impact significance due to impediment to faunal movement, light, noise and human disturbances. With the implementation of mitigation measures such as sound and dust control, the **Moderate** impact significance due to impediment to faunal movement, light, noise and human disturbances remains as **Moderate**, for reasons similar to what was described for the Mt. Imbiah Study Area.

7.12 Summary of Key Findings

Mt. Imbiah Study Area

There are five habitat and vegetation types present at the Mt. Imbiah Study Area, namely, (1) native-dominated secondary forest, (2) mixed forest, (3) scrubland and herbaceous vegetation, (4) managed vegetation, and (5) others (infrastructure). Native-dominated secondary forest was observed to be the largest habitat type in the study area. A total of 172 plant species and species groups represented by 68 families were recorded, of which 31 were considered of conservation significance. Twenty-three large specimens and one other plant specimen of value (a *Thyrsostachys siamensis* bamboo cluster of 2 m spread) were recorded. Thirty-five species of fauna were recorded, with nearly two-thirds of the recorded assemblage dominated by bird species (22 species) and four species of conservation significance.

In the assessment of ecological value, four habitat types found in the Mt. Imbiah Study Area were evaluated: one is of high ecological value (native-dominated secondary forest), two are of medium ecological value (mixed forest as well as scrubland and herbaceous vegetation), and the last is of low ecological value (managed vegetation). For plant species receptors, 172 species were assessed: 46 are of high value, 55 of medium value, and 71 of low value. For faunal species receptors, 41 species were assessed and five are of high value.

In the evaluation of impacts for the biodiversity sensitive receptors, the three habitat types with **Moderate – High** ecological value were evaluated: the impact significance was **Moderate** for both the mixed forest as well as scrubland and herbaceous vegetation, and **Minor** for the native-dominated secondary forest. For plant species receptors, 30 species were evaluated: the impact significance was **Major** for two plant species, **Moderate** for nine plant species, and **Minor** for the remaining 19 plant species. For faunal species receptors, five species were evaluated: the impact significance was **Major** for one species (bamboo bat) and **Minor** for four species (the Oriental pied hornbill, red junglefowl, blue-crowned hanging parrot, and black-bearded tomb bat).

Following the implementation of mitigation measures, the residual impact significance for the mixed forest as well as scrubland and herbaceous vegetation (both with originally **Moderate** impact significance) was reduced to **Negligible**. For the 11 plant species with the original **Major** (two) and **Moderate** (nine) impact significance, the residual impact significance was reduced to **Minor** (eight) and **Negligible** (three). For the only faunal species (bamboo bat) originally with **Major** impact significance, the residual impact significance was reduced to **Moderate**.

Mt. Serapong Study Area

The Mt. Serapong Study Area comprises two vegetated areas located on either side of Woolwich Road, collectively comprising six habitat and vegetation types: (1) native-dominated secondary forest, (2) mixed forest, (3) scrubland and herbaceous vegetation, (4) managed vegetation, and (5) waterbodies, and (6) others (infrastructure). Native-dominated secondary forest was found to be the largest habitat type in the study area. A total of 194 plant species and species groups across 77 families were found, of which 49 were considered of conservation significance. Twenty-nine large specimens (two of which are heritage trees) and one other plant specimen of value (a *Bambusa vulgaris* bamboo cluster of 1 m spread) were recorded. Sixty species of fauna were recorded, with about a half of the recorded assemblage dominated by bird (32 species) and five species of conservation significance.

In the assessment of ecological value, five habitat types found in the Mt. Serapong Study Area were evaluated: one is of high ecological value (native-dominated secondary forest), two are of medium ecological value (mixed forest as well as scrubland and herbaceous vegetation), and the remaining two are of low ecological value (managed vegetation and waterbody). For plant species receptors, 192 species were assessed: 60 plant species were assessed to be of high ecological value, 60 of medium value, and 72 of low value. For faunal species receptors, 78 species were assessed and six are of high value.

In the evaluation of impacts for the biodiversity sensitive receptors, the three habitat types with **Moderate – High** ecological value were evaluated: the impact significance for mixed forest was **Moderate**, while that for native-dominated secondary forest as well as scrubland and herbaceous vegetation was **Minor**. For plant species receptors, 45 species were evaluated: the significance of the impacts was **Major** for one species, **Moderate** for six species, and **Minor** for the remaining 38 species. For faunal species receptors, six species were evaluated: the significance of the impacts was **Major** for one species (long-tailed macaque), **Moderate** for two species (red-legged crane and bamboo bat), and **Minor** for three species (Oriental pied hornbill, changeable hawk-eagle, and black bearded tomb bat).

Following the implementation of mitigation measures, the residual impact significance for the mixed forest (originally **Moderate** impact significance) was reduced to **Negligible**. For the seven plant species with the original **Major** (one) and **Moderate** (six) impact significance, the residual impact significance was reduced to **Minor** (one) and **Negligible** (six). For the faunal species (long-tailed macaque) originally with **Major** impact significance, the residual impact significance was reduced to **Moderate**. For the two faunal species originally with **Moderate** impact significance, the residual impact significance was reduced to **Minor** for the red-legged crane while the residual impact significance remained at **Moderate** for the bamboo bat.

8. Airborne Noise

8.1 Introduction

This section presented the detailed assessment of airborne noise impacts from the construction of the Project to the identified ecologically sensitive receptors and human receptors. Noise from construction activities might be perceivable, especially to receptors in proximity and those having a direct line-of-sight to the noise sources from the study areas. The key steps for conducting the noise impact assessment were listed as follows:

- Review baseline noise monitoring data to assess the current baseline noise level in the study area;
- Identify and classify the sensitivity of the receptors surrounding the study area;
- Conduct noise impact assessment to quantitatively assess noise impacts during the construction phase;
- Recommend minimum control and mitigation measures to be implemented; and
- Determine the overall significance of the residual noise impacts after the implementation of the mitigation measures.

8.2 Methodology and Assumption

The sections below outlined the methodology used in the noise impact assessment for the construction phase of the Project.

8.2.1 Study Area

The study area for airborne noise impact assessment was recommended as 150 m from the construction worksites in accordance with the *Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2008* [R-18] for the impacts on ecologically sensitive receptors (ESRs) and human receptors. To determine the areas which are sensitive to potential impacts from the construction phase, an initial screening of sensitive receptors was conducted during the scoping phase.

As documented in the Inception Report [G-1], the study area for ESRs were screened for the above-ground construction worksites and their corresponding 150m buffer areas that were located at or in the vicinity of the Nature Areas (Mt. Imbiah and Mt. Serapong) and the connected forested habitats within the defined biodiversity study areas, i.e. MH1, MH2, MH16, MH17, MH18, MH19, MH20, MH21, MH22, MH28, MH29, MH30, MH31 and MH32 worksites. Representative ESRs were selected based on their proximity to the worksites to represent the potential airborne noise impacts on the ESRs as reflected in Figure 8-2. Whereas, human receptors would include buildings that were identified to be situating within 150 m of the construction worksites as reflected in Figure 8-2.

8.2.2 Baseline Airborne Noise Study

Baseline noise monitoring was used to establish the existing noise levels in the study areas. Site reconnaissance was conducted on 20 November 2020 for up to 150 m from the construction worksite areas of the 40 manholes. A total of six (6) noise monitoring locations were proposed (at the Inception stage), based on the following considerations:

- Identification of noise sensitive receptors (NSRs) (hospitals, schools, childcare facilities, old age homes, residences, fauna and habitats of high ecological value) within the defined study area for airborne noise impact;
- Elimination of other NSRs away from the construction worksites, as these receptors were assumed to be barricaded by the first row of buildings;
- Avoidance of NSRs with areas having ongoing construction;
- Exclusion of NSRs where the owner denied permission during site walkover;
- Selection of the NSR closest to the construction worksites; and
- Conduct of noise monitoring at different floor heights (e.g., mid-level, top level) for a high rise residential sensitive receptor. This was targeted to capture the terrain variation and its impact on noise levels.

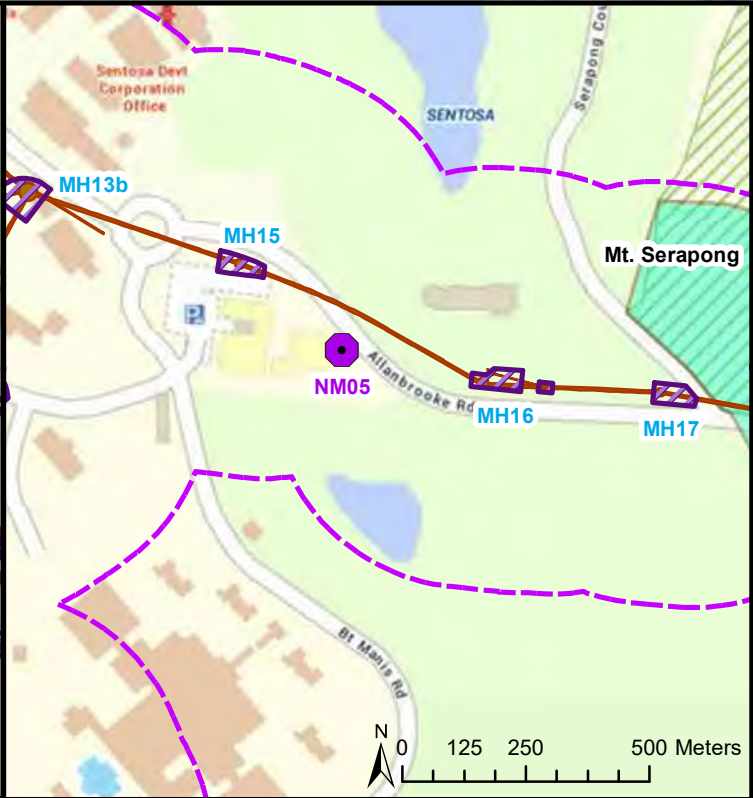
The noise monitoring locations were detailed in Table 8-1 and reflected in Figure 8-1. Noise monitoring was conducted for one week (weekdays and weekends) to capture baseline noise levels over periods of 12 hours (long term), 1 hour, and 5 minutes (short term) at each location. The NEA-approved Norsonic 131 Type 1 Sound Level Meter (SLM) was used to record the noise levels during the time periods. The method and results were detailed in the baseline noise monitoring report in Appendix J and would be further discussed in Section 8.5.

Table 8-1 Proposed Baseline Noise Monitoring Locations

Monitoring Location	Nearest Construction Worksite Area	Sensitivity of Receptor at Monitoring Location		Justification	Photo of Monitoring Location
		Ecologically Sensitive Receptors	Human Receptors		
NM01: Near Nestopia at Siloso Beach Walk	MH1 Worksite (Mt. Imbiah)	Priority 1, 2, 3 (dependent on species sensitivity)	Commercial & Residential	The area near Nestopia at Siloso Beach Walk was selected as a representative baseline noise monitoring location for the beach environment along Sentosa's beaches, where the proposed MH1 worksite would be located nearby. The purpose of assessing the baseline noise levels at this location was to determine the noise criteria for noise impact assessment of proposed worksites located in a similar beach environment at the west-southern side of Sentosa Island.	
NM02: Near Imbiah Lookout Station at Sentosa Island	MH32 Worksite (Mt. Imbiah)	Priority 1, 2, 3 (dependent on species sensitivity)	Commercial & Residential	The area opposite to the Imbiah Lookout Station was selected as a representative baseline noise monitoring location of the natural environment and human activities near Mt. Imbiah, where the MH32 worksite would be located nearby. The purpose of assessing the baseline noise levels at this location was to determine the noise criteria for noise impact assessment of proposed worksites near both natural environment and entertainment facilities at the western side of Sentosa Island.	

Monitoring Location	Nearest Construction Worksite Area	Sensitivity of Receptor at Monitoring Location		Justification	Photo of Monitoring Location
		Ecologically Sensitive Receptors	Human Receptors		
NM03: Near Amara Sanctuary Resort Sentosa	MH26 Worksite	NA.	Commercial & Residential	The area near the road entrance to the Amara Sanctuary Resort was selected as a representative baseline monitoring location of the hotel area (e.g. The Barracks Hotel, Village Hotel, Outpost Hotel) in the central of Singapore where entertainment facilities (e.g. Universal Studios Singapore, etc.) were in the vicinity. The nearest construction worksites would be the proposed MH25a, MH25b and MH26 worksites. The purpose of assessing the baseline noise levels at this location was to determine the noise criteria for noise impact assessment of proposed worksites under a mixed development environment dominated by short-term residential and entertainment activities in the central of Sentosa Island.	
NM04: Near Palawan Beach and Opposite Capella Singapore	MH10 Worksite	NA.	Commercial & Residential	The area along Palawan Beach Walk with Capella Singapore overlooking the area from above was chosen as a representative baseline noise monitoring location for the beach environment along Sentosa's beaches, where the proposed MH10 worksite would be located nearby. The purpose of assessing the baseline noise levels at this location was to determine the noise criteria for noise impact assessment of impacts arising from construction works at MH10 to the residents in Capella Singapore. This could also serve as a reference for other worksites along the southern beaches in Sentosa Island.	

Monitoring Location	Nearest Construction Worksite Area	Sensitivity of Receptor at Monitoring Location		Justification	Photo of Monitoring Location
		Ecologically Sensitive Receptors	Human Receptors		
NM05: At roadside behind Islander Pre-School	MH15 and MH16 Worksite (Mt. Serapong)	Priority 1, 2, 3 (dependent on species sensitivity)	Commercial & Educational Institution	The area behind Islander Pre-School was chosen as a representative baseline noise monitoring location within the study area due to the nature of the establishment and its proximity to MH15 and MH16 worksites. The purpose of assessing the baseline noise levels at this location was to determine the noise criteria for noise impact assessment of impacts arising from construction works from the proposed worksites on receptors of educational uses.	
NM06: Opposite Lakeshore View residence along Ocean Drive and near Sentosa Cove Village Car Park	MH22 Worksite (Mt. Serapong)	Priority 1, 2, 3 (dependent on species sensitivity)	Commercial & Residential	The area near Lakeshore View residence was chosen as a representative baseline noise monitoring location for the residential-dominant development (e.g. Sentosa Cove houses, shops and recreational facilities, etc.) at the eastern side of Sentosa, where the proposed MH22 worksite would be located nearby. The purpose of assessing the baseline noise levels at this location was to determine the noise criteria for noise impact assessment of proposed worksites under a mixed development environment dominated by long-term residential and recreational activities in the eastern side of Sentosa Island.	



Legend

- Baseline Airborne Noise Monitoring Location
- Construction Worksites
- DGS Manholes & Pipeline
- Nature Areas
- Biodiversity Study Area for Mt. Imbiah and Mt. Serapong
- Study Area (150m)

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A	AUG 2021	SYT	Final Report Rev A	JAG/NHT	JAG
-	MAY 2021	SYT	Final Report	JAG/NHT	JAG
Rev.	Date	By	Description	Chk'd	App'd

Qualified Person Endorsement :
NA

Client Endorsement :
NA

Consultant :
AECOM

Project Title :
**Contract No. SDC/21.8.2/19:
Environmental Study
For The Proposed Deep Gravity
Sewer Project at Sentosa**

Designed
SYT

Checked
JAG/NHT

Approved
JAG

Figure Title :
**Baseline Airborne Noise
Monitoring Locations**

Figure No. :
8-1

Rev.
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1 of 1

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8.2.3 Classification of Noise Sensitive Receptors

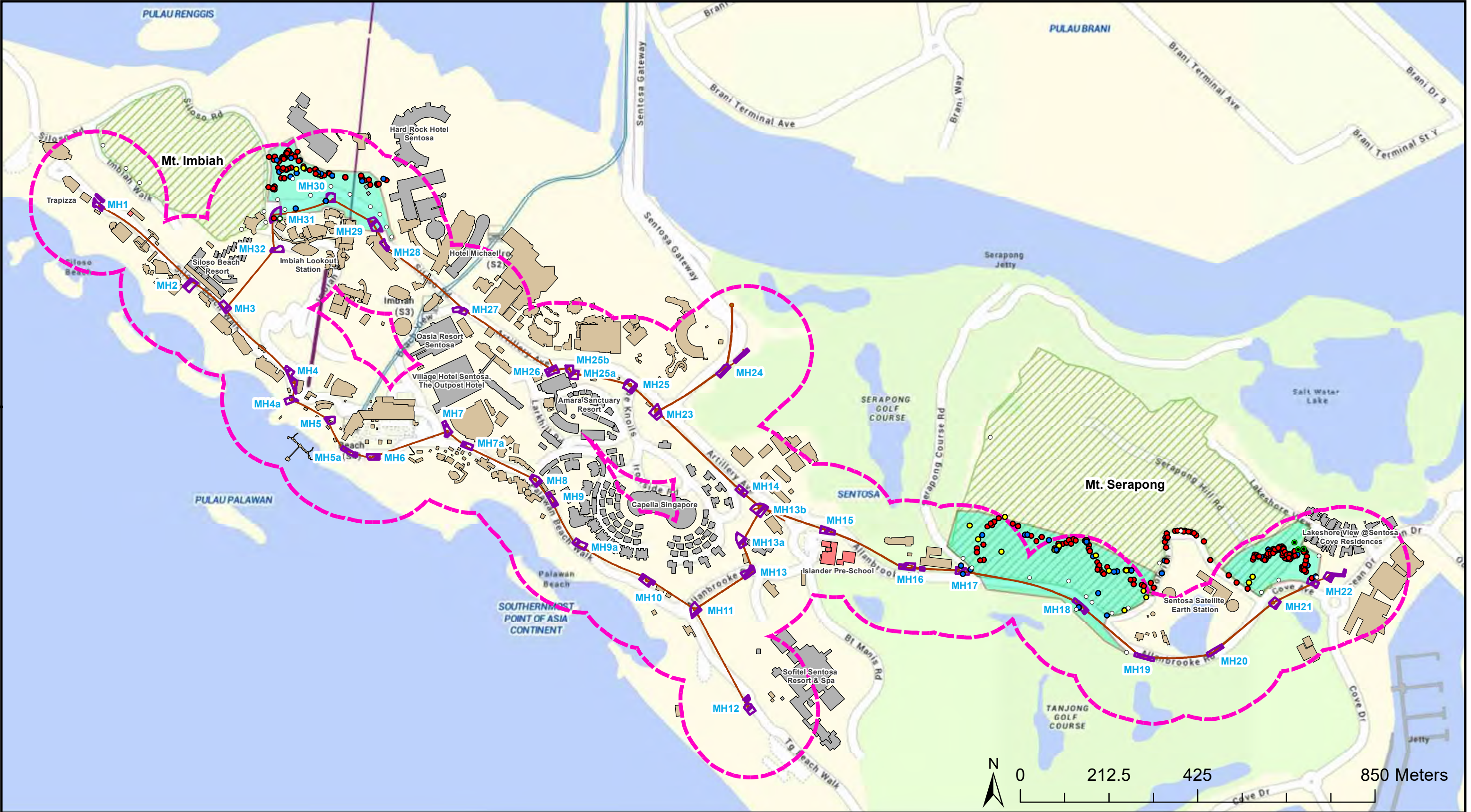
The classification of both ecologically sensitive and human receptors was described as follows and visualized in Figure 8-2. Further discussion on the identification of noise sensitive receptors was detailed in Section 8.4.

Ecologically Sensitive Receptors

Based on the assessment methodology in Table 6-1, the classification of ecologically sensitive receptors was conducted based on the auditory sensitivity of the respective species. Species that use sound for communication, foraging and breeding or are known to have their behaviours disrupted by sound, thus was assigned Priority 1 status due to their auditory sensitivity. Species that are less affected by airborne noise and/or of Conservation Significance was assigned as Priority 2. While species that less affected by airborne noise and are not of Conservation Significance was assigned as Priority 3.

Human Receptors

As an initial step towards baseline noise impact assessment for the construction phase, buildings within the 150 m study area from the construction worksites were analysed. This was conducted in accordance to the *Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2008* [R-18] (refer to Section 6.2.1). There are three classifications (namely Priority 1, Priority 2, Priority 3) of human noise sensitive receptors which relates to the nature of the establishment, be it educational institution, residential space, commercial or industrial space and so on, as described in Table 6-1. In this Environmental Study, commercial space which consisting of hotels and villas was defined as residential space and was assessed accordingly to this definition.



Legend

- Base Construction Worksites
- DGS Manholes & Pipeline
- Nature Areas
- Biodiversity Study Area for Mt. Imbiah and Mt. Serapong
- Bamboo Clusters
- Study Area (150m)

Noise Sensitive Receptors

Human Receptors

Receptor Sensitivity

- Priority 1
- Priority 2
- Priority 3

Ecologically Sensitive Receptors

Representative Ecologically Sensitive Receptors

- Auditory Sensitivity
 - Priority 1
 - Priority 2
 - Priority 3

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-	MAY 2021	SYT	Final Report	JAG/NHT	JAG	
Rev.	Date	By	Description	Chk'd	App'd	

Qualified Person Endorsement :
NA

Client Endorsement :
NA

Consultant :
AECOM

Project Title :
**Contract No. SDC/21.8.2/19:
Environmental Study
For The Proposed Deep Gravity
Sewer Project at Sentosa**

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	Drawn SYT	Date NOV 2021

Figure Title :
Noise Sensitive Receptors

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Source of basemap - OneMap

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8.2.4 Assessment Criteria

8.2.4.1 Ecologically Sensitive Receptors

The guidelines and standards used in this report to assess the construction noise impact on human receptors are the only noise standards and guidelines available as of current.

The ecological impacts from airborne noise are species dependent and hence the assessment was based on species identified during site surveys around the two Nature Areas, Mt. Imbiah and Mt. Serapong, as well as the connected forested habitat within the defined biodiversity study area (see Section 8.4.1) for airborne noise sensitive receptors to align with the biodiversity study in Section 7. Species which are noise sensitive are those that use noise, for example for their communication or identification of their way, at certain times of the day. Construction and noisy activities during their active times can cause interference with their day to day activities. Therefore, at these times, construction noise is curtailed beyond the human noise criteria.

As no guidelines or standards were available to assess construction noise impacts on the ecologically sensitive receptors (ESRs), the baseline monitoring results in the vicinity of the Nature Areas were applied to form the assessment criteria for the airborne noise impact assessment on ESRs. Unlike human receptors, baseline monitoring results were chosen as a basis of comparison for ESRs because fauna species face a direct form of impact, given that the habitats where they reside in are directly impacted by the noises emitted from the introduction of construction activities in the vicinity. Therefore, it is not advisable to adopt similar assessment criteria to human receptors where they operate in different nature.

For the purpose of noise impact assessment on ESRs in this Environmental Study, a criterion of no-worse-off than baseline was adopted in absence of adequate research data on criteria was applied to faunal receptors at the two Nature Areas (Mt. Imbiah and Mt. Serapong). This was further detailed in Section 8.5.3.1.

8.2.4.2 Human Receptors

The human receptors were categorised into their priorities based on the nature of the establishment, be it educational institution, residential space, commercial or industrial space etc. In this Environmental Study, commercial space which consisting of hotels and villas was defined as residential space and was assessed accordingly to this definition.

In determining the impact of the construction noise to sensitive receptors, the baseline noise levels detailed in Section 8.5 was included in the calculation to derive a background noise correction factor to establish the maximum noise level permitted from the construction activities in accordance to the *Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2008* [R-18]. It should be noted that airborne noise impacts will only occur from above-ground construction sites.

The legislative requirements for environmental noise in Singapore contain three parts which specify the applicable noise criteria for construction sites over different time periods. The corresponding maximum permissible noise criteria were provided in Table 8-2 to Table 8-4 for periods of different duration, defined as follows:

- $L_{Aeq(12 \text{ hour})}$ which refers to equivalent continuous noise level over a period of 12 hours;
- $L_{Aeq(1 \text{ hour})}$ which refers to equivalent continuous noise level over a period of 1 hour within a 24-hr period; and
- $L_{Aeq(5 \text{ min})}$ which refers to equivalent continuous noise level over a period of 5 minutes within a 24-hr period.

Table 8-2 Maximum Permissible Noise Levels for Construction Works over a Period of 12 hours

Types of Affected Buildings	Days of the week	Maximum Permissible $L_{Aeq(12 \text{ hour})}$, dB	
		7am – 7pm	7pm – 7am
(a) Hospitals, schools, institutions of higher learning, homes for the aged or sick etc.	All days	60	50
(b) Residential buildings located less than 150 m from the construction site where the noise is being emitted	All days	75	–

Types of Affected Buildings	Days of the week	Maximum Permissible $L_{Aeq}(12 \text{ hour})$, dB	
		7am – 7pm	7pm – 7am
(c) Buildings (other than those in paragraphs (a) and (b))	All days	75	65

Table 8-3 Maximum Permissible Noise Levels for Construction Works over a Period of 1 hour

Types of affected buildings	Days of the week	Maximum Permissible $L_{Aeq} (1 \text{ hour})$ (dB)		
		7am – 7pm	7pm – 10pm	10pm – 7am
(a) Hospitals, schools, institutions of higher learning, homes for the aged sick, etc.	Monday to Saturday	–	–	–
(b) Residential buildings located less than 150 m from the construction site where the noise is being emitted	Monday to Saturday	–	65	55
(c) Buildings (other than those in paragraphs (a) and (b))	Monday to Saturday	–	–	–

Table 8-4 Maximum Permissible Noise Levels for Construction Works over a Period of 5 minutes

Types of affected buildings	Days of the week	Maximum Permissible $L_{Aeq} (5 \text{ mins})$ (dB)		
		7am – 7pm	7pm – 10pm	10pm – 7am
(a) Hospitals, schools, institutions of higher learning, homes for the aged or sick etc.	All days	75	55	55
(b) Residential buildings located less than 150 m from the construction site where the noise is being emitted	Monday to Saturday	90	70	55
	Sunday and PH	75	55	55
(c) Buildings (other than those in paragraphs (a) and (b))	All days	90	70	70

As per legislation, if there are other sources of noise affecting the measurement of noise emitted from the construction site, the maximum permissible noise levels from construction sites will be subjected to adjustments by the addition of a correction factor to account for the existing background noise levels in the area. The correction factor corresponds to the difference between the relevant permissible levels, and the background noise level and was presented in Table 8-5. The difference in the noise levels were then added to the higher of the two noise levels (background noise/ criteria as appropriate to give the applicable noise criteria for the specified construction area).

Table 8-5 Construction Noise Correction Factor

Difference between Permissible & Background Noise Levels (dB(A))	Correction Factor to be Added to the Higher of the Two Noise Levels, (dB(A))
Below 2	3
2 to less than 4	2
4 to less than 10	1
10 and above	Nil.

8.2.5 Prediction and Evaluation of Impact Assessment

The airborne noise impact assessment included the evaluation of construction noise impact to the noise sensitive receptors (NSRs) (ecologically sensitive receptors i.e. fauna, and human receptors).

The study on the construction noise impact to NSRs were focused on the worst-case noisiest scenario for the construction activity that would be active during certain construction period according to the schedule provided by the Design Team (see Appendix L). It should be noted that for all construction activities involved, only “Pipe Jacking” would run throughout the day for 24 hours due to possible safety issues posed to the public at above-ground levels if segments of pipes jacked underground are incomplete. 24 hours pipe jacking would still subject to approval from SDC and Agencies. Within the “Pipe Jacking” activity, two (2) scenarios were considered to account for 24-hour Machine Operation and emergency situation which differs in the types of Powered Mechanical Equipment (PMEs) engaged as reflected in Appendix L. Neither of these two (2) scenarios are independent of the other and are mutually exclusive meaning, if Scenario 2a occurs, Scenario 2b will not occur vice versa. Apart from pipe jacking, other construction activities would only occur within the 7am – 7pm construction schedule for weekdays, in-line with SDC’s allowed construction work schedule of 8:30am – 6pm for weekdays.

Three (3) scenarios were focused for the study on construction noise impact on the NSRs, as follows:

- Scenario 1: Ground Improvement Work;
- Scenario 2a: Pipe Jacking.(24-hour Machine Operation); and
- Scenario 2b: Pipe Jacking (Emergency Situation).

These scenarios were selected as a conservative representation of the construction phase based on the worst-case scenario with the activities selected having the highest 12 hour and 5 min effective sound power level for 7am – 7pm for “Ground Improvement Work” for Weekdays, and the highest 12 hour, 1 hour and 5 min effective sound power levels for 7am – 7pm, 7pm – 7am, 7pm – 10pm and 10pm – 7am for “Pipe Jacking” emitted from the equipment during construction for Weekdays (excluding Day time 7am – 7pm), and Weekend/ Public Holidays (refer to Table 8-6 and Appendix L).

It was assumed that within the scenarios, the works would be carried out at the same time between the different worksites. The intent of selecting these three (3) worst-case scenarios was such that if noise could be controlled in these scenarios by permanent features during the entire construction, the noise from other less noisy phases would also be mitigated.

For the assessment of noise impacts of the construction phase, the prediction of the noise levels generated from the equipment used during construction, detailed in Section 8.3, was predicted using SoundPLAN ver 8.2. Where pockets of topography were not available, a flat terrain based on the nearest spot height from the topography survey was taken within the study area. A quantitative prediction of noise impact to the NSRs (within the 150 m study area) was carried out and compared with the stipulated *Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2008*. Noise contours were provided to the extent where topography was available.

As detailed in the assessment methodology (see Section 6.4.2), NSRs were first identified and classified by the nature of the receptors as reflected in Table 6-1. Then, Impact Intensity was determined by the magnitude of noise exceedances predicted as reflected in Table 6-4. By considering both Impact Intensity and Receptor Sensitivity, Impact Consequence could be obtained as per the matrix in Table 6-5. Thereafter, Likelihood of the impact from the construction activities of this Project were calculated based on the percentage of the duration of the activity over the construction timeline at the worksite (e.g. an activity happening < 5% of the construction timeline at the

worksite, resulting in Unlikely/ Remote for Likelihood) as shown in Table 6-6. By relating both Impact Consequence and Likelihood of Occurrence, the Impact Significance of airborne noise impacts were predicted with the consideration of minimum control measures (see Section 8.6). Further analysis and evaluation were then conducted to recommend additional mitigation measures (e.g. noise barriers, etc.) where necessary. At the end a monitoring plan was established and triggers for action determined so that the impacts could be controlled within acceptable limits or as low as reasonably practicable.

8.3 Potential Sources of Airborne Noise Impacts and Likelihood of Impacts

This section discussed the potential equipment and activities which could contribute to noise impacts during the construction phase of the Project. The main source of noise was identified to be from the Powered Mechanical Equipment (PMEs) used for construction works. The PMEs and their respective sound power levels used in this study were listed in Appendix K.

Based on the construction programme proposed by SDC, the manhole worksites (MH1 to MH32) would follow a cut and cover construction method where caisson shafts would be constructed at each manhole worksite. For the construction of the DGS pipeline itself, pipejacking method would be implemented as described in Section 3.3.2.3. The summary of the proposed construction activities was provided in Table 8-6 below. The detailed list of equipment inventory associated with these construction activities could be found in Appendix L.

As mentioned in Section 8.2.4, the construction phase was modelled as a result of the construction activities expected to occur at the worksites. The activities chosen for assessment was based on the worst-case scenarios with the highest overall sound power level of the construction phase (refer to Appendix L for list of overall sound power level of the activities). Based on the effective sound power level generated from the construction worksites as summarized in previous Table 8-6, the three (3) worst-case scenarios' noise levels applied for construction noise modelling was shown in Table 8-7 below.

Table 8-6 Effective Sound Power Level (Construction Phase)

Construction Activity	Effective Sound Power Level L_{WA} , dB(A) from overall equipment inventory							
	L_{Aeq} (12 hour)		L_{Aeq} (1 hour)			L_{Aeq} (5 min)		
	7am - 7pm	7pm - 7am	7am - 7pm	7pm - 10pm	10pm - 7am	7am - 7pm	7pm - 10pm	10pm - 7am
Site Clearance for Construction	109		NA.			113		
Preparation for Jet Grouting Works (to produce grout mix)	110		NA.			111		
Ground Improvement Work	110		NA.			116		
Installing/ Removing sheet pile [#]	96		NA.			101		
Shaft Construction	110		NA.			113		
Pipe Jacking (24-hour Machine Operation)	95	89	NA.	89	89	98	89	89
Pipe Jacking (Emergency Situation)	95	89	NA.	92	92	98	92	92
Manhole Construction	105		NA.			111		
Note: NA. – Not Applicable as there is no assessment criteria for this time phase. [#]Installing/ Removing sheet pile may be required and will subject to ground conditions during the actual construction. Only pipe jacking was considered for night-works from 7pm – 10pm and 10pm – 7am. As such, grey cells reflect blank inputs for other construction activities that were not considered for night-time construction.								

Table 8-7 Effective Sound Power Level (Noise Model Input)

Scenario/ Worksite	Effective Sound Power Level L_{wA} , dB(A) used in the Noise Model							
	L_{Aeq} (12 hour)		L_{Aeq} (1 hour)			L_{Aeq} (5 min)		
	Day Time (7am - 7pm)	Night Time (7pm - 7am)	Day Time (7am - 7pm)	Evening Time (7pm - 10pm)	Night Time (10pm - 7am)	Day Time (7am - 7pm)	Evening Time (7pm - 10pm)	Night Time (10pm - 7am)
Scenario 1: Ground Improvement Work (From Table 8-6 Ground Improvement Work)								
All Construction Worksites (see Figure 8-3)	110		NA.			116		
Scenario 2a: Pipe Jacking (24-hour Machine Operation) (From Table 8-6 Pipe Jacking (24-hour Machine Operation))								
All Construction Worksites (see Figure 8-3)	95	89	NA.	89	89	98	89	89
Scenario 2b: Pipe Jacking (Emergency Situation) (From Table 8-6 Pipe Jacking (Emergency Situation))								
All Construction Worksites (see Figure 8-3)	95	89	NA.	92	92	98	92	92
<i>Note: NA. – Not Applicable as there is no assessment criteria for this time phase.</i> <i>*Installing/ Removing sheet pile may be required and will subject to ground conditions during the actual construction.</i> <i>Only pipe jacking was considered for night-works from 7pm – 10pm and 10pm – 7am. As such, grey cells reflect blank inputs for other construction activities that were not considered for night-time construction.</i>								

8.3.1 Likelihood of Impacts

The Likelihood of Occurrence of the potential noise impacts were determined based on the construction timeline and selected construction activities from Table 8-7.

Scenario 1: Ground Improvement Work and other significant impact phases

In determining the Likelihood of Occurrence for Scenario 1, source noise levels and the predicted impact intensity for ground improvement works was first determined. Thereafter, it was observed that despite practically the highest noise barrier, the noise exceedances were observed beyond the criteria. Although ground improvement works would occur for a short period of time it still meant that noise criteria of 'no worse off' would not be met at this stage. Therefore, overall source noise levels from other construction phases were also then assessed using quick model runs for discreet receptors to check if these phases also caused significant impacts in terms of noise levels as compared to the ambient noise levels. It was found that construction activities which deemed to contribute to considerable noise impacts and potentially resulting in unacceptable levels of noise exceedances would include: Site Clearance for Construction; Preparation for Jet Grouting Works; Ground Improvement Work; Shaft Construction; and Manhole Construction.

Though as mentioned previously where only the construction activity with the worst-case scenario (i.e. Ground Improvement Work) was applied for construction noise modelling for Scenario 1, it was not justifiable that only Ground Improvement Work to be considered as the only activity that would contribute to noise impacts on the noise sensitive receptors (NSRs) in the vicinity of the worksites, as in fact they would also occur during the same construction schedule (7am – 7pm), especially while evaluating the likelihood of a considerable significant impact. Therefore, additional construction activities as listed in Table 8-8 were also included to provide a more accurate picture of the Likelihood of Occurrence of the noise impacts on the nearby receptors.

According to the information provided by the design team (refer to Appendix L), the total duration of months consumed by the selected construction activities over the total construction timeline would cover **10.5 months** out of a total of **51 months** for the Construction of the Proposed DGS System at Sentosa. This equated to approximately **20.5%** of the total construction timeline.

As shown in Table 6-6, activities happening for 16 – 25% of the construction timeline at the worksite would have a Likelihood of **Possible/ Occasional** (*either one could be applied in this report*) as reflected in Table 8-8.

Scenario 2a, 2b: Pipe Jacking (24-hour Machine Operation, Emergency Situation)

Scenario 2a: Pipe Jacking (24-hour Machine Operation) and Scenario 2b: Pipe Jacking (Emergency Situation) were the two (2) scenarios of the "Pipe Jacking" construction activity considered to account for 24-hour machine operation and emergency situation which differed in the types of Powered Mechanical Equipment (PMEs) engaged as reflected in Appendix L. Neither of these two (2) scenarios are independent of the other and are mutually exclusive meaning, if Scenario 2a occurs, Scenario 2b will not occur vice versa.

For the Likelihood of Occurrence for Scenario 2a and 2b, it was the sole construction activity considered for assessment for 7am – 7pm (excluding Weekdays), 7pm – 7am, 7pm – 10pm and 10pm – 7am for Weekdays and Weekend/ Public Holidays as it was the only activity that would contribute to noise impacts on the NSRs at these construction schedules given that only "Pipe Jacking" would continue to operate for 24 hours outside of the 7am – 7pm schedule if permission from SDC and Agencies were granted for night works.

According to information provided by the design team (refer to Appendix L), the total duration of months consumed by pipe jacking over the total construction timeline would cover **3 months** out of a total of **51 months** for the Construction of the Proposed DGS System at Sentosa. This equated to approximately **5.8%** of the total construction timeline.

As shown in Table 6-6, activities happening for 5 – 15 % of the construction timeline at the worksite would have a Likelihood of **Less Likely/ Rare** (*either one could be applied in this report*) as reflected in Table 8-8.

Table 8-8 Likelihood Evaluation on Construction Activities for Airborne Noise Assessment

Worksites	Construction Activities and Duration	Likelihood
Scenario 1: Ground Improvement Work and other significant impact phases		
All Construction Worksites (see Figure 8-3)	The Total Construction Timeline is 51 months (based on the tentative schedule in Section 3.4). Construction of Proposed DGS System for L_{Aeq} (12 hour) and L_{Aeq} (5 min) for 7am – 7pm include the following key activities with estimated period required at each worksite: • Site Clearance for Construction – 1 month • Preparation for Jet Grouting Works – 0.5 months • Ground Improvement Work – 1 month • Shaft Construction – 4 months • Manhole Construction – 4 months	Likelihood of Occurrence of Construction Activities for L_{Aeq} (12 hour) and L_{Aeq} (5 min) (7am – 7pm) – approximately 20.5%. Likelihood: Possible/ Occasional (see Table 6-6)
Scenario 2a and 2b: Pipe Jacking		
All Construction Worksites (see Figure 8-3)	The Total Construction Timeline is 51 months (based on the tentative schedule in Section 3.4). Construction of Proposed DGS System for L_{Aeq} (12 hour), L_{Aeq} (1 hour), and L_{Aeq} (5 min) for 7am – 7pm, 7pm – 7am, 7pm – 10pm and 10pm – 7am include the following key activity with estimated period required at each worksite: • Pipe Jacking – 3 months	Likelihood of Occurrence of Construction Activities for L_{Aeq} (12 hour), L_{Aeq} (1 hour) and L_{Aeq} (5 min) (7am – 7pm (excluding Weekdays), 7pm – 10pm, 10pm – 7am) – approximately 5.8%. Likelihood: Less Likely/ Rare (see Table 6-6)



Legend Base Construction Worksites DGS Manholes & Pipeline Nature Areas Biodiversity Study Area for Mt. Imbiah and Mt. Serapong Study Area (150m)							Qualified Person Endorsement : NA	Consultant : AECOM	Project Title : Contract No. SDC/21.8.2/19: Environmental Study For The Proposed Deep Gravity Sewer Project at Sentosa			Figure Title : Airborne Noise Sources - Construction Phase			
	B	NOV 2021	SYT	Final Report Rev B	JAG/NHT	JAG	Client Endorsement : NA		Designed SYT	Checked JAG/NHT	Approved JAG	Figure No. : 8-3		Rev. B	Sheet 1 of 1
	A	AUG 2021	SYT	Final Report Rev A	JAG/NHT	JAG									
	-	MAY 2021	SYT	Final Report	JAG/NHT	JAG									
	Rev.	Date	By	Description	Chk'd	App'd									

CAD File Name : NA												A3
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8.4 Identification of Airborne Noise Sensitive Receptors

This study focused on the noise impacts to the ecologically sensitive receptors (fauna) and human receptors within the study area during the construction phase of the Project. The classification of ecologically sensitive receptors and human receptors was based on the auditory sensitivity of respective species as described in previous Section 8.2.3 and reflected in Figure 8-2. The identified ecologically sensitive and human receptors were further discussed in the following Section 8.4.1 and Section 8.4.2 respectively.

8.4.1 Ecologically Sensitive Receptors

Receptor Importance

The prioritisation of the ecologically sensitive receptors (ESRs) within the Nature Areas follows the approach listed in the below order:

1. The actual presence or likely presence (from records) from faunistic field assessment conducted;
2. The conservation significance or importance of the indemnified ecologically sensitive receptors; and
3. The ecologically sensitive receptor's likely sensitivity to noise impacts.

Based on faunistic field assessment within the Nature Areas, the receptors of concern in line with the biodiversity section were discussed below. The full list of ecologically sensitive receptors was reflected in Appendix N.

Priority 1 and Priority 2 fauna species were identified in Table 8-10 and Table 8-11 for Mt. Imbiah and Mt. Serapong respectively. These identified fauna species form the focal ESRs which were of particular concern due to their auditory sensitivities. Priority 3 fauna species were excluded from the list of focal ESRs as these fauna species were identified as animals not likely to be affected by noise as discussed below.

Receptor Sensitivity to Airborne Noise

The following paragraphs discussed the ecologically sensitive receptors and the rationale for their respective auditory sensitivity.

The priority levels for auditory sensitivity reflected in Table 8-9 were assigned based on the following general framework provided by the biodiversity specialists of this Project:

- Priority 1: Animals that vocalise during important life cycle stages such as courtship, territorial claims and/or mating;
- Priority 2: Animals that have auditory sensory systems but do not necessarily need to vocalise during important life cycle stages; and
- Priority 3: Animals that are not likely to be affected by noise.

Lepidoptera such as the butterflies are known to behaviourally respond to low-frequency vibrations and sounds to avoid insect predators and parasites [P-28]. Adult butterflies are known to make use of existing airborne noise in order to avoid predators [P-29]. Based on the above, lepidopterans are considered highly auditory. Hence, classified as Priority 2 ecologically sensitive receptors.

It is documented that adult odonates are able to hear however sound does not appear to cause significant behavioural change [P-27]. Odonates are consequently regarded as being less auditory sensitive. Hence, they were classified as a Priority 3 ecologically sensitive receptors.

Amphibians such as frogs are considered to have highly auditory sensitive as studies have demonstrated that anthropogenic noise is likely to substantially decrease the reproductive success in frogs [P-30]. Hence, amphibians were classified as Priority 1 ecologically sensitive receptors.

Reptiles such as lizards and skinks are considered to be moderately auditory sensitive due to studies showing these species exhibiting stress responses when exposed to anthropogenic noise [P-31]. Snakes, though not equipped with outer-ears and tympanic middle ear, have vestiges for hearing inside their heads and can feel low-frequency airborne sounds [P-35]. Based on the above, reptiles are considered to have moderate auditory sensitivity and were classified as Priority 2 ecologically sensitive receptor.

Birds are considered to be highly auditory sensitive as most make use of sound for communication and breeding. Studies have also shown that birds are impacted negatively by anthropogenic noise [P-32]. Hence, birds were classified as Priority 1 ecologically sensitive receptors.

Non-volant mammals such as rodents are known to display stressed behaviour in response to sounds of heavy machinery which could be common occurrence from construction noise [P-33]. Hence, non-volant mammals are deemed to be moderately auditory sensitive and were classified as Priority 2 ecologically sensitive receptors.

Anthropogenic noise is known to impacts bats negatively by disrupting foraging patterns [P-34] and are hence classified as highly auditory sensitive. Based on faunistic surveys, bats of conservation significance were observed, for example the bamboo bats found at the bamboo cluster near MH31 worksite. Hence, they were classified as a Priority 1 ecologically sensitive receptor.

Table 8-9 Ecologically Sensitive Receptors and Airborne Noise Sensitivity Classification

Receptor Number	Nature Areas	Receptors	Sensitivity Classification
1	Mt. Imbiah and Mt. Serapong	Butterfly	Priority 2
2		Odonate	Priority 3
3		Amphibian	Priority 1
4		Reptile	Priority 2
5		Bird	Priority 1
6		Mammal (Non-volant)	Priority 2
7		Mammal (Bat)	Priority 1

Table 8-10 Focal Ecologically Sensitive Receptors – Mt. Imbiah

No.	Faunal Group	Species	Common name	Global status	Local status	Auditory Sensitivity
1.	Amphibian	<i>Duttaphrynus melanostictus</i>	Asian toad	Least Concern	Not assessed	1
2.	Amphibian	<i>Eleutherodactylus planirostris</i>	Greenhouse frog	Least Concern	Not assessed	1
3.	Reptile	<i>Ahaetulla prasina</i>	Oriental whip snake	Least Concern	Not assessed	2
4.	Bird	<i>Accipiter gularis</i>	Japanese sparrowhawk	Least Concern	Not assessed	1
5.	Bird	<i>Acridotheres javanicus</i>	Javan myna	Least Concern	Not assessed	1
6.	Bird	* <i>Anthracoceros albirostris</i>	Oriental pied hornbill	Least Concern	Critically Endangered	1
7.	Bird	<i>Anthreptes malacensis</i>	Brown-throated sunbird	Least Concern	Not assessed	1
8.	Bird	<i>Aplonis panayensis</i>	Asian glossy starling	Least Concern	Not assessed	1
9.	Bird	<i>Cacatua goffiniana</i>	Tanimbar corella	Near Threatened	Not assessed	1
10.	Bird	<i>Dicaeum cruentatum</i>	Scarlet-backed flowerpecker	Least Concern	Not assessed	1
11.	Bird	<i>Dicaeum trigonostigma</i>	Orange-bellied flowerpecker	Least Concern	Not assessed	1
12.	Bird	* <i>Gallus gallus</i>	Red junglefowl	Least Concern	Endangered	1
13.	Bird	<i>Geopelia striata</i>	Zebra dove	Least Concern	Not assessed	1
14.	Bird	<i>Gracula religiosa</i>	Common hill myna	Least Concern	Not assessed	1
15.	Bird	<i>Haliastur indus</i>	Brahminy kite	Least Concern	Not assessed	1
16.	Bird	* <i>Loriculus galgulus</i>	Blue-crowned hanging-parrot	Least Concern	Endangered	1
17.	Bird	<i>Mixornis gularis</i>	Pin-striped tit-babbler	Least Concern	Not assessed	1
18.	Bird	<i>Oriolus chinensis</i>	Black-naped oriole	Least Concern	Not assessed	1
19.	Bird	<i>Orthotomus atrogularis</i>	Dark-necked tailorbird	Least Concern	Not assessed	1
20.	Bird	<i>Otus lempiji</i>	Sunda scops owl	Least Concern	Not assessed	1
21.	Bird	<i>Phylloscopus borealis</i>	Arctic warbler	Least Concern	Not assessed	1
22.	Bird	<i>Pycnonotus goiavier</i>	Yellow-vented bulbul	Least Concern	Not assessed	1
23.	Bird	<i>Pycnonotus jocosus</i>	Red-whiskered bulbul	Least Concern	Not assessed	1
24.	Bird	<i>Pycnonotus plumosus</i>	Olive-winged bulbul	Least Concern	Not assessed	1
25.	Bird	<i>Spilopelia chinensis</i>	Spotted dove	Least Concern	Not assessed	1
26.	Bird	<i>Todiramphus chloris</i>	Collared kingfisher	Least Concern	Not assessed	1
27.	Bird	<i>Treron vernans</i>	Pink-necked green pigeon	Least Concern	Not assessed	1
28.	Mammal	<i>Callosciurus notatus</i>	Plantain squirrel	Least Concern	Not assessed	2
29.	Mammal	<i>Felis catus</i>	Feral cat	Not Assessed	Not assessed	2
30.	Bat	<i>Myotis muricola</i>	Whiskered myotis	Least Concern	Not assessed	1
31.	Bat	<i>Scotophilus kuhlii</i>	Asiatic lesser yellow house bat	Least Concern	Not assessed	1

No.	Faunal Group	Species	Common name	Global status	Local status	Auditory Sensitivity
32.	Bat	<i>*Taphozous melanopogon</i>	Black-bearded tomb bat	Least Concern	Endangered	1
33.	Bat	<i>*Tylonycteris</i> sp.	Bamboo bat	-	-	1
34.	Other less auditory sensitive fauna species.					3
Note: * Denotes fauna species of Conservation Significance (CS). A detailed list of all ESRs is provided in Appendix N.						

Table 8-11 Focal Ecologically Sensitive Receptors – Mt. Serapong

No.	Faunal Group	Species	Common name	Global status	Local status	Auditory Sensitivity
1.	Amphibian	<i>Eleutherodactylus planirostris</i>	Greenhouse frog	Least Concern	Not assessed	1
2.	Amphibian	<i>Kaloula pulchra</i>	Banded bull frog	Least Concern	Not assessed	1
3.	Amphibian	<i>Polypedates leucomystax</i>	Four-lined tree frog	Least Concern	Not assessed	1
4.	Reptile	<i>Ahaetulla prasina</i>	Oriental whip snake	Least Concern	Not assessed	2
5.	Reptile	<i>Eutropis multifasciata</i>	Many-lined sun skink	Not assessed	Not assessed	2
6.	Reptile	<i>Gekko monarchus</i>	Spotted house gecko	Not assessed	Not assessed	2
7.	Reptile	<i>Naja sumatrana</i>	Equatorial spitting cobra	Least Concern	Not assessed	2
8.	Bird	<i>Acridotheres javanicus</i>	Javan myna	Least Concern	Not assessed	1
9.	Bird	<i>Aethopyga siparaja</i>	Crimson sunbird	Least Concern	Not assessed	1
10.	Bird	<i>*Anthracoceros albirostris</i>	Oriental pied hornbill	Least Concern	Critically Endangered	1
11.	Bird	<i>Anthreptes malacensis</i>	Brown-throated sunbird	Least Concern	Not assessed	1
12.	Bird	<i>Aplonis panayensis</i>	Asian glossy starling	Least Concern	Not assessed	1
13.	Bird	<i>Cacatua goffiniana</i>	Tanimbar corella	Near Threatened	Not assessed	1
14.	Bird	<i>Caprimulgus macrurus</i>	Large-tailed nightjar	Least Concern	Not assessed	1
15.	Bird	<i>Chalcophaps indica</i>	Common emerald dove	Least Concern	Not assessed	1
16.	Bird	<i>Cinnyris jugularis</i>	Olive-backed sunbird	Least Concern	Not assessed	1
17.	Bird	<i>Dicaeum cruentatum</i>	Scarlet-backed flowerpecker	Least Concern	Not assessed	1
18.	Bird	<i>Dicrurus paradiseus</i>	Greater racket-tailed drongo	Least Concern	Not assessed	1
19.	Bird	<i>Eudynamis scolopaceus</i>	Asian koel	Least Concern	Not assessed	1
20.	Bird	<i>Eurystomus orientalis</i>	Oriental dollarbird	Least Concern	Not assessed	1
21.	Bird	<i>Garrulax canorus</i>	Chinese hwamei	Least Concern	Not assessed	1
22.	Bird	<i>Gracula religiosa</i>	Common hill myna	Least Concern	Not assessed	1
23.	Bird	<i>Haliaeetus leucogaster</i>	White-bellied sea eagle	Least Concern	Not assessed	1
24.	Bird	<i>Merops viridis</i>	Blue-throated bee-eater	Least Concern	Not assessed	1
25.	Bird	<i>Mixornis gularis</i>	Pin-striped tit-babbler	Least Concern	Not assessed	1

No.	Faunal Group	Species	Common name	Global status	Local status	Auditory Sensitivity
26.	Bird	<i>Muscicapa dauurica</i>	Asian brown flycatcher	Least Concern	Not assessed	1
27.	Bird	* <i>Nisaetus cirrhatus</i>	Changeable hawk-eagle	Least Concern	Endangered	1
28.	Bird	<i>Oriolus chinensis</i>	Black-naped oriole	Least Concern	Not assessed	1
29.	Bird	<i>Orthotomus atrogularis</i>	Dark-necked tailorbird	Least Concern	Not assessed	1
30.	Bird	<i>Otus lempiji</i>	Sunda scops owl	Least Concern	Not assessed	1
31.	Bird	<i>Pernis ptilorhynchus</i>	Crested honey-buzzard	Least Concern	Not assessed	1
32.	Bird	<i>Phylloscopus borealis</i>	Arctic warbler	Least Concern	Not assessed	1
33.	Bird	<i>Pitta sordida</i>	Hooded pitta	Least Concern	Not assessed	1
34.	Bird	<i>Psilopogon lineatus</i>	Lineated barbet	Least Concern	Not assessed	1
35.	Bird	<i>Pycnonotus goiavier</i>	Yellow-vented bulbul	Least Concern	Not assessed	1
36.	Bird	<i>Pycnonotus jocosus</i>	Red-whiskered bulbul	Least Concern	Not assessed	1
37.	Bird	<i>Pycnonotus plumosus</i>	Olive-winged bulbul	Least Concern	Not assessed	1
38.	Bird	<i>Todiramphus chloris</i>	Collared kingfisher	Least Concern	Not assessed	1
39.	Bird	<i>Treron vernans</i>	Pink-necked green pigeon	Least Concern	Not assessed	1
40.	Mammal	<i>Callosciurus notatus</i>	Plantain squirrel	Least Concern	Not assessed	2
41.	Mammal	* <i>Macaca fascicularis</i>	Long-tailed macaque	Vulnerable	Not assessed	2
42.	Mammal	<i>Rattus tiomanicus</i>	Malaysian wood rat	Least Concern	Not assessed	2
43.	Mammal	<i>Felis catus</i>	Feral cat	Not Assessed	Not assessed	2
44.	Bat	<i>Cynopterus brachyotis</i>	Lesser dog-faced fruit bat	Least Concern	Not assessed	1
45.	Bat	<i>Myotis muricola</i>	Whiskered myotis	Least Concern	Not assessed	1
46.	Bat	<i>Saccolaimus</i>	Pouch-bearing bat	Least Concern	Not assessed	1
47.	Bat	<i>Scotophilus kuhlii</i>	Asiatic lesser yellow house bat	Least Concern	Not assessed	1
48.	Bat	* <i>Taphozous melanopogon</i>	Black-bearded tomb bat	Least Concern	Endangered	1
49.	Bat	* <i>Tylonycteris</i> sp.	Bamboo bat	-	-	1
50.	Other less auditory sensitive fauna species.					3

Note: * Denotes fauna species of Conservation Significance (CS). A detailed list of all ESRs is provided in Appendix N.

8.4.2 Human Receptors

According to the *Environmental Project and Management Regulation (2008)* [R-18], the sensitive receptors were identified as buildings within 150 m from the overall study area. As the initial step of construction noise impact assessment, the buildings within the study area that might be potentially sensitive to construction noise from the Project were analysed. As a result, the human noise sensitive receptors (NSRs) for the construction phase were reflected in Figure 8-2 and Table 8-12 where the respective sensitivity classifications were based on Table 6-4.

Table 8-12 Noise Sensitive Receptors (Human)

No.	Noise Sensitive Receptors	Receptor Sensitivity	Nearest Noise Logger	Receptor Type
1	AJ Hackett Sentosa	3	NM01	Commercial
2	AJ's Bar and Beach Dining	3	NM01	Commercial
3	Bikini Bar, Coastes	3	NM01	Commercial
4	Cable Car Siloso Point Station	3	NM01	Commercial
5	Emerald Pavilion	3	NM01	Commercial
6	First Aid Station along Siloso Beach Walk	1	NM01	Medical Facility
7	Fun Shop Beach Plaza	3	NM01	Commercial
8	Gogreen Segway, Eco Adventure	3	NM01	Commercial
9	Good Old Days Restaurant	3	NM01	Commercial
10	iFly Singapore	3	NM01	Commercial
11	Mega Adventure Ticketing Booth	3	NM01	Commercial
12	Nestopia	3	NM01	Commercial
13	Ola Beach Club	3	NM01	Commercial
14	Refill Station - Skyline Luge	3	NM01	Commercial
15	Rumour's Beach Club, Baristart Coffee	3	NM01	Commercial
16	Sand Bar	3	NM01	Commercial
17	Sapphire Pavillion	3	NM01	Commercial
18	Show Bites	3	NM01	Commercial
19	Siloso Beach Resort - Eco Alfresco Café	3	NM01	Commercial
20	Skyline Luge - Ticketing Booth	3	NM01	Commercial
21	Skyline Luge (near iFly Singapore)	3	NM01	Commercial
22	Trapizza	3	NM01	Commercial
23	Wings of Time Musical	3	NM01	Commercial
24	42 Imbiah Road	3	NM02	Commercial
25	51A Imbiah Road	3	NM02	Commercial
26	6 Beach View	3	NM02	Commercial
27	Adventure Cove Waterpark	3	NM02	Commercial
28	Butterfly Park & Insect Kingdom	3	NM02	Commercial
29	Cable Car Arrival Plaza	3	NM02	Commercial
30	Crockfords Tower	2	NM02	Residential
31	Resorts World Theatre	2	NM02	Residential
32	Equarius Hotel	2	NM02	Residential
33	Festive Hotel	2	NM02	Residential
34	Hard Rock Hotel	2	NM02	Residential
35	Hotel Michael	2	NM02	Residential
36	Images of Singapore	3	NM02	Commercial
37	Imbiah Lookout Bus Stop	3	NM02	Commercial

No.	Noise Sensitive Receptors	Receptor Sensitivity	Nearest Noise Logger	Receptor Type
38	Imbiah Office	3	NM02	Commercial
39	Madame Tussauds Singapore	3	NM02	Commercial
40	Marvel 4D Experience	3	NM02	Commercial
41	Resorts World Sentosa Casino	2	NM02	Residential
42	Sentosa 4D Magix	3	NM02	Commercial
43	Sentosa CineBlast	3	NM02	Commercial
44	Sentosa Nature Discovery	3	NM02	Commercial
45	Siloso Beach Resort	2	NM02	Residential
46	Siloso Beach Resort 1 - 12	2	NM02	Residential
47	Skyline Luge (near Imbiah Lookout)	3	NM02	Commercial
48	TreeTop Loft	3	NM02	Commercial
49	81H Palawan Beach Walk	3	NM03	Commercial
50	Amara Sanctuary Resort - Main Building	2	NM03	Residential
51	Amara Sanctuary Resort 1 - 8	2	NM03	Residential
52	Amara Sanctuary Resort - 3 Larkhill Road	2	NM03	Residential
53	Amara Sanctuary Resort - 5 Larkhill Road	2	NM03	Residential
54	Amara Sanctuary Resort - Facility Building	2	NM03	Residential
55	Animal and Bird Encounters	3	NM03	Commercial
56	Beach Arrival Plaza	3	NM03	Commercial
57	Beach Station	3	NM03	Commercial
58	Beach Station - Guard House	3	NM03	Commercial
59	Block G - Lady M Boutique	3	NM03	Commercial
60	66 Allanbrooke Road	3	NM03	Commercial
61	Focus Adventure Office	3	NM03	Commercial
62	Imbiah Station	3	NM03	Commercial
63	LiHo - Beach Arrival Plaza	3	NM03	Commercial
64	Old Chang Kee - Beach Arrival Plaza	3	NM03	Commercial
65	Mess Hall	3	NM03	Commercial
66	Palawan Amphitheatre	3	NM03	Commercial
67	*Palawan Kid's City, KidZania	3	NM03	Commercial
68	Quentin's Bar and Restaurant	3	NM03	Commercial
69	The Barracks Hotel	2	NM03	Residential
70	The Events Centre, Village Hotel Sentosa	2	NM03	Residential
71	Universal Studios Singapore	3	NM03	Commercial
72	Universal Studios Singapore - Accelerator	3	NM03	Commercial
73	Universal Studios Singapore - Battlestar Galactica	3	NM03	Commercial
74	Universal Studios Singapore - Jurassic Park Rapids Adventure	3	NM03	Commercial
75	Universal Studios Singapore - Lights Camera Action, New York	3	NM03	Commercial
76	Universal Studios Singapore - SciFi City	3	NM03	Commercial
77	Universal Studios Singapore - Transformers	3	NM03	Commercial

No.	Noise Sensitive Receptors	Receptor Sensitivity	Nearest Noise Logger	Receptor Type
78	Universal Studios Singapore - Treasure Hunters	3	NM03	Commercial
79	Universal Studios Singapore - WaterWorld	3	NM03	Commercial
80	Village Hotel Sentosa, The Outpost Hotel	2	NM03	Residential
81	Capella Singapore	2	NM04	Residential
82	Capella Singapore - Facility Building	2	NM04	Residential
83	Capella Singapore - Tennis Courts	2	NM04	Residential
84	Capella Singapore - Garden Villas 1 - 38	2	NM04	Residential
85	Capella The Club Residences 1 - 11	2	NM04	Residential
86	The Manor, Capella Singapore 1 - 10	2	NM04	Residential
87	FOC Restaurant, Frankly Maintenance Pte Ltd	3	NM04	Commercial
88	Focus Adventure Camp	3	NM04	Commercial
89	Ranger Station	3	NM04	Commercial
90	30 Allanbrooke Road	3	NM05	Commercial
91	66 Allanbrooke Road	3	NM05	Commercial
92	EIS International Pre-School	1	NM05	Educational Institution
93	EtonHouse International Pre-School	1	NM05	Educational Institution
94	Islander Pre-School	1	NM05	Educational Institution
95	ilLido at the cliff	3	NM05	Commercial
96	Recycling Building along Artillery Avenue	3	NM05	Commercial
97	SCDF Sentosa Fire Station	3	NM05	Commercial
98	SDC Facility Complex	3	NM05	Commercial
99	SDC Office	3	NM05	Commercial
100	Sentosa Maintenance Workshop	3	NM05	Commercial
101	Sentosa Pavilion	3	NM05	Commercial
102	Sentosa Transport Office	3	NM05	Commercial
103	Sofitel Sentosa Resort & Spa	2	NM05	Residential
104	Sofitel So FIT & So SPA	2	NM05	Residential
105	9 - 12, 16 - 18, 20 - 29 Lakeshore View @Sentosa Cove	2	NM06	Residential
106	ONE 15 Marina - Tennis Court	3	NM06	Commercial
107	PUB owned buildings	3	NM06	Commercial
108	Sentosa Cove Village, Carpark	3	NM06	Commercial
109	Sentosa Satellite Earth Station	3	NM06	Commercial

8.5 Baseline Airborne Noise

8.5.1 Baseline Monitoring Personnel

The assessment and site surveys were conducted by the following personnel:

- Ms. Jagriti Dawra, AECOM (Technical Lead)
- Mr. Hanzel Lalitan, AECOM (Air and Noise Consultant)
- Mr. Zay Phyoo, AECOM (Noise Consultant)
- Ms. Mavis Lee, AECOM (Air and Noise Consultant)
- Ms. Sim Yi Ting, AECOM (Air and Noise Consultant)

To understand the ambient noise environment near the Project alignment, site reconnaissance was conducted on 20 November 2020. Besides, baseline noise monitoring was conducted between the dates listed below to obtain the baseline noise levels for comparison, so that the noise correction factors could be derived as stated in the *NEA Maximum Permissible Noise levels for construction-related activities* [R-50].

The baseline monitoring dates were as follows:

- 2 – 9 December 2020 (for NM01, NM02, NM05 and NM06);
- 11 – 18 December (for NM03); and
- 29 December 2020 – 5 January 2021 (for NM04).

8.5.2 Baseline Monitoring Results

Table 8-13 and Table 8-14 presented a summary of the baseline results for $L_{Aeq}(12 \text{ hour})$, $L_{Aeq}(1 \text{ hour})$ and $L_{Aeq}(5 \text{ min})$ for Weekdays and Weekend/ Public Holidays respectively. The detailed baseline monitoring result was provided in Appendix J.

Table 8-13 Summary of Baseline Noise Monitoring Results - Construction Noise Impact Assessment (Weekdays)

Location	Date of Monitoring	L _{Aeq} (12 hour), dB		L _{Aeq} (1 hour), dB						L _{Aeq} (5 min), dB								
		7am-7pm	7pm-7am	7pm - 10pm			10pm - 7am			7am-7pm			7pm-10pm			10pm-7am		
		Overall		Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
NM01: Near Nestopia at Siloso Beach Walk (near MH1)	2 Dec - 9 Dec 2020	65	55	58	80	66	47	67	54	44	78	56	54	87	64	43	75	52
NM02: Near Imbiah Lookout Station at Sentosa Island (near MH32)	2 Dec - 9 Dec 2020	66	56	59	75	65	47	62	55	44	76	58	55	85	65	46	68	55
NM03: Near Amara Sanctuary Resort Sentosa (near MH26)	11 Dec - 18 Dec 2020	67	63	62	67	65	48	67	57	52	76	65	51	72	63	46	71	54
NM04: Near Palawan Beach and Opposite Capella Singapore (near MH10)	29 Dec 2020 - 5 Jan 2021	63	55	51	60	56	46	65	53	50	78	61	45	68	55	45	69	52
NM05: At roadside behind Islander Pre-School (near MH15 and MH16)	2 Dec - 9 Dec 2020	70	67	63	68	65	51	66	59	62	82	69	58	75	65	45	71	58
NM06: Opposite Lakeshore View residence along Ocean Drive and near Sentosa Cove Village Car Park (near MH22)	2 Dec - 9 Dec 2020	66	63	59	64	62	52	65	57	54	81	65	57	70	62	47	75	56
<i>Note: It is important to note that as baseline monitoring was conducted during the COVID-19 Phase 2 period (from 19 June 2020) for NM01 – NM03, NM05 and NM06, where Sentosa was operating on approximately 50% capacity as stated by SDC. These baseline monitoring results were adjusted by doubling the noise sources based on logarithmic addition of 3 dB(A) to provide a more accurate reflection of the situation when Sentosa Island resumes to 100% operation post-COVID in future.</i>																		

Table 8-14 Summary of Baseline Noise Monitoring Results – Construction Noise Impact Assessment (Weekend/ Public Holidays)

Location	Date of Monitoring	L _{Aeq} (12 hour), dB		L _{Aeq} (5 min), dB								
		7am-7pm	7pm-7am	7am-7pm			7pm-10pm			10pm-7am		
		Overall		Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
NM01: Near Nestopia at Siloso Beach Walk (near MH1)	2 Dec - 9 Dec 2020	67	52	44	70	56	60	82	65	43	71	52
NM02: Near Imbiah Lookout Station at Sentosa Island (near MH32)	2 Dec - 9 Dec 2020	70	56	48	77	59	63	86	69	47	66	55
NM03: Near Amara Sanctuary Resort Sentosa (near MH26)	11 Dec - 18 Dec 2020	66	64	52	75	64	52	71	63	46	71	52
NM04: Near Palawan Beach and Opposite Capella Singapore (near MH10)	29 Dec 2020 - 5 Jan 2021	59	53	53	73	58	49	60	54	46	61	50
NM05: At roadside behind Islander Pre-School (near MH15 and MH16)	2 Dec - 9 Dec 2020	68	67	65	79	69	60	70	65	47	74	57
NM06: Opposite Lakeshore View residence along Ocean Drive and near Sentosa Cove Village Car Park (near MH22)	2 Dec - 9 Dec 2020	65	63	61	80	66	59	69	62	49	71	56
<i>Note: It is important to note that as baseline monitoring was conducted during the COVID-19 Phase 2 period (from 19 June 2020) for NM01 – NM03, NM05 and NM06, where Sentosa was operating on approximately 50% capacity as stated by SDC. These baseline monitoring results were adjusted by doubling the noise sources based on logarithmic addition of 3 dB(A) to provide a more accurate reflection of the situation when Sentosa Island resumes to 100% operation post-COVID in future.</i>												

8.5.3 Corrected Baseline Noise Criteria

Based on the baseline airborne noise monitoring results and corrected noise criteria performed in accordance to the “adjusted maximum permissible noise level” as explained in Section 8.2.4, the noise criteria for airborne noise impact assessment of the human and ecologically sensitive receptors were deduced separately.

Construction noise criteria for $L_{Aeq}(12 \text{ hour})$, $L_{Aeq}(1 \text{ hour})$ and $L_{Aeq}(5 \text{ min})$ were deduced for the period of 7am – 7pm, 7pm – 7am, 7pm – 10pm and 10pm – 7am for Weekdays (Monday – Saturday) and Weekend/ Public Holidays according to regulations.

8.5.3.1 Ecologically Sensitive Receptors

As mentioned in Section 8.2.4, there are currently no guidelines or standards available to assess construction noise impacts on the ecologically sensitive receptors, thus the baseline monitoring results in Table 8-13 (for Weekdays) and Table 8-14 (for Weekend/ Public Holidays) formed the assessment criteria for construction noise impact on ecologically sensitive receptors, as reflected in Table 8-15 and Table 8-16 respectively. This approach was taken as part of a conservative means; that if no noise exceedances was predicted when compared to these stringent criteria, the airborne noise impact on fauna in the vicinity would also not experience noise levels exceeding the established criteria. The detailed calculations were provided in Appendix M.

Table 8-15 Criteria for Ecologically Sensitive Receptors Airborne Noise Impact Assessment (Weekdays)

Location	Date of Monitoring	L _{Aeq} (12 hour), dB		L _{Aeq} (1 hour), dB		L _{Aeq} (5 min), dB		
		7am-7pm	7pm-7am	7pm - 10pm	10pm - 7am	7am-7pm	7pm-10pm	10pm-7am
Near Mt. Imbiah								
NM01: Near Nestopia at Siloso Beach Walk (near MH1)	2 Dec - 9 Dec 2020	65	55	66	54	56	64	52
NM02: Near Imbiah Lookout Station at Sentosa Island (near MH32)	2 Dec - 9 Dec 2020	66	55	65	55	58	65	55
Near Mt. Serapong								
NM05: At roadside behind Islander Pre-School (near MH15 and MH16)	2 Dec - 9 Dec 2020	70	67	65	59	69	65	58
NM06: Opposite Lakeshore View residence along Ocean Drive and near Sentosa Cove Village Car Park (near MH22)	2 Dec - 9 Dec 2020	66	63	62	57	65	62	56
Note: * The ESRs are assessed in a no worse-off manner due to the unavailability of airborne noise regulations and criteria for ESRs. The baseline monitoring results of NM01, NM02, NM05 and NM06 in Table 8-14 were selected to establish the assessment criteria for ESRs near Mt. Imbiah and Mt. Serapong respectively.								

Table 8-16 Criteria for Ecologically Sensitive Receptors Airborne Noise Impact Assessment (Weekend/ Public Holidays)

Location	Date of Monitoring	L _{Aeq} (12 hour), dB		L _{Aeq} (5 min), dB		
		7am-7pm	7pm-7am	7am-7pm	7pm-10pm	10pm-7am
Near Mt. Imbiah						
NM01: Near Nestopia at Siloso Beach Walk (near MH1)	2 Dec - 9 Dec 2020	67	52	56	65	52
NM02: Near Imbiah Lookout Station at Sentosa Island (near MH32)	2 Dec - 9 Dec 2020	70	56	59	69	55
Near Mt. Serapong						
NM05: At roadside behind Islander Pre-School (near MH15 and MH16)	2 Dec - 9 Dec 2020	68	67	69	65	57
NM06: Opposite Lakeshore View residence along Ocean Drive and near Sentosa Cove Village Car Park (near MH22)	2 Dec - 9 Dec 2020	65	63	66	62	56
Note: * The ESRs are assessed in a no worse-off manner due to the unavailability of airborne noise regulations and criteria for ESRs. The baseline monitoring results of NM01, NM02, NM05 and NM06 in Table 8-14 were selected to establish the assessment criteria for ESRs near Mt. Imbiah and Mt. Serapong respectively.						

8.5.3.2 Human Receptors

For human receptors, the corrected noise criteria was deduced from using the overall noise levels for L_{Aeq} (12 hour), L_{Aeq} (1 hour) and L_{Aeq} (5 min) from NM01 to NM06 to calculate the “adjusted maximum permissible noise level” as per the *Environmental Protection and Management (Control of Noise at Construction Sites) Regulations (2008)*. Table 8-17 and Table 8-18 below reflected the corrected noise criteria for Weekdays (Monday – Saturday) and Weekend/Public Holidays according to *EPM (2008)* [R-18]. The detailed calculations were provided in Appendix M.

Table 8-17 Corrected Noise Criteria (Weekdays)

No.	Types of Affected Buildings	L_{Aeq} (12 hour), dB		L_{Aeq} (1 hour), dB		L_{Aeq} (5 min), dB		
		7am-7pm	7pm-7am	7pm-10pm	10pm-7am	7am-7pm	7pm-10pm	10pm-7am
NM01	(a) Noise Sensitive (e.g. educational institution, medical facilities) (Priority 1)	66	56	–	–	75	65	57
	(b) Residential (Priority 2)	75	–	69	58	90	71	57
	(c) Others (e.g. commercial, recreational, etc.) (Priority 3)	75	65	–	–	90	71	70
NM02	(a) Noise Sensitive (e.g. educational institution, medical facilities) (Priority 1)	67	57	–	–	75	65	58
	(b) Residential (Priority 2)	76	–	68	58	90	71	58
	(c) Others (e.g. commercial, recreational, etc.) (Priority 3)	76	66	–	–	90	71	70
NM03	(a) Noise Sensitive (e.g. educational institution, medical facilities) (Priority 1)	62	63	–	–	75	64	58
	(b) Residential (Priority 2)	75	–	68	59	90	71	58
	(c) Others (e.g. commercial, recreational, etc.) (Priority 3)	75	67	–	–	90	71	70

No.	Types of Affected Buildings	L _{Aeq} (12 hour), dB		L _{Aeq} (1 hour), dB		L _{Aeq} (5 min), dB		
		7am-7pm	7pm-7am	7pm-10pm	10pm-7am	7am-7pm	7pm-10pm	10pm-7am
NM04	(a) Noise Sensitive (e.g. educational institution, medical facilities) (Priority 1)	65	56	–	–	75	58	57
	(b) Residential (Priority 2)	75	–	66	57	90	70	57
	(c) Others (e.g. commercial, recreational, etc.) (Priority 3)	75	65	–	–	90	70	70
NM05	(a) Noise Sensitive (e.g. educational institution, medical facilities) (Priority 1)	70	67	–	–	76	65	60
	(b) Residential (Priority 2)	76	–	68	60	90	71	60
	(c) Others (e.g. commercial, recreational, etc.) (Priority 3)	76	69	–	–	90	71	70
NM06	(a) Noise Sensitive (e.g. educational institution, medical facilities) (Priority 1)	67	63	–	–	75	63	59
	(b) Residential (Priority 2)	76	–	67	59	90	71	59
	(c) Others (e.g. commercial, recreational, etc.) (Priority 3)	76	67	–	–	90	71	70

Table 8-18 Corrected Noise Criteria (Weekend/ Public Holidays)

No.	Types of Affected Buildings	L _{Aeq} (12 hour), dB			L _{Aeq} (5 min), dB	
		7am-7pm	7pm-7am	7am-7pm	7pm-10pm	10pm-7am
NM01	(a) Noise Sensitive (e.g. educational institution, medical facilities) (Priority 1)	68	54	75	65	57
	(b) Residential (Priority 2)	76	–	75	65	57
	(c) Others (e.g. commercial, recreational, etc.) (Priority 3)	76	65	90	71	70
NM02	(a) Noise Sensitive (e.g. educational institution, medical facilities) (Priority 1)	70	57	75	65	58
	(b) Residential (Priority 2)	76	–	75	65	58
	(c) Others (e.g. commercial, recreational, etc.) (Priority 3)	76	66	90	71	70
NM03	(a) Noise Sensitive (e.g. educational institution, medical facilities) (Priority 1)	67	64	75	64	58
	(b) Residential (Priority 2)	76	–	75	64	58
	(c) Others (e.g. commercial, recreational, etc.) (Priority 3)	76	68	90	71	70
NM04	(a) Noise Sensitive (e.g. educational institution, medical facilities) (Priority 1)	63	55	75	58	57
	(b) Residential	75	–	75	58	57

No.	Types of Affected Buildings	L _{Aeq} (12 hour), dB			L _{Aeq} (5 min), dB		
		7am-7pm	7pm-7am	7am-7pm	7pm-10pm	10pm-7am	
	(Priority 2)						
	(c) Others (e.g. commercial, recreational, etc.) (Priority 3)	75	65	90	70	70	
NM05	(a) Noise Sensitive (e.g. educational institution, medical facilities) (Priority 1)	69	67	76	65	60	
	(b) Residential (Priority 2)	76	–	76	65	60	
	(c) Others (e.g. commercial, recreational, etc.) (Priority 3)	76	69	90	71	70	
NM06	(a) Noise Sensitive (e.g. educational institution, medical facilities) (Priority 1)	66	63	75	63	59	
	(b) Residential (Priority 2)	75	–	75	63	59	
	(c) Others (e.g. commercial, recreational, etc.) (Priority 3)	75	67	90	71	70	

8.6 Minimum Control for Potential Airborne Noise Impacts

This section proposed minimum controls, or standard practices, commonly implemented in Singapore for similar construction activities, that were assumed to be implemented for the purposes of impact assessment.

The list below is non-exhaustive and should be practised as minimum control to reduce noise levels during the construction phase of the Project:

- All machinery and equipment used shall be labelled with a weather-proof sticker clearly indicating its noise emission level (at source) under normal operating conditions;
- All machinery and equipment used on site should be sound-reduced, as far as is practicable;
- Stationary noisy equipment should be housed in enclosures on site where necessary;
- Machine operators and workers must be trained and briefed on quieter work techniques;
- Ad-hoc noise monitoring must be carried out when work progresses during noisy operations;
- Additional noise measures should be implemented when noise monitoring indicates the noise levels are approaching or exceeding permissible noise levels; and
- Avoid shouting, whistling, sirens or similar loud intermittent noises especially near ecologically sensitive receptors which can be impacted by them.

8.7 Prediction and Evaluation of Airborne Noise Impacts

8.7.1 Ecologically Sensitive Receptors

The predicted noise levels for the ecologically sensitive receptors (ESRs) were deduced based on the representative ESRs selected within the study area. This is to predict the potential noise levels that the ESRs could have experienced during the construction phase of the Project. As shown in Figure 8-2, identified fauna species that fall within the proposed construction worksites would not be accounted for noise assessment as these species would inadvertently have to move away from these locations during construction phase, to the nearby areas where the representative ESRs were located. For less mobile fauna species, such as bamboo bats identified by the fauna specialist, in order to cater for these animals, pre-clearance inspections would be carried out prior to vegetation removal. Should any animal be found, the wildlife response plan could be executed. This would ensure that no animal would be trapped or accidentally injured or killed during site clearance. Following this, construction works would then commence, which by then the animals would have moved away and were no longer present at the worksites. Figure 8-4 and Figure 8-5 reflected the location of the representative ESRs near Mt. Imbiah and Mt. Serapong respectively.

The construction noise predictions for the representative ESRs at specific heights of 1.5 m and 12 m for Mt. Imbiah, and 1.5 m and 20 m for Mt. Serapong were presented in Appendix U for all three (3) scenarios with the summarized construction noise impacts reflected in Table 8-20 and Table 8-21 below. These elevations were deduced based on the average heights of trees observed at Mt. Imbiah and Mt. Serapong, averaging at around 12 m and 20 m respectively, and to account for ground-dwelling fauna species on ground level elevations of up to 1.5 m. The noise impact on ground level (1.5 m) would differ from that at a higher elevation (12 m, 20 m) even in the same location, resulting in the variation of response from ecologically sensitive receptors according to the noise levels were well as type of fauna inhabiting or present at the different levels.

From the construction noise predictions of the three (3) scenarios reflected in Appendix U, it could be observed that ESRs subjected to noise arising from activities related to both Scenario 2a and Scenario 2b were predicted to not experience any noise exceedances resulting in an **Negligible** Impact Significance as shown in Table 8-20 and Table 8-21 below for the two Nature Areas. While construction noise arising from Scenario 1 was predicted to result in significant noise exceedances (see Appendix U) and an Impact Significance ranging from **Minor – Moderate** for Mt. Imbiah and ranging from **Negligible – Moderate** for Mt. Serapong, being the worst-case scenario of the three (3) scenarios identified for assessment.

The resulting noise contours representative of the conservative worst-case assumption for all three (3) scenarios represented by Scenario 1 Ground Improvement Work, of the three (3) scenarios were reflected at ground level (1.5 m) and at higher elevations of 12 m for Mt. Imbiah, and 20 m for Mt. Serapong in the following as listed in Table 8-19 below. The respective findings for ESRs near Mt. Imbiah and ESRs near Mt. Serapong were further discussed in Section 8.7.1.1 and Section 8.7.1.2 below respectively.

Table 8-19 List of Grid Noise Map Figures for Ecological Impacts

Scenario	Elevation	Weekdays/ Weekend/ Public Holidays (Construction Schedule)	L _{Aeq}	Figure
Scenario 1: Ground Improvement Work				
Mt. Imbiah	1.5 m	Weekdays (7am – 7pm)	L _{Aeq} (12 hour)	Figure 8-6
		Weekdays (7am – 7pm)	L _{Aeq} (5 min)	Figure 8-7
	12 m	Weekdays (7am – 7pm)	L _{Aeq} (12 hour)	Figure 8-8
		Weekdays (7am – 7pm)	L _{Aeq} (5 min)	Figure 8-9
Mt Serapong	1.5 m	Weekdays (7am – 7pm)	L _{Aeq} (12 hour)	Figure 8-10
		Weekdays (7am – 7pm)	L _{Aeq} (5 min)	Figure 8-11
	20 m	Weekdays (7am – 7pm)	L _{Aeq} (12 hour)	Figure 8-12
		Weekdays (7am – 7pm)	L _{Aeq} (5 min)	Figure 8-13

Based on the predicted noise levels and maximum noise exceedances observed for the three (3) scenarios reflected in Appendix U, construction noise impact assessment for ecologically sensitive receptors at different heights was conducted as summarized in Table 8-20 and Table 8-21. This evaluation was carried out based on the assessment methodology in Section 6.4.2.

Table 8-20 Summary of Construction Noise Impacts - Ground Level (1.5 m), Ecological Impacts

Nature Areas	Nearest Noise Logger No. for Baseline Monitoring Result	Receptor Priority	Maximum Exceedance Observed, dB(A)	Impact Intensity	Impact Consequence	Likelihood	Impact Significance
Scenario 1: Ground Improvement Work							
Mt. Imbiah	NM01	1	4	Medium	Medium	Occasional	Moderate
		2		Medium	Medium	Occasional	Moderate
		3		Medium	Very Low	Occasional	Minor
	NM02	1	7	High	High	Occasional	Moderate
		2		High	High	Occasional	Moderate
		3		High	Low	Occasional	Minor
Mt. Serapong	NM05	1	3	Medium	Medium	Occasional	Moderate
		2		Medium	Medium	Occasional	Moderate
		3		Medium	Very Low	Occasional	Minor
	NM06	1	-	Negligible	Very Low	Occasional	Minor
		2		Negligible	Very Low	Occasional	Minor
		3		Negligible	Imperceptible	Occasional	Negligible
Scenario 2a: Pipe Jacking (24-hour Machine Operation)							
Mt. Imbiah	NM01	1	-	Negligible	Very Low	Rare	Negligible
		2		Negligible	Very Low	Rare	Negligible
		3		Negligible	Imperceptible	Rare	Negligible
	NM02	1	-	Negligible	Very Low	Rare	Negligible
		2		Negligible	Very Low	Rare	Negligible
		3		Negligible	Imperceptible	Rare	Negligible
Mt. Serapong	NM05	1	-	Negligible	Very Low	Rare	Negligible
		2		Negligible	Very Low	Rare	Negligible
		3		Negligible	Imperceptible	Rare	Negligible
	NM06	1	-	Negligible	Very Low	Rare	Negligible
		2		Negligible	Very Low	Rare	Negligible
		3		Negligible	Imperceptible	Rare	Negligible
Scenario 2b: Pipe Jacking (Emergency Situation)							
Mt. Imbiah	NM01	1	-	Negligible	Very Low	Rare	Negligible
		2		Negligible	Very Low	Rare	Negligible
		3		Negligible	Imperceptible	Rare	Negligible
	NM02	1	-	Negligible	Very Low	Rare	Negligible
		2		Negligible	Very Low	Rare	Negligible
		3		Negligible	Imperceptible	Rare	Negligible

Nature Areas	Nearest Noise Logger No. for Baseline Monitoring Result	Receptor Priority	Maximum Exceedance Observed, dB(A)	Impact Intensity	Impact Consequence	Likelihood	Impact Significance
Mt. Serapong	NM05	1	–	Negligible	Very Low	Rare	Negligible
		2		Negligible	Very Low	Rare	Negligible
		3		Negligible	Imperceptible	Rare	Negligible
	NM06	1	–	Negligible	Very Low	Rare	Negligible
		2		Negligible	Very Low	Rare	Negligible
		3		Negligible	Imperceptible	Rare	Negligible

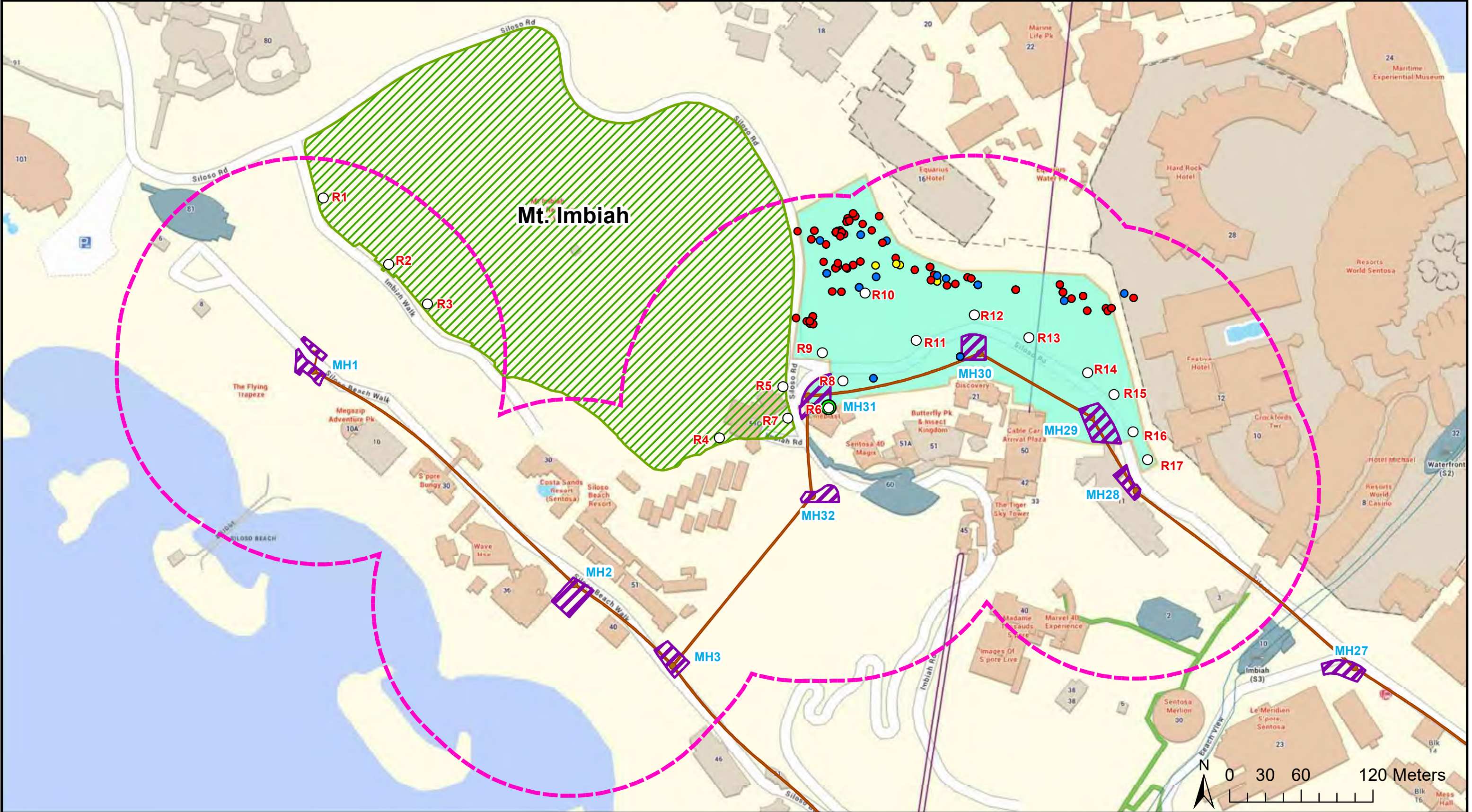
Note: The colour of the cells corresponds to that of the assessment matrices in Section 6.4.2.

The full list of construction noise prediction results for the individual representative ESRs was presented in Appendix U.

Table 8-21 Summary of Construction Noise Impacts - Higher Elevation (12 m/ 20 m), Ecological Impacts

Nature Areas	Nearest Noise Logger No. for Baseline Monitoring Result	Receptor Priority	Maximum Exceedance Observed, dB(A)	Impact Intensity	Impact Consequence	Likelihood	Impact Significance
Scenario 1: Ground Improvement Work							
Mt. Imbiah (12 m)	NM01	1	10	High	High	Occasional	Moderate
		2		High	High	Occasional	Moderate
		3		High	Low	Occasional	Minor
	NM02	1	10	High	High	Occasional	Moderate
		2		High	High	Occasional	Moderate
		3		High	Low	Occasional	Minor
Mt. Serapong (20 m)	NM05	1	3	Medium	Medium	Occasional	Moderate
		2		Medium	Medium	Occasional	Moderate
		3		Medium	Very Low	Occasional	Minor
	NM06	1	8	High	High	Occasional	Moderate
		2		High	High	Occasional	Moderate
		3		High	Low	Occasional	Minor
Scenario 2a: Pipe Jacking (24-hour Machine Operation)							
Mt. Imbiah (12 m)	NM01	1	-	Negligible	Very Low	Rare	Negligible
		2		Negligible	Very Low	Rare	Negligible
		3		Negligible	Imperceptible	Rare	Negligible
	NM02	1	-	Negligible	Very Low	Rare	Negligible
		2		Negligible	Very Low	Rare	Negligible
		3		Negligible	Imperceptible	Rare	Negligible
Mt. Serapong (20 m)	NM05	1	-	Negligible	Very Low	Rare	Negligible
		2		Negligible	Very Low	Rare	Negligible
		3		Negligible	Imperceptible	Rare	Negligible
	NM06	1	-	Negligible	Very Low	Rare	Negligible
		2		Negligible	Very Low	Rare	Negligible
		3		Negligible	Imperceptible	Rare	Negligible
Scenario 2b: Pipe Jacking (Emergency Situation)							
Mt. Imbiah (12 m)	NM01	1	-	Negligible	Very Low	Rare	Negligible
		2		Negligible	Very Low	Rare	Negligible
		3		Negligible	Imperceptible	Rare	Negligible
	NM02	1	-	Negligible	Very Low	Rare	Negligible
		2		Negligible	Very Low	Rare	Negligible
		3		Negligible	Imperceptible	Rare	Negligible
Mt. Serapong	NM05	1	-	Negligible	Very Low	Rare	Negligible
		2		Negligible	Very Low	Rare	Negligible

Nature Areas	Nearest Noise Logger No. for Baseline Monitoring Result	Receptor Priority	Maximum Exceedance Observed, dB(A)	Impact Intensity	Impact Consequence	Likelihood	Impact Significance
(20 m)		3		Negligible	Imperceptible	Rare	Negligible
	NM06	1	–	Negligible	Very Low	Rare	Negligible
		2		Negligible	Very Low	Rare	Negligible
		3		Negligible	Imperceptible	Rare	Negligible
Note: The colour of the cells corresponds to that of the assessment matrices in Section 6.4.2. The full list of construction noise results for the individual representative ESRs was presented in Appendix U.							



Legend

- Construction Worksites
- DGS Manholes & Pipeline
- Nature Areas
- Biodiversity Study Area for Mt. Imbiah and Mt. Serapong
- Bamboo Clusters
- Study Area (150m) - Ecologically Sensitive Receptors

Noise Sensitive Receptors

- Representative Ecologically Sensitive Receptors

Ecologically Sensitive Receptors

- Representative Ecologically Sensitive Receptors

Auditory Sensitivity

- Priority 1
- Priority 2
- Priority 3

B	NOV 2021	SYT	Final Report Rev B	JAG/NHT	JAG
A	JUL 2021	SYT	Final Report Rev A	JAG/NHT	JAG
-	MAY 2021	SYT	Final Report	JAG/NHT	JAG
Rev.	Date	By	Description	Chk'd	App'd

Qualified Person Endorsement :
NA

Client Endorsement :
NA

Consultant :
AECOM

Project Title :
**Contract No. SDC/21.8.2/19:
Environmental Study
For The Proposed Deep Gravity
Sewer Project at Sentosa**

Designed
SYT

Checked
JAG/NHT

Approved
JAG

Drawn
SYT

Date
NOV 2021

Figure Title :
**Representative
Ecologically Sensitive Receptors
near Mt. Imbiah**

Figure No. :
8-4

Rev.
B

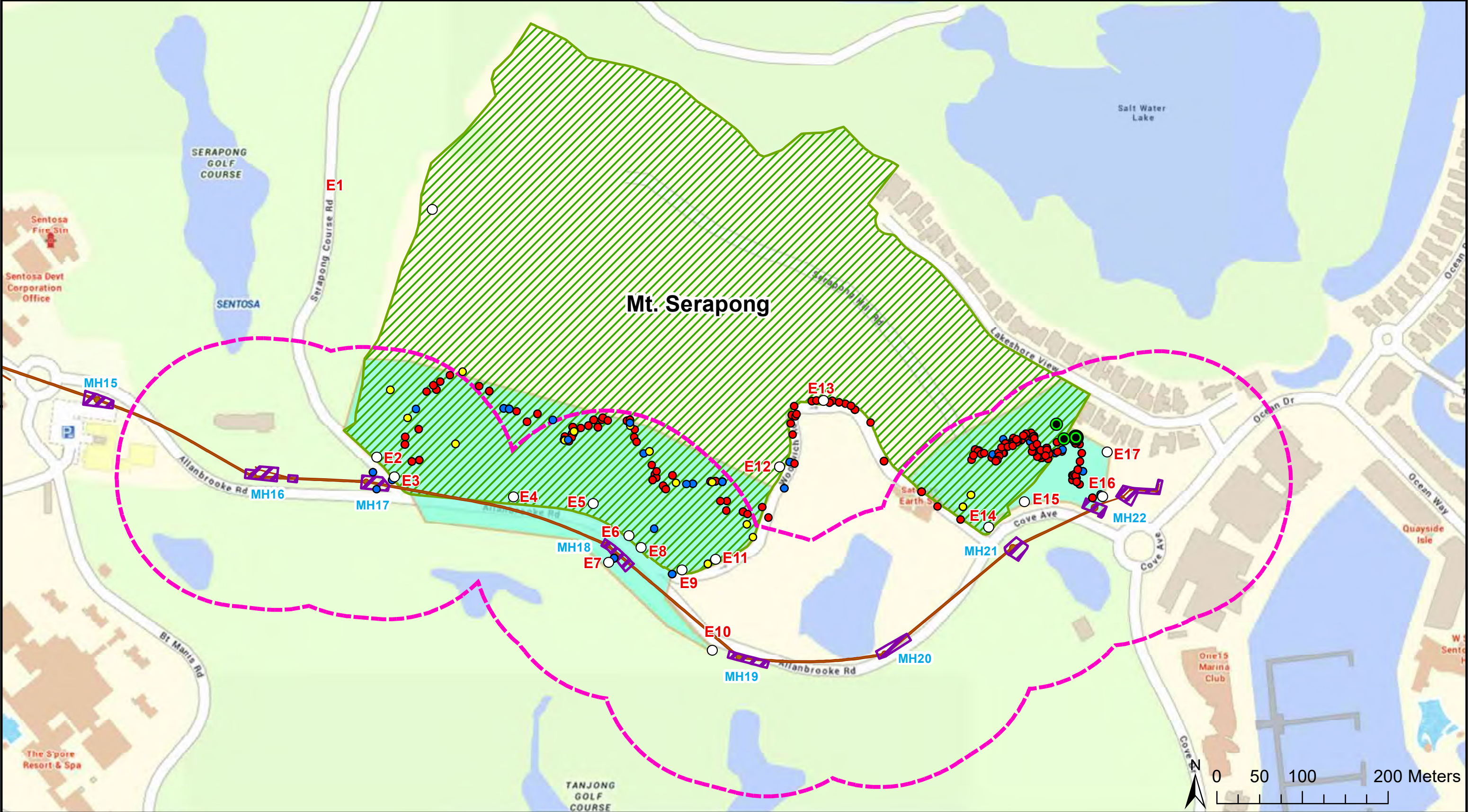
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1 of 1

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Legend

- Construction Worksites
- DGS Manholes & Pipeline
- Nature Areas
- Biodiversity Study Area for Mt. Imbiah and Mt. Serapong
- Bamboo Clusters
- Study Area (150m) - Ecologically Sensitive Receptors

Noise Sensitive Receptors

- Ecologically Sensitive Receptors
 - Representative Ecologically Sensitive Receptors
- Auditory Sensitivity
 - Priority 1
 - Priority 2
 - Priority 3

A	NOV 2021	SYT	Final Report Rev B	JAG/NHT	JAG
A	JUL 2021	SYT	Final Report Rev A	JAG/NHT	JAG
-	MAY 2021	SYT	Final Report	JAG/NHT	JAG
Rev.	Date	By	Description	Chk'd	App'd

Qualified Person Endorsement :
NA

Client Endorsement :
NA

Consultant :
AECOM

Project Title :
**Contract No. SDC/21.8.2/19:
Environmental Study
For The Proposed Deep Gravity
Sewer Project at Sentosa**

Designed
SYT

Checked
JAG/NHT

Approved
JAG

Drawn
SYT

Date
NOV 2021

Figure Title :
**Representative
Ecologically Sensitive Receptors
near Mt. Serapong**

Figure No. :
8-5

Rev.
B

Sheet
1 of 1

CAD File Name : NA

A3

Source of basemap - OneMap

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8.7.1.1 Mt. Imbiah

Mt. Imbiah is of close proximity (within 150 m from construction worksites) to MH1, MH2 and MH28 – MH32 worksites. During the construction phase, ground level receptors were expected to have noise exceedances of up to 8 dB(A) during the construction phase. Fauna species at ground level are typically ground dwellers that comprise odonates and mammals such as the identified rat species (refer to Appendix N). Impact on these faunal species are not yet clearly known, but at least it could be predicted that at these times, the immediate vicinity of the construction worksites will be avoided by these species. It is also possible that some species will find refuge further into the Mt. Imbiah and its connected forested habitat, away from the construction worksites.

Preliminary prediction of noise levels at higher levels from the ground was also performed for the representative ESRs at the height of 12 m as described in Section 8.7.1. The faunal receptors at higher levels from the ground were also expected to experience noise exceedances with the highest exceedance being 10 dB(A) during the construction phase. It should be noted that the noise levels predicted were the noise levels observed at the closest boundary of Mt. Imbiah and its connected forested habitat within biodiversity study area, to the construction worksites. It could be expected that the fauna species which are highly mobile are able to move deeper within Mt. Imbiah, away from the construction noise. Mammal and avian species (at least 18 species types identified in surveys) impacted are likely to be able to find alternative habitats in the surrounding irrespective of construction noise, but largely due to human activities. Hence, for the areas around MH1, MH2 and MH28 – MH32 worksites, the bird species will move away during the construction period and likely to return once construction is completed since the footprint of manhole is very small at that time.

Butterflies or lepidopterans are perturbed by intermittent noise. Therefore, as a minimum control for the worksites in this area, it was recommended to avoid high intermittent noises as much as possible while not compromising human safety.

The two species of amphibians observed in this area (viz. Asian toad and greenhouse frog) are common species. However, the amphibians were found during site reconnaissance by fauna specialists to be further into the forested areas (see Figure 7-32), instead of around the worksites along the roadsides. It was noted from the surface water quality impact assessment that no natural waterbodies were observed to be directly encroached by the proposed worksites or with potential to receive surface run-off from the construction worksites, except for a few manmade ponds and concrete drains (see Table 10-9) that the amphibians might have adapted to and inhabit in. Therefore, even though they are sensitive to noise, it is unlikely that these species will be impacted.

For reptiles, only one (1) common species of no biodiversity conservation significance (i.e. Oriental whipsnake) was observed in this area. Snakes, though not equipped with outer-ears and tympanic middle ear, have vestiges for hearing inside their heads and can feel low-frequency airborne sounds. Four (4) bat species were identified in this area, one of which, namely the black-bearded tomb bat is locally endangered and were found within the original MH31 worksite.

As discussed in Section 8.2.5, the overall Impact Significance for ecologically sensitive receptors (ESRs) at Mt. Imbiah was classified by considering the Impact Intensity, Impact Consequence and Likelihood of Occurrence of impacts from the construction phase. The overall Impact Significance of each of the three (3) different scenarios was deduced as follows:

Scenario 1: Ground Improvement Work

As reflected in Table 8-20 (1.5 m) and Table 8-21 (12 m), the Impact Intensity for Scenario 1 was assessed to range from **Medium – High** for ESRs (3 – 6 dB(A) (Medium), > 6dB (A) (High) exceedance, refer to Table 6-4) in Mt. Imbiah, and the corresponding Impact Consequence for the ESRs of varying auditory priorities were determined to range from **Very Low – High** (refer to Table 6-5). In relation to the Impact Consequence and the **Occasional** Likelihood (refer to Table 6-6) of Scenario 1, it was determined that the Impact Significance for ESRs near Mt. Imbiah to range from **Minor – Moderate** (refer to Table 6-7) as reflected in Table 8-22. As such, mitigation measures were proposed in this study (refer to Section 8.8) with aims to control the airborne noise impacts on the ESRs arising from Scenario 1: Ground Improvement Work, during the construction phase of this Project to reduce the Impact Significance on ESRs near Mt. Imbiah to within **Negligible – Minor**.

Scenario 2a: Pipe Jacking (24-hour Machine Operation)

As shown in Table 8-20 (1.5 m) and Table 8-21 (12 m), the Impact Intensity for Scenario 2a was assessed to be **Negligible** (no exceedance, refer to Table 6-4) in Mt. Imbiah, and the corresponding Impact Consequence for the ESRs of varying auditory priorities were determined to range from **Imperceptible – Very Low** (refer to Table 6-5). In relation to the Impact Consequence and the **Rare** Likelihood (refer to Table 6-6) of Scenario 2a, it was determined that the Impact Significance for ESRs near Mt. Imbiah to be **Negligible** (refer to Table 6-7) as reflected in Table 8-22. As no exceedance was predicted to arise from Scenario 2a: Pipe Jacking (24-hour Machine Operation), no mitigation measures would be required for this scenario.

Scenario 2b: Pipe Jacking (Emergency Situation)

According to Table 8-20 (1.5 m) and Table 8-21 (12 m), the Impact Intensity for Scenario 2b was assessed to be **Negligible** (no exceedance, refer to Table 6-4) in Mt. Imbiah, and the corresponding Impact Consequence for the ESRs of varying auditory priorities were determined to range from **Imperceptible – Very Low** (refer to Table 6-5). In relation to the Impact Consequence and the **Rare** Likelihood (refer to Table 6-6) of Scenario 2b, it was determined that the Impact Significance for ESRs near Mt. Imbiah to be **Negligible** (refer to Table 6-7) as reflected in Table 8-22. Therefore, no mitigation measures would be required for Scenario 2b: Pipe Jacking (Emergency Situation).

Table 8-22 Summary of Noise Impacts to Focal Ecologically Sensitive Receptors - Mt. Imbiah

No.	Faunal Group	Common name	Auditory Sensitivity	Highest Impact Significance		
				Scenario 1: Ground Improvement Work	Scenario 2a: Pipe Jacking (24-hour Machine Operation)	Scenario 2b: Pipe Jacking (Emergency Situation)
1	Amphibian	Asian toad	1	Moderate	Negligible	Negligible
2	Amphibian	Greenhouse frog	1	Moderate	Negligible	Negligible
3	Reptile	Oriental whip snake	2	Moderate	Negligible	Negligible
4	Bird	Japanese sparrowhawk	1	Moderate	Negligible	Negligible
5	Bird	Javan myna	1	Moderate	Negligible	Negligible
6	Bird	*Oriental pied hornbill	1	Moderate	Negligible	Negligible
7	Bird	Brown-throated sunbird	1	Moderate	Negligible	Negligible
8	Bird	Asian glossy starling	1	Moderate	Negligible	Negligible
9	Bird	Tanimbar corella	1	Moderate	Negligible	Negligible
10	Bird	Scarlet-backed flowerpecker	1	Moderate	Negligible	Negligible
11	Bird	Orange-bellied flowerpecker	1	Moderate	Negligible	Negligible
12	Bird	*Red junglefowl	1	Moderate	Negligible	Negligible
13	Bird	Zebra dove	1	Moderate	Negligible	Negligible
14	Bird	Common hill myna	1	Moderate	Negligible	Negligible
15	Bird	Brahminy kite	1	Moderate	Negligible	Negligible
16	Bird	*Blue-crowned hanging-parrot	1	Moderate	Negligible	Negligible
17	Bird	Pin-striped tit-babbler	1	Moderate	Negligible	Negligible
18	Bird	Black-naped oriole	1	Moderate	Negligible	Negligible
19	Bird	Dark-necked tailorbird	1	Moderate	Negligible	Negligible
20	Bird	Sunda scops owl	1	Moderate	Negligible	Negligible
21	Bird	Arctic warbler	1	Moderate	Negligible	Negligible
22	Bird	Yellow-vented bulbul	1	Moderate	Negligible	Negligible
23	Bird	Red-whiskered bulbul	1	Moderate	Negligible	Negligible
24	Bird	Olive-winged bulbul	1	Moderate	Negligible	Negligible
25	Bird	Spotted dove	1	Moderate	Negligible	Negligible
26	Bird	Collared kingfisher	1	Moderate	Negligible	Negligible
27	Bird	Pink-necked green pigeon	1	Moderate	Negligible	Negligible
28	Mammal	Plantain squirrel	2	Moderate	Negligible	Negligible
29	Mammal	Feral cat	2	Moderate	Negligible	Negligible
30	Bat	Whiskered myotis	1	Moderate	Negligible	Negligible

No.	Faunal Group	Common name	Auditory Sensitivity	Highest Impact Significance		
				Scenario 1: Ground Improvement Work	Scenario 2a: Pipe Jacking (24-hour Machine Operation)	Scenario 2b: Pipe Jacking (Emergency Situation)
31	Bat	Asiatic lesser yellow house bat	1	Moderate	Negligible	Negligible
32	Bat	Black-bearded tomb bat	1	Moderate	Negligible	Negligible
33	Bat	Bamboo bat	1	Moderate	Negligible	Negligible
34	Other less auditory sensitive fauna species.		3	Minor	Negligible	Negligible
<i>Note: * Denotes fauna species of Conservation Significance (CS). A detailed ESR list reflecting the Impact Significance on the other ESRs not in the table would be provided in Appendix N.</i> <i>The colour of the cells corresponds to that of the assessment matrices in Section 6.4.2.</i>						

8.7.1.2 Mt. Serapong

Mt. Serapong, similarly, is of close proximity (within 150 m from the construction worksites) to MH16 – MH22 worksites. During the construction phase, the ground level receptors were expected to experience noise exceedances of up to 3 dB(A). As discussed in previous sections, impact on these faunal species are not yet clearly known, but it is possible that some species will find refuge further into the Mt. Serapong and its connected forested habitat during construction phase and move away from the construction worksites.

Preliminary prediction of noise levels at higher levels from the ground was also performed for the representative ESRs at the height of 20 m as described in Section 8.7.1. The faunal receptors at higher levels from the ground were also expected to experience noise exceedances with the highest exceedance being 8 dB(A) during the construction phase. It should be noted that the noise levels predicted were the noise levels observed at the closest boundary of Mt. Serapong and its connected forested habitat within biodiversity study area, to the construction worksites. Similarly, it could be expected that the fauna species which highly mobile are able to move deeper within Mt. Serapong and away from the construction noise. Mammal and avian species (at least 27 species types identified in surveys) impacted are likely to be able to find alternative habitats in the surrounding irrespective of noise, but largely driven to relocate due to increase in human activities when the construction phase commences. Hence, for areas around MH16 – MH22 worksites, the bird species will likely move away during the construction period and will likely to return once the construction phase is completed, as the footprint of the manhole is very small once completed.

Butterflies or lepidopterans are perturbed by intermittent noise. Therefore, as a minimum control for the worksites in this area, it was recommended to avoid high intermittent noises as much as possible while not compromising human safety.

The three species of amphibians observed in this area namely: greenhouse frog; banded bull frog; and four-lined tree frog, are common species. However, the amphibians were found during site reconnaissance by fauna specialists to be further into the forested areas (see Figure 7-32), instead of around the worksites along the roadsides. It was noted from the surface water quality impact assessment that no natural waterbodies were observed to be directly encroached by the proposed worksites or with potential to receive surface run-off from the construction worksites, except for a few manmade ponds and concrete drains (see Table 10-9) that the amphibians might have adapted to and inhabit in. Therefore, even though they are sensitive to noise, it is unlikely that these species will be impacted.

For reptiles, four (4) different reptile species were observed in this area (viz. Oriental whip snake, many-lined sun skink, spotted house gecko, equatorial spitting cobra). Skinks and geckoes are considered to be highly auditory sensitive and exhibits stress responses when exposed to anthropogenic noise. Snakes, though not equipped with outer-ears and tympanic middle ear, have vestiges for hearing inside their heads and can feel low-frequency airborne sounds. Six (6) bat species were identified in this area, one of which, namely the black-bearded tomb bat, is locally endangered. The area of prevalence of these species is approximately 75 m away from the worksites with MH22 being the nearest.

As reflected in Section 8.2.5, the overall Impact Significance for ecologically sensitive receptors (ESRs) at Mt. Serapong was classified by considering the Impact Intensity, Impact Consequence and Likelihood of Occurrence of impacts from the construction phase. The overall Impact Significance of each of the three (3) different scenarios was reflected as follows:

Scenario 1: Ground Improvement Work

According to Table 8-20 (1.5 m) and Table 8-21 (12 m), the Impact Intensity for Scenario 1 was assessed to range from **Negligible – High** for ESRs (refer to Table 6-4) in Mt. Serapong, and the corresponding Impact Consequence for the ESRs of varying auditory priorities were determined to range from **Imperceptible – High** (refer to Table 6-5). In relation to the Impact Consequence and the **Occasional** Likelihood (refer to Table 6-6) of Scenario 1, it was determined that the Impact Significance for ESRs near Mt. Serapong to range from **Negligible – Moderate** (refer to Table 6-7) as reflected in Table 8-23. As such, mitigation measures were proposed in this study (refer to Section 8.8) aimed at controlling the airborne noise impacts on the ESRs arising from Scenario 1: Ground Improvement Work, during the construction phase of this Project to reduce the Impact Significance on ESRs near Mt. Serapong to within **Negligible – Minor**.

Scenario 2a: Pipe Jacking (24-hour Machine Operation)

As shown in Table 8-20 (1.5 m) and Table 8-21 (12 m), the Impact Intensity for Scenario 2a was assessed to be **Negligible** (no exceedance, refer to Table 6-4) in Mt. Serapong, and the corresponding Impact Consequence for the ESRs of varying auditory priorities were determined to range from **Imperceptible – Very Low** (refer to Table 6-5). In relation to the Impact Consequence and the **Rare** Likelihood (refer to Table 6-6) of Scenario 2b, it was determined that the Impact Significance for ESRs near Mt. Serapong to be **Negligible** (refer to Table 6-7) as

reflected in Table 8-23. As no exceedance was predicted to arise from Scenario 2a: Pipe Jacking (Emergency Situation), no mitigation measures would be required for this scenario.

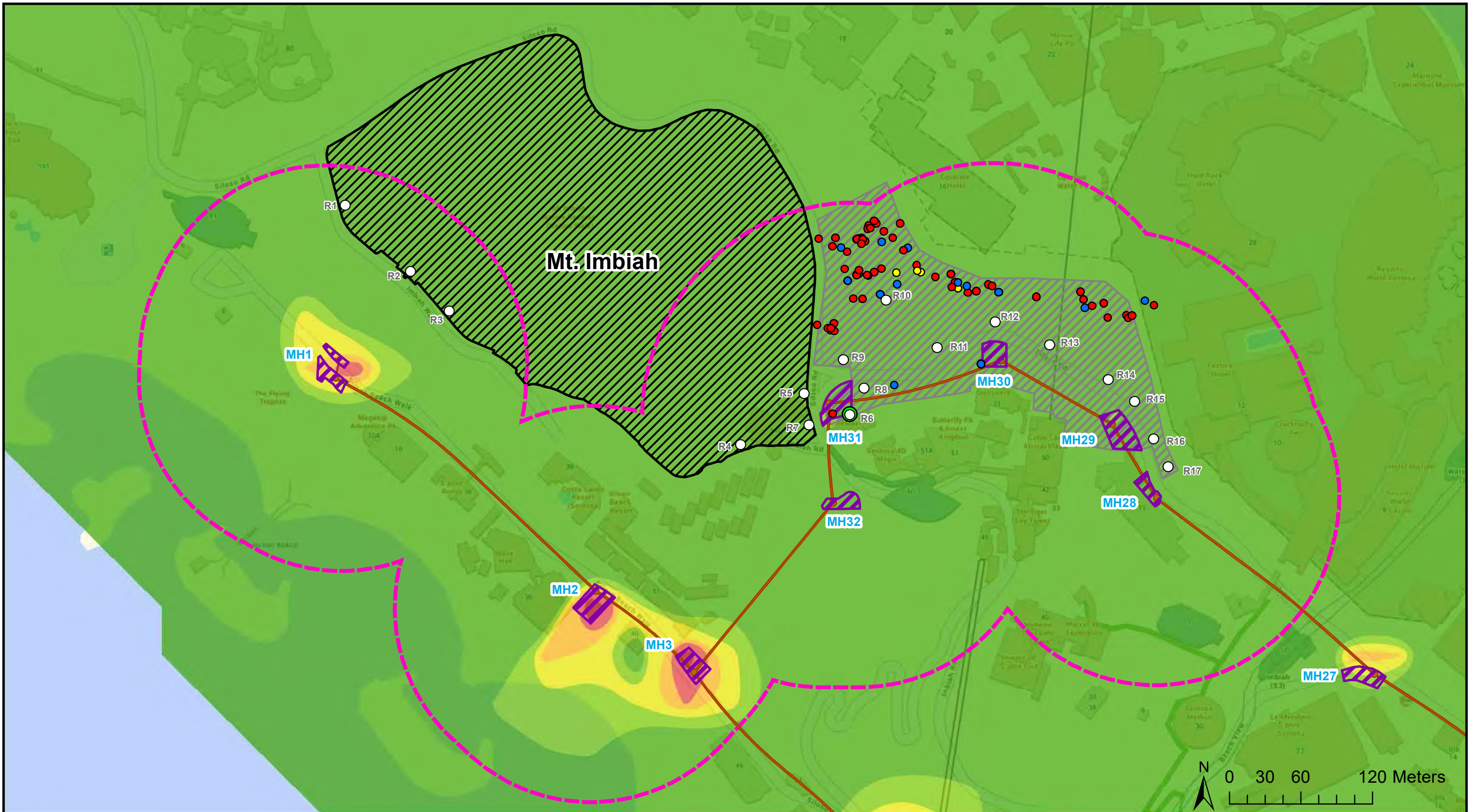
Scenario 2b: Pipe Jacking (Emergency Situation)

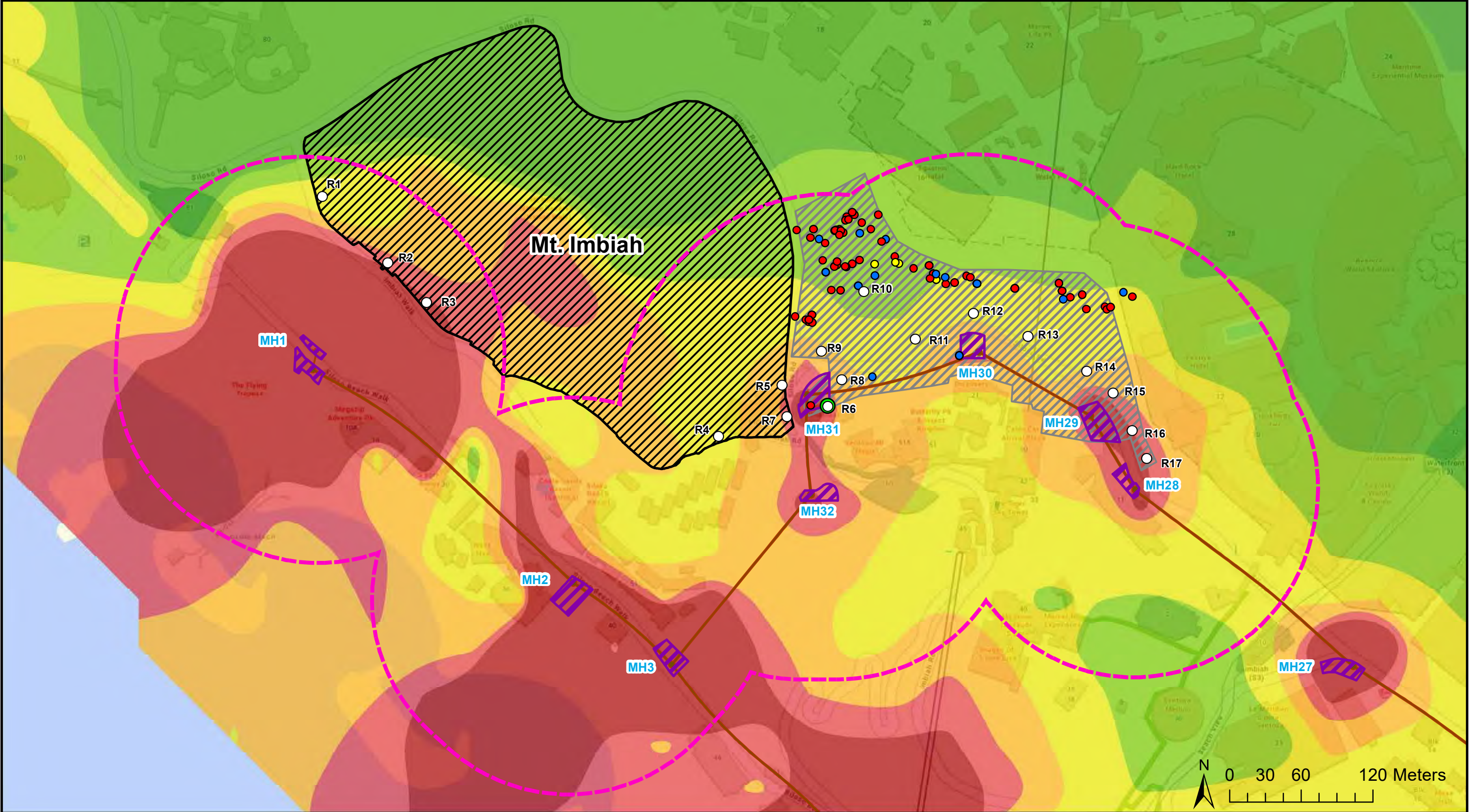
In accordance with information reflected in Table 8-20 (1.5 m) and Table 8-21 (12 m), the Impact Intensity for Scenario 2a was assessed to be **Negligible** (no exceedance, refer to Table 6-4) in Mt. Serapong, and the corresponding Impact Consequence for the ESRs of varying auditory priorities were determined to range from **Imperceptible – Very Low** (refer to Table 6-5). In relation to the Impact Consequence and the **Rare** Likelihood (refer to Table 6-6) of Scenario 2a, it was determined that the Impact Significance for ESRs near Mt. Serapong to be **Negligible** (refer to Table 6-7) as reflected in Table 8-23. As no exceedance was predicted to arise from Scenario 2b: Pipe Jacking (Emergency Situation), no mitigation measures would be required for this scenario.

Table 8-23 Summary of Noise Impacts to Focal Ecologically Sensitive Receptors - Mt. Serapong

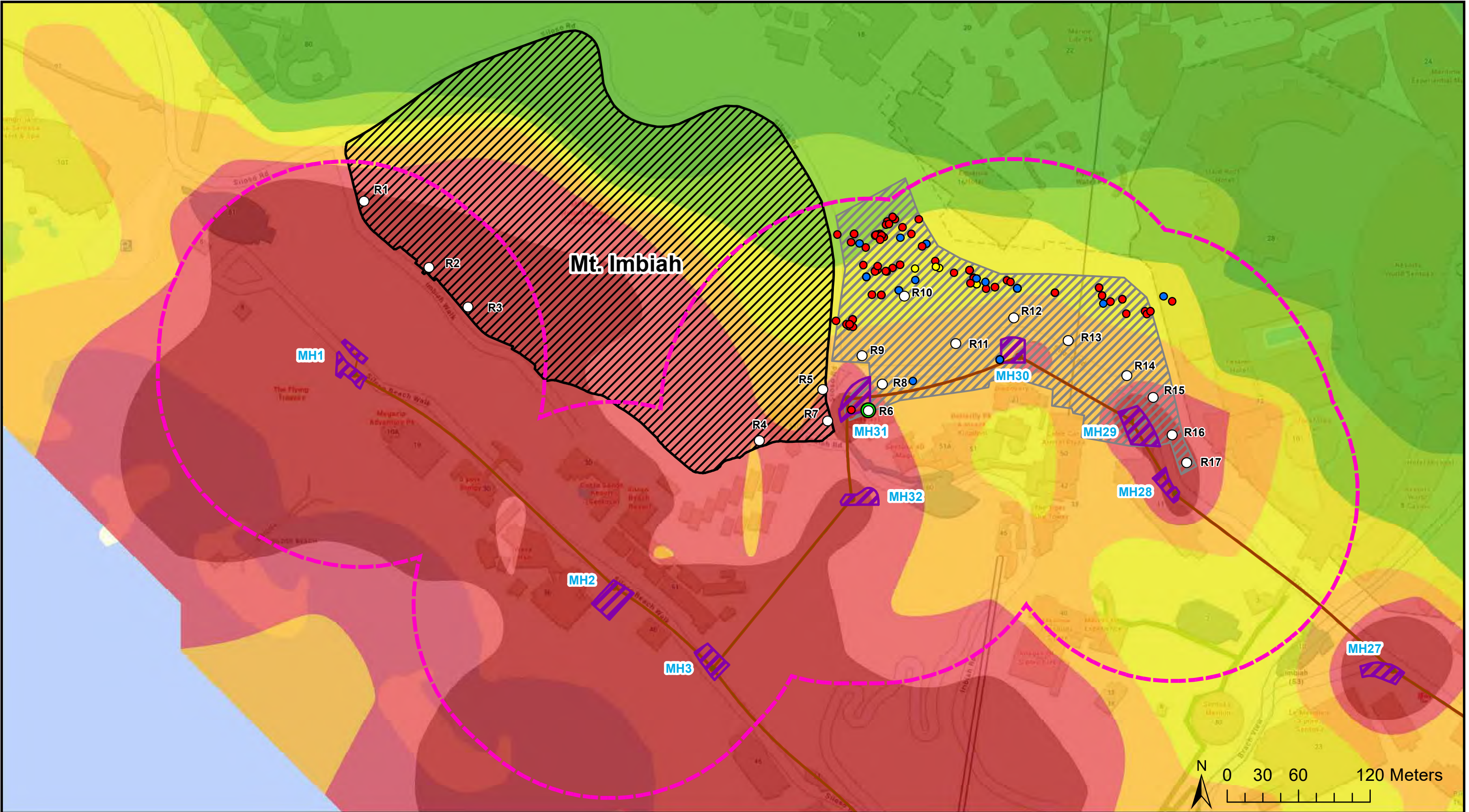
No.	Faunal Group	Common name	Auditory Sensitivity	Highest Impact Significance		
				Scenario 1: Ground Improvement Work	Scenario 2a: Pipe Jacking (24-hour Machine Operation)	Scenario 2b: Pipe Jacking (Emergency Situation)
1	Amphibian	Greenhouse frog	1	Moderate	Negligible	Negligible
2	Amphibian	Banded bull frog	1	Moderate	Negligible	Negligible
3	Amphibian	Four-lined tree frog	1	Moderate	Negligible	Negligible
4	Reptile	Oriental whip snake	2	Moderate	Negligible	Negligible
5	Reptile	Many-lined sun skink	2	Moderate	Negligible	Negligible
6	Reptile	Spotted house gecko	2	Moderate	Negligible	Negligible
7	Reptile	Equatorial spitting cobra	2	Moderate	Negligible	Negligible
8	Bird	Javan myna	1	Moderate	Negligible	Negligible
9	Bird	Crimson sunbird	1	Moderate	Negligible	Negligible
10	Bird	*Oriental pied hornbill	1	Moderate	Negligible	Negligible
11	Bird	Brown-throated sunbird	1	Moderate	Negligible	Negligible
12	Bird	Asian glossy starling	1	Moderate	Negligible	Negligible
13	Bird	Tanimbar corella	1	Moderate	Negligible	Negligible
14	Bird	Large-tailed nightjar	1	Moderate	Negligible	Negligible
15	Bird	Common emerald dove	1	Moderate	Negligible	Negligible
16	Bird	Olive-backed sunbird	1	Moderate	Negligible	Negligible
17	Bird	Scarlet-backed flowerpecker	1	Moderate	Negligible	Negligible
18	Bird	Greater racket-tailed drongo	1	Moderate	Negligible	Negligible
19	Bird	Asian koel	1	Moderate	Negligible	Negligible
20	Bird	Oriental dollarbird	1	Moderate	Negligible	Negligible
21	Bird	Chinese hwamei	1	Moderate	Negligible	Negligible
22	Bird	Common hill myna	1	Moderate	Negligible	Negligible
23	Bird	White-bellied sea eagle	1	Moderate	Negligible	Negligible
24	Bird	Blue-throated bee-eater	1	Moderate	Negligible	Negligible
25	Bird	Pin-striped tit-babbler	1	Moderate	Negligible	Negligible
26	Bird	Asian brown flycatcher	1	Moderate	Negligible	Negligible
27	Bird	*Changeable hawk-eagle	1	Moderate	Negligible	Negligible
28	Bird	Black-naped oriole	1	Moderate	Negligible	Negligible
29	Bird	Dark-necked tailorbird	1	Moderate	Negligible	Negligible
30	Bird	Sunda scops owl	1	Moderate	Negligible	Negligible

No.	Faunal Group	Common name	Auditory Sensitivity	Highest Impact Significance		
				Scenario 1: Ground Improvement Work	Scenario 2a: Pipe Jacking (24-hour Machine Operation)	Scenario 2b: Pipe Jacking (Emergency Situation)
31	Bird	Crested honey-buzzard	1	Moderate	Negligible	Negligible
32	Bird	Arctic warbler	1	Moderate	Negligible	Negligible
33	Bird	Hooded pitta	1	Moderate	Negligible	Negligible
34	Bird	Lineated barbet	1	Moderate	Negligible	Negligible
35	Bird	Yellow-vented bulbul	1	Moderate	Negligible	Negligible
36	Bird	Red-whiskered bulbul	1	Moderate	Negligible	Negligible
37	Bird	Olive-winged bulbul	1	Moderate	Negligible	Negligible
38	Bird	Collared kingfisher	1	Moderate	Negligible	Negligible
39	Bird	Pink-necked green pigeon	1	Moderate	Negligible	Negligible
40	Mammal	Plantain squirrel	2	Moderate	Negligible	Negligible
41	Mammal	*Long-tailed macaque	2	Moderate	Negligible	Negligible
42	Mammal	Malaysian wood rat	2	Moderate	Negligible	Negligible
43	Mammal	Feral cat	2	Moderate	Negligible	Negligible
44	Bat	Lesser dog-faced fruit bat	1	Moderate	Negligible	Negligible
45	Bat	Whiskered myotis	1	Moderate	Negligible	Negligible
46	Bat	Pouch-bearing bat	1	Moderate	Negligible	Negligible
47	Bat	Asiatic lesser yellow house bat	1	Moderate	Negligible	Negligible
48	Bat	Black-bearded tomb bat	1	Moderate	Negligible	Negligible
49	Bat	Bamboo bat	1	Moderate	Negligible	Negligible
50	Other less auditory sensitive fauna species.		3	Minor	Negligible	Negligible
Note: * Denotes fauna species of Conservation Significance (CS). A detailed ESR list reflecting the Impact Significance on the other ESRs not in the table was provided in Appendix N. The colour of the cells corresponds to that of the assessment matrices in Section 6.4.2.						

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Legend Construction Worksites DGS Manholes & Pipeline Nature Areas Biodiversity Study Area for Mt. Imbiah and Mt. Serapong Bamboo Clusters Study Area (150m) - Ecologically Sensitive Receptors Noise Sensitive Receptors Ecologically Sensitive Receptors Representative Ecologically Sensitive Receptors Auditory Sensitivity Priority 1 Priority 2 Priority 3 Noise Exceedance Criteria (Weekdays): NM01: 56 dB(A) NM02: 58 dB(A) Noise level L_{Aeq}(5 min) in dB(A) <= 47 47 < <= 50 50 < <= 53 53 < <= 56 56 < <= 59 59 <							Qualified Person Endorsement : NA	Consultant : AECOM	Project Title : Contract No. SDC/21.8.2/19: Environmental Study For The Proposed Deep Gravity Sewer Project at Sentosa			Figure Title : Construction Phase L_{Aeq} (5min) Noise Contours for ESRs near Mt. Imbiah (1.5 m) Scenario 1: Ground Improvement Work Weekdays (7am - 7pm)		
							Client Endorsement : NA							
	B	NOV 2021	SYT	Final Report Rev B	JAG/NHT	JAG			Designed SYT	Checked JAG/NHT	Approved JAG	Figure No. : 8-7	Rev. B	Sheet 1 of 1
	A	JUL 2021	SYT	Final Report Rev A	JAG/NHT	JAG				Drawn SYT	Date NOV 2021	CAD File Name : NA		
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	Rev.	Date	By	Description	Chk'd	App'd								



Legend

- Construction Worksites
- DGS Manholes & Pipeline
- Nature Areas
- Biodiversity Study Area for Mt. Imbiah and Mt. Serapong
- Bamboo Clusters
- Study Area (150m) - Ecologically Sensitive Receptors

Noise Sensitive Receptors

Ecologically Sensitive Receptors

- Representative Ecologically Sensitive Receptors

Auditory Sensitivity

- Priority 1
- Priority 2
- Priority 3

Noise Exceedance Criteria (Weekdays):
NM01: 56 dB(A)
NM02: 58 dB(A)

Noise level LAeq(5 min) in dB(A)

<= 47	Green
47 < 50	Light Green
50 < 53	Yellow
53 < 56	Orange
56 < 59	Red

B	NOV 2021	SYT	Final Report Rev B	JAG/NHT	JAG	
A	JUL 2021	SYT	Final Report Rev A	JAG/NHT	JAG	
-	MAY 2021	SYT	Final Report	JAG/NHT	JAG	
Rev.	Date	By	Description	Chk'd	App'd	

Qualified Person Endorsement :
NA

Client Endorsement :
NA

Consultant :
AECOM

Project Title :
**Contract No. SDC/21.8.2/19:
Environmental Study
For The Proposed Deep Gravity
Sewer Project at Sentosa**

Designed SYT	Checked JAG/NHT	Approved JAG
	Drawn SYT	Date NOV 2021

Figure Title : **Construction Phase LAeq (5min)
Comparison of Noise Contours
for ESRs near Mt. Imbiah (12 m)
Scenario 1: Ground Improvement Work
Weekdays (7am - 7pm)**

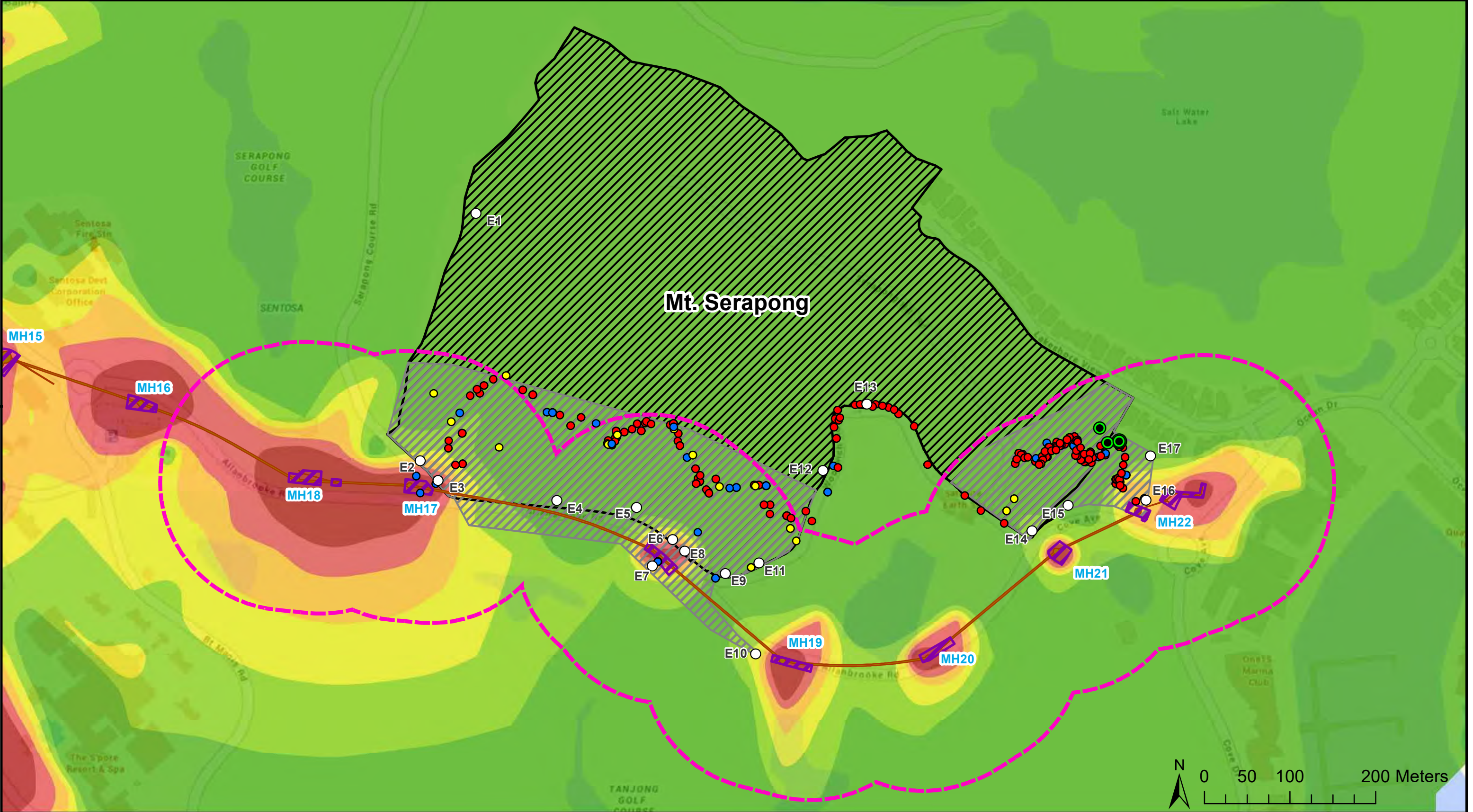
Figure No. : 8-9	Rev. B	Sheet 1 of 1
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CAD File Name : NA

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Legend

- Construction Worksites
- DGS Manholes & Pipeline
- Nature Areas
- Biodiversity Study Area for Mt. Imbiah and Mt. Serapong
- Bamboo Clusters
- Study Area (150m) - Ecologically Sensitive Receptors

Noise Sensitive Receptors

Ecologically Sensitive Receptors

- Representative Ecologically Sensitive Receptors

Auditory Sensitivity

- Priority 1
- Priority 2
- Priority 3

Noise Exceedance Criteria (Weekdays):
NM05: 69 dB(A)
NM06: 65 dB(A)

Noise level LAeq(5 min) in dB(A)

56 <	≤ 56
59 <	≤ 59
62 <	≤ 62
65 <	≤ 65
68 <	≤ 68

B	NOV 2021	SYT	Final Report Rev B	JAG/NHT	JAG	
A	JUL 2021	SYT	Final Report Rev A	JAG/NHT	JAG	
-	MAY 2021	SYT	Final Report	JAG/NHT	JAG	
Rev.	Date	By	Description	Chk'd	App'd	

Qualified Person Endorsement :
NA

Client Endorsement :
NA

Consultant :
AECOM

Project Title :
**Contract No. SDC/21.8.2/19:
Environmental Study
For The Proposed Deep Gravity
Sewer Project at Sentosa**

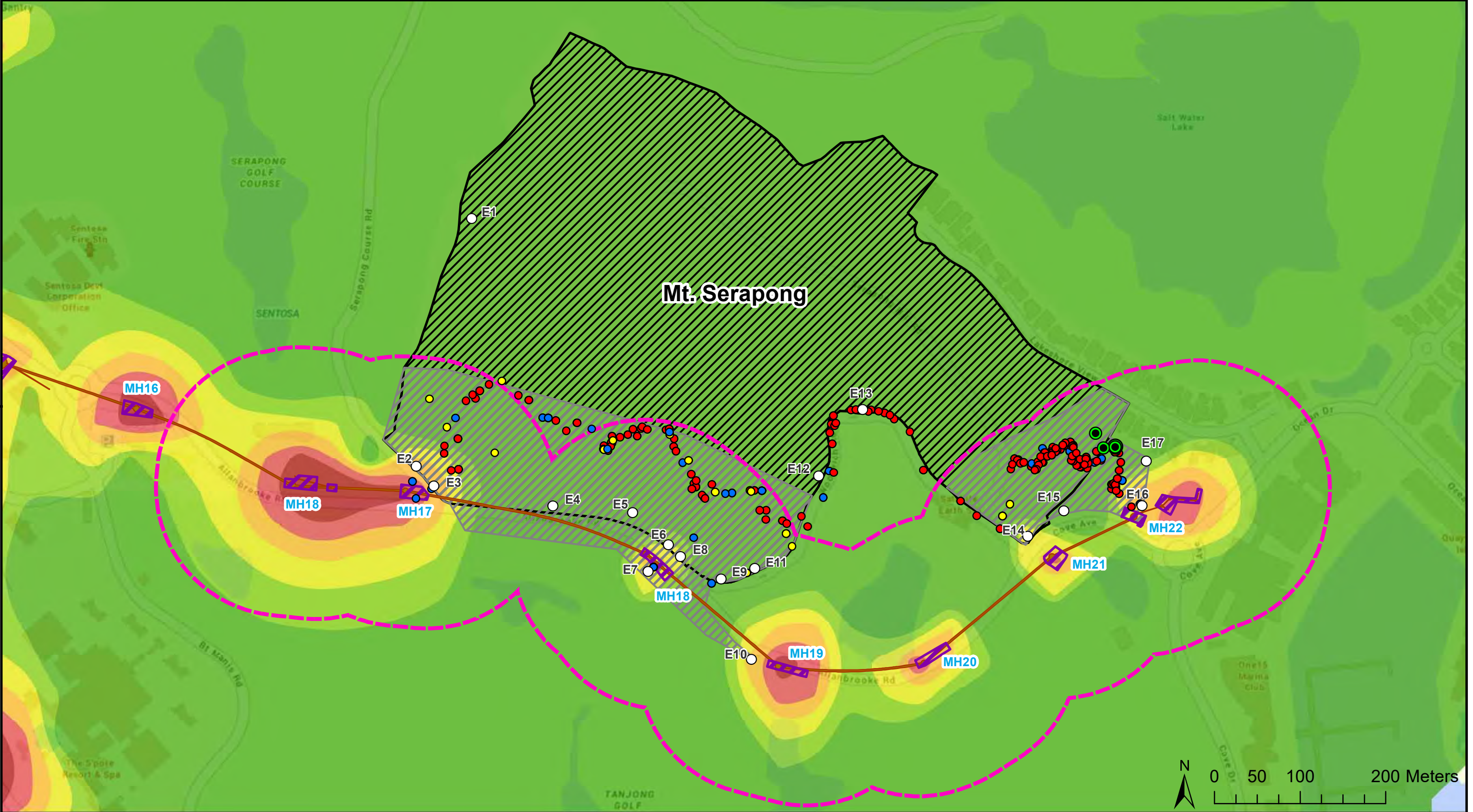
Designed SYT	Checked JAG/NHT	Approved JAG
	Drawn SYT	Date NOV 2021

Figure Title : **Construction Phase LAeq (5min)
Noise Contours for ESRs
near Mt. Serapong (1.5 m)
Scenario 1: Ground Improvement Work
Weekdays (7am - 7pm)**

Figure No. : 8-11	Rev. B	Sheet 1 of 1
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CAD File Name : NA

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Legend

- Construction Worksites
- DGS Manholes & Pipeline
- Nature Areas
- Biodiversity Study Area for Mt. Imbiah and Mt. Serapong
- Bamboo Clusters
- Study Area (150m) - Ecologically Sensitive Receptors

Noise Sensitive Receptors

Ecologically Sensitive Receptors

- Representative Ecologically Sensitive Receptors

Auditory Sensitivity

- Priority 1
- Priority 2
- Priority 3

Noise level $L_{Aeq}(12\text{ hour})$ in dB(A)

57 <	≤ 57
60 <	≤ 60
63 <	≤ 63
66 <	≤ 66
69 <	≤ 69

Noise Exceedance Criteria (Weekdays):
NM05: 70 dB(A)
NM06: 66 dB(A)

B	NOV 2021	SYT	Final Report Rev B	JAG/NHT	JAG	
A	JUL 2021	SYT	Final Report Rev A	JAG/NHT	JAG	
-	MAY 2021	SYT	Final Report	JAG/NHT	JAG	
Rev.	Date	By	Description	Chk'd	App'd	

Qualified Person Endorsement :
NA

Client Endorsement :
NA

Consultant :

AECOM

Project Title :

**Contract No. SDC/21.8.2/19:
Environmental Study
For The Proposed Deep Gravity
Sewer Project at Sentosa**

Designed SYT	Checked JAG/NHT	Approved JAG
	Drawn SYT	Date NOV 2021

Figure Title : **Construction Phase $L_{Aeq}(12\text{hour})$
Noise Contours for ESRs
near Mt. Serapong (20 m)
Scenario 1: Ground Improvement Work
Weekdays (7am - 7pm)**

Figure No. :
8-12

CAD File Name : NA

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Source of basemap - OneMap

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8.7.2 Human Receptors

The noise impact assessment results with the respective Impact Significance for the three (3) different scenarios were reflected in Appendix U. Based on results predicted by the noise models, human receptors were predicted to be not experiencing noise exceedance arising from noise emitted from the construction activities in all three (3) different scenarios. The resulting Impact Intensity was **Negligible** due to no predicted noise exceedances (refer to Table 6-4), and the corresponding Impact Consequence for the human receptors were determined to range from **Imperceptible – Very Low** (refer to Table 6-5).

In relation to the Impact Consequence and Likelihoods of the three (3) different scenarios, it was determined for Scenario 1 with an **Occasional** Likelihood, and Scenario 2a and Scenario 2b with a Likelihood of **Rare**, that the Impact Significance arising from the proposed construction activities would result in an overall Impact Significance ranging from **Minor – Negligible** (refer to Table 6-7) as reflected in Table 8-25 below. As such, mitigation measures were not required as no noise exceedance on human receptors were predicted to occur based on the noise modelling results (see Appendix U).

The resulting noise contours representative of the worst-case noisiest scenario, Scenario 1: Ground Improvement Work, with the highest sound power level input of the three (3) scenarios (see Table 8-7) were reflected in the following as listed in Table 8-24 below.

Table 8-24 List of Grid Noise Map Figures for Human Impacts

Scenario	Weekdays/ Weekend/ Public Holidays (Construction Schedule)	L _{Aeq}	Figure
Scenario 1: Ground Improvement Work			
West	Weekdays (7am – 7pm)	L _{Aeq} (12 hour)	Figure 8-14
	Weekdays (7am – 7pm)	L _{Aeq} (5 min)	Figure 8-15
North	Weekdays (7am – 7pm)	L _{Aeq} (12 hour)	Figure 8-16
	Weekdays (7am – 7pm)	L _{Aeq} (5 min)	Figure 8-17
South	Weekdays (7am – 7pm)	L _{Aeq} (12 hour)	Figure 8-18
	Weekdays (7am – 7pm)	L _{Aeq} (5 min)	Figure 8-19
East	Weekdays (7am – 7pm)	L _{Aeq} (12 hour)	Figure 8-20
	Weekdays (7am – 7pm)	L _{Aeq} (5 min)	Figure 8-21
<i>Note: For construction schedules sharing the same sound power levels (see Table 8-7) were grouped together and represented by the same figure.</i>			

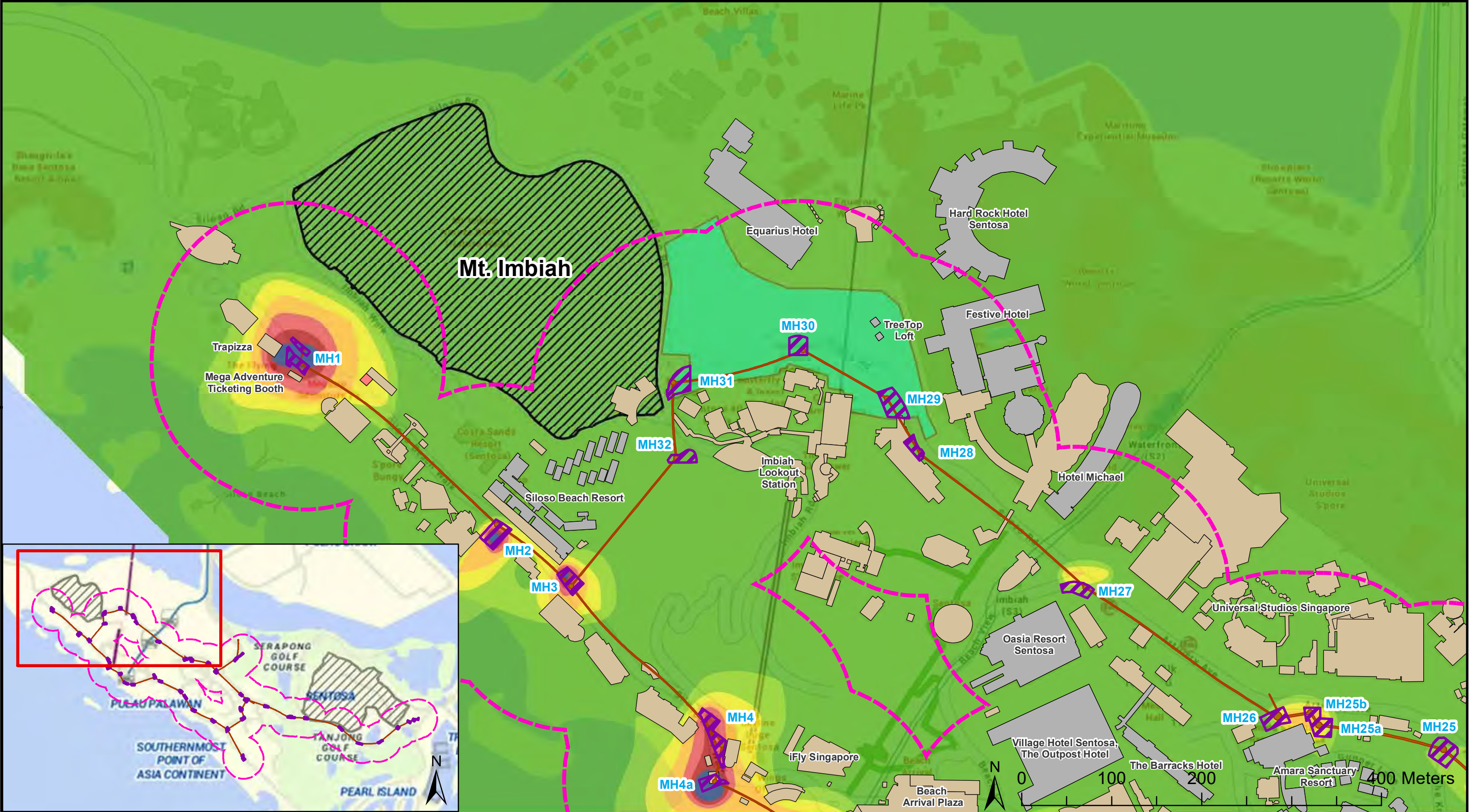
Based on the predicted noise levels and maximum noise exceedances observed for the three (3) scenarios reflected in Appendix U, construction noise impact assessment for human receptors was performed and summarized in Table 8-25 below. This evaluation was carried out based on the assessment methodology in Section 6.4.2.

Table 8-25 Summary of Construction Noise Impacts - Human Impacts

Nearest Noise Logger / Scenario	Noise Sensitive Receptors	Maximum Exceedance Observed, dB(A)	Impact Intensity	Impact Consequence	Likelihood	Impact Significance
NM01: Near Nestopia at Siloso Beach Walk						
Scenario 1: Ground Improvement Work	(a) Noise Sensitive (Priority 1)	–	Negligible	Very Low	Occasional	Minor
	(b) Residential (Priority 2)	NA.	NA.	NA.	NA.	NA.
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Occasional	Negligible
Scenario 2a: Pipe Jacking (24-hour Machine Operation)	(a) Noise Sensitive (Priority 1)	–	Negligible	Very Low	Rare	Minor
	(b) Residential (Priority 2)	NA.	NA.	NA.	NA.	NA.
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Rare	Negligible
Scenario 2b: Pipe Jacking (Emergency Situation)	(a) Noise Sensitive (Priority 1)	–	Negligible	Very Low	Rare	Minor
	(b) Residential (Priority 2)	NA.	NA.	NA.	NA.	NA.
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Rare	Negligible
NM02: Near Imbiah Lookout Station at Sentosa Island						
Scenario 1: Ground Improvement Work	(a) Noise Sensitive (Priority 1)	NA.	NA.	NA.	NA.	NA.
	(b) Residential (Priority 2)	–	Negligible	Imperceptible	Occasional	Negligible
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Occasional	Negligible
Scenario 2a: Pipe Jacking (24-hour Machine Operation)	(a) Noise Sensitive (Priority 1)	NA.	NA.	NA.	NA.	NA.
	(b) Residential (Priority 2)	–	Negligible	Imperceptible	Rare	Negligible
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Rare	Negligible
Scenario 2b: Pipe Jacking (Emergency Situation)	(a) Noise Sensitive (Priority 1)	NA.	NA.	NA.	NA.	NA.
	(b) Residential (Priority 2)	–	Negligible	Imperceptible	Rare	Negligible
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Rare	Negligible
NM03: Near Amara Sanctuary Resort Sentosa						
Scenario 1: Ground Improvement Work	(a) Noise Sensitive (Priority 1)	NA.	NA.	NA.	NA.	NA.
	(b) Residential (Priority 2)	–	Negligible	Imperceptible	Occasional	Negligible
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Occasional	Negligible

Nearest Noise Logger / Scenario	Noise Sensitive Receptors	Maximum Exceedance Observed, dB(A)	Impact Intensity	Impact Consequence	Likelihood	Impact Significance
Scenario 2a: Pipe Jacking (24-hour Machine Operation)	(a) Noise Sensitive (Priority 1)	NA.	NA.	NA.	NA.	NA.
	(b) Residential (Priority 2)	–	Negligible	Imperceptible	Rare	Negligible
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Rare	Negligible
Scenario 2b: Pipe Jacking (Emergency Situation)	(a) Noise Sensitive (Priority 1)	NA.	NA.	NA.	NA.	NA.
	(b) Residential (Priority 2)	–	Negligible	Imperceptible	Rare	Negligible
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Rare	Negligible
NM04: Near Palawan Beach and Opposite Capella Singapore						
Scenario 1: Ground Improvement Work	(a) Noise Sensitive (Priority 1)	NA.	NA.	NA.	NA.	NA.
	(b) Residential (Priority 2)	–	Negligible	Imperceptible	Occasional	Negligible
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Occasional	Negligible
Scenario 2a: Pipe Jacking (24-hour Machine Operation)	(a) Noise Sensitive (Priority 1)	NA.	NA.	NA.	NA.	NA.
	(b) Residential (Priority 2)	–	Negligible	Imperceptible	Rare	Negligible
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Rare	Negligible
Scenario 2b: Pipe Jacking (Emergency Situation)	(a) Noise Sensitive (Priority 1)	NA.	NA.	NA.	NA.	NA.
	(b) Residential (Priority 2)	–	Negligible	Imperceptible	Rare	Negligible
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Rare	Negligible
NM05: At roadside behind Islander Pre-School						
Scenario 1: Ground Improvement Work	(a) Noise Sensitive (Priority 1)	–	Negligible	Very Low	Occasional	Minor
	(b) Residential (Priority 2)	–	Negligible	Imperceptible	Occasional	Negligible
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Occasional	Negligible
Scenario 2a: Pipe Jacking (24-hour Machine Operation)	(a) Noise Sensitive (Priority 1)	–	Negligible	Very Low	Rare	Minor
	(b) Residential (Priority 2)	–	Negligible	Imperceptible	Rare	Negligible
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Rare	Negligible
Scenario 2b: Pipe Jacking (Emergency Situation)	(a) Noise Sensitive (Priority 1)	–	Negligible	Very Low	Rare	Minor
	(b) Residential	–	Negligible	Imperceptible	Rare	Negligible

Nearest Noise Logger / Scenario	Noise Sensitive Receptors	Maximum Exceedance Observed, dB(A)	Impact Intensity	Impact Consequence	Likelihood	Impact Significance
	(Priority 2)					
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Rare	Negligible
NM06: Opposite Lakeshore View residence along Ocean Drive and near Sentosa Cove Village Car Park						
Scenario 1: Ground Improvement Work	(a) Noise Sensitive (Priority 1)	NA.	NA.	NA.	NA.	NA.
	(b) Residential (Priority 2)	–	Negligible	Imperceptible	Occasional	Negligible
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Occasional	Negligible
Scenario 2a: Pipe Jacking (24-hour Machine Operation)	(a) Noise Sensitive (Priority 1)	NA.	NA.	NA.	NA.	NA.
	(b) Residential (Priority 2)	–	Negligible	Imperceptible	Rare	Negligible
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Rare	Negligible
Scenario 2b: Pipe Jacking (Emergency Situation)	(a) Noise Sensitive (Priority 1)	NA.	NA.	NA.	NA.	NA.
	(b) Residential (Priority 2)	–	Negligible	Imperceptible	Rare	Negligible
	(c) Others (Priority 3)	–	Negligible	Imperceptible	Rare	Negligible
<i>Note: NA. – Not Applicable</i> <i>The colour of the cells corresponds to that of the assessment matrices in Section 6.4.2,</i> <i>Refer to Table 6-1 for the definition of the noise sensitive human receptors.</i> <i>The full list of construction noise prediction results for the individual human receptors was presented in Appendix U.</i>						



Legend

- Base Construction Worksites
- DGS Manholes & Pipeline
- Nature Areas
- Study Area (150m)
- Biodiversity Study Area for Mt. Imbiah and Mt. Serapong

Noise Sensitive Receptors

Human Receptors

Receptor Sensitivity	Corrected Noise Criteria (Weekdays):
Priority 1	NM01: 66 dB(A) NM02: 67 dB(A)
Priority 2	NM01: 75 dB(A) NM02: 76 dB(A)
Priority 3	NM01: 75 dB(A) NM02: 76 dB(A)

Noise level LAeq(12 hour) in dB(A)

57 <	<= 57
57 <	<= 60
60 <	<= 63
63 <	<= 66
66 <	<= 69
69 <	<= 72
72 <	

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B	NOV 2021	SYT	Final Report Rev B	JAG/NHT	JAG
A	AUG 2021	SYT	Final Report Rev A	JAG/NHT	JAG
-	MAY 2021	SYT	Final Report	JAG/NHT	JAG

Qualified Person Endorsement : NA

Client Endorsement : NA

Consultant : **AECOM**

Project Title : **Contract No. SDC/21.8.2/19: Environmental Study For The Proposed Deep Gravity Sewer Project at Sentosa**

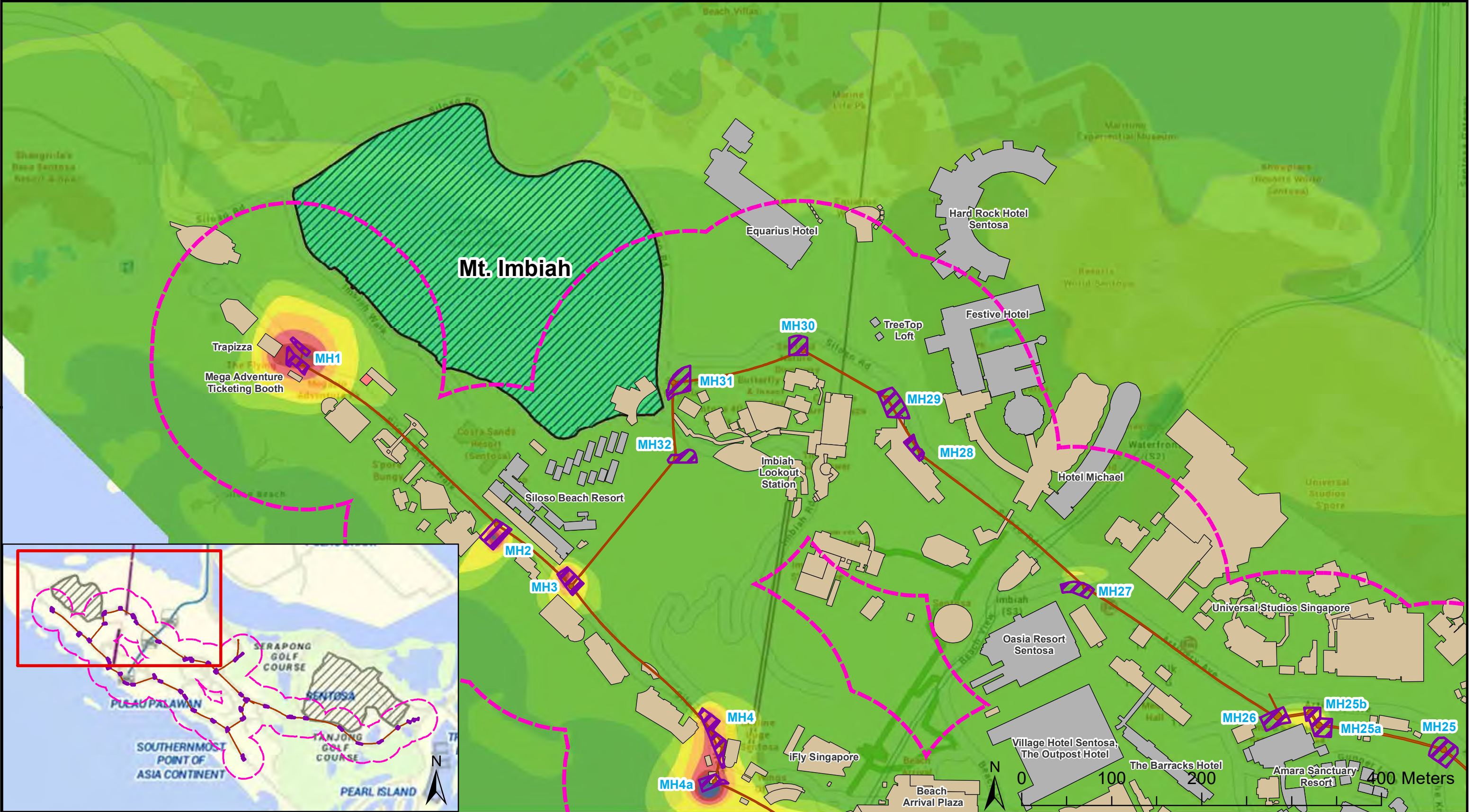
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	Drawn SYT	Date NOV 2021

Figure Title : **Construction Phase, Scenario 1: Ground Improvement Work, LAeq (12hour) for Weekdays (7am – 7pm), West of Sentosa Island for Human Receptors**

Figure No. : 8-14	Rev. B	Sheet 1 of 4
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Legend

- Base Construction Worksites
- DGS Manholes & Pipeline
- Nature Areas
- Study Area (150m)
- Biodiversity Study Area for Mt. Imbiah and Mt. Serapong

Noise Sensitive Receptors

Human Receptors

Receptor Sensitivity	Corrected Noise Criteria (Weekdays):
Priority 1	NM01: 75 dB(A) NM02: 75 dB(A)
Priority 2	NM01: 90 dB(A) NM02: 90 dB(A)
Priority 3	NM01: 90 dB(A) NM02: 90 dB(A)

Noise level LAeq(5 min) in dB(A)

66 <	<= 66
69 <	<= 69
72 <	<= 72
75 <	<= 75
78 <	<= 78
81 <	<= 81

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Qualified Person Endorsement : NA

Client Endorsement : NA

Consultant : **AECOM**

Project Title : **Contract No. SDC/21.8.2/19: Environmental Study For The Proposed Deep Gravity Sewer Project at Sentosa**

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Drawn	Date
SYT	NOV 2021

Figure Title : **Construction Phase, Scenario 1: Ground Improvement Work, L Aeq (5min) for Weekdays (7am – 7pm), West of Sentosa Island for Human Receptors**

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CAD File Name : NA

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Legend

- Base Construction Worksites
- DGS Manholes & Pipeline
- Study Area (150m)
- Biodiversity Study Area for Mt. Imbiah and Mt. Serapong

Noise Sensitive Receptors

Human Receptors

Receptor Sensitivity	Corrected Noise Criteria (Weekdays):
Priority 1	NM03: 75 dB(A)
Priority 2	NM03: 90 dB(A)
Priority 3	NM03: 90 dB(A)

Noise level LAeq(5 min) in dB(A)

66 <	<= 66
69 <	<= 69
72 <	<= 72
75 <	<= 75
78 <	<= 78
81 <	<= 81

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B	NOV 2021	SYT	Final Report Rev B	JAG/NHT	JAG
A	AUG 2021	SYT	Final Report Rev A	JAG/NHT	JAG
-	MAY 2021	SYT	Final Report	JAG/NHT	JAG

Qualified Person Endorsement : NA

Client Endorsement : NA

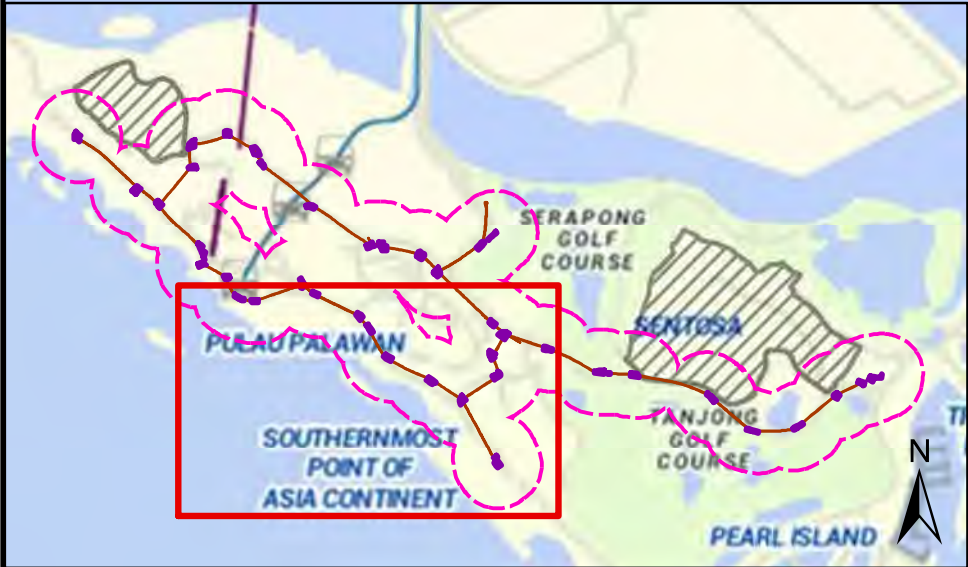
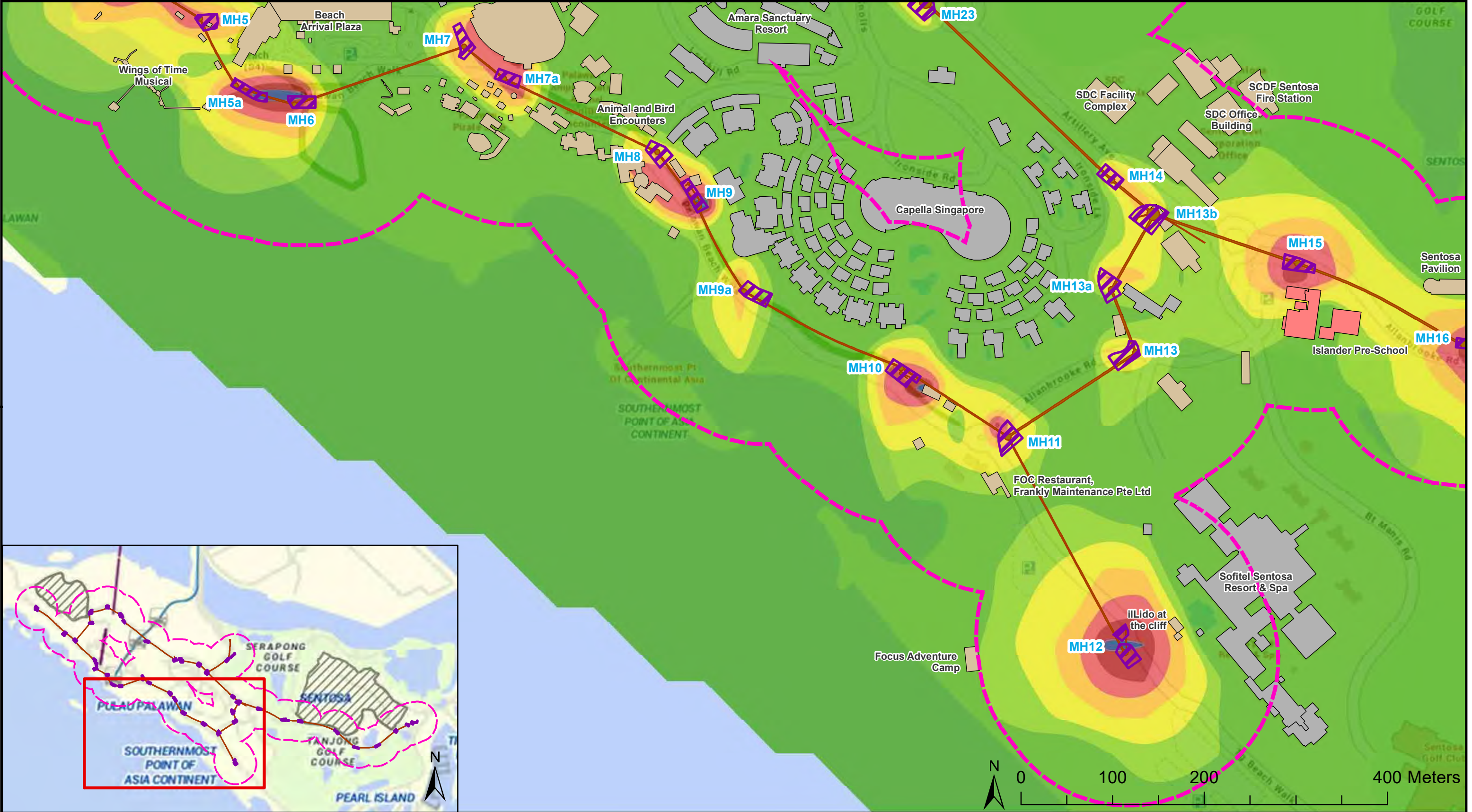
Consultant : **AECOM**

Project Title : **Contract No. SDC/21.8.2/19: Environmental Study For The Proposed Deep Gravity Sewer Project at Sentosa**

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Figure Title : **Construction Phase, Scenario 1: Ground Improvement Work, L Aeq (5min) for Weekdays (7am – 7pm), North of Sentosa Island for Human Receptors**

Figure No. : 8-17	Rev. B	Sheet 2 of 4
CAD File Name : NA		A3



Legend

- Base Construction Worksites
- DGS Manholes & Pipeline
- Study Area (150m)
- Biodiversity Study Area for Mt. Imbiah and Mt. Serapong

Noise Sensitive Receptors

Human Receptors

Receptor Sensitivity	Corrected Noise Criteria (Weekdays):
Priority 1	NM04: 65 dB(A)
Priority 2	NM04: 75 dB(A)
Priority 3	NM04: 75 dB(A)

Noise level LAeq(12 hour) in dB(A)

56 <	<= 56
59 <	<= 59
62 <	<= 62
65 <	<= 65
68 <	<= 68
71 <	<= 71

						Qualified Person Endorsement : NA
						Client Endorsement : NA
B	NOV 2021	SYT	Final Report Rev B	JAG/NHT	JAG	
A	AUG 2021	SYT	Final Report Rev A	JAG/NHT	JAG	
-	MAY 2021	SYT	Final Report	JAG/NHT	JAG	
Rev.	Date	By	Description	Chk'd	App'd	

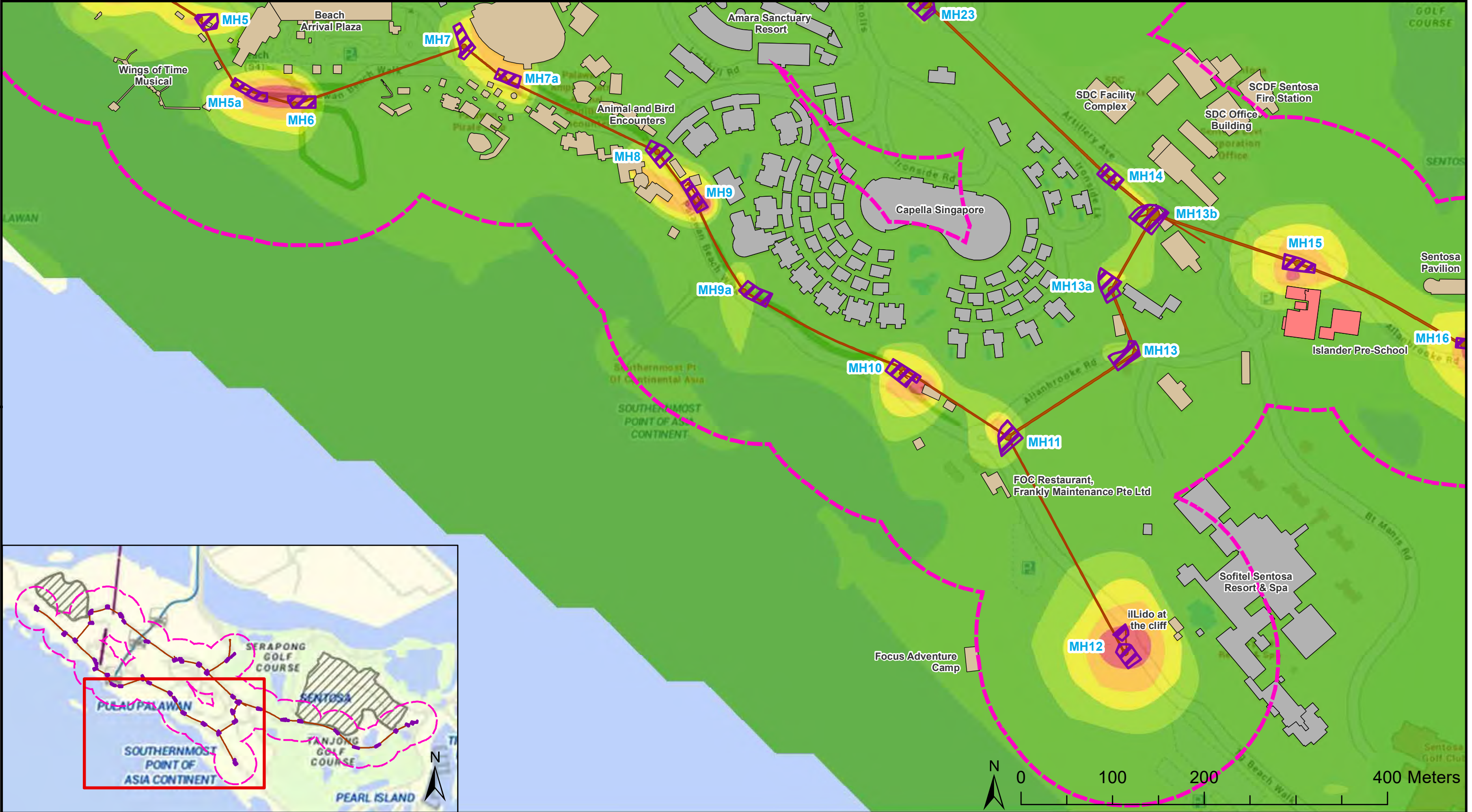
Consultant :
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Project Title :
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Environmental Study
For The Proposed Deep Gravity
Sewer Project at Sentosa**

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Figure Title :
**Construction Phase,
Scenario 1: Ground Improvement Work,
LAeq (12hour) for Weekdays (7am – 7pm),
South of Sentosa Island
for Human Receptors**

Figure No. : 8-18	Rev. B	Sheet 3 of 4
CAD File Name : NA		A3



Legend

- Base Construction Worksites
- DGS Manholes & Pipeline
- Study Area (150m)
- Biodiversity Study Area for Mt. Imbiah and Mt. Serapong

Noise Sensitive Receptors

Human Receptors

Receptor Sensitivity	Corrected Noise Criteria (Weekdays):
Priority 1	NM04: 75 dB(A)
Priority 2	NM04: 90 dB(A)
Priority 3	NM04: 90 dB(A)

Noise level LAeq(5 min) in dB(A)

66 <	<= 66
69 <	<= 69
72 <	<= 72
75 <	<= 75
78 <	<= 78
81 <	<= 81

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-	MAY 2021	SYT	Final Report	JAG/NHT	JAG

Qualified Person Endorsement : NA

Client Endorsement : NA

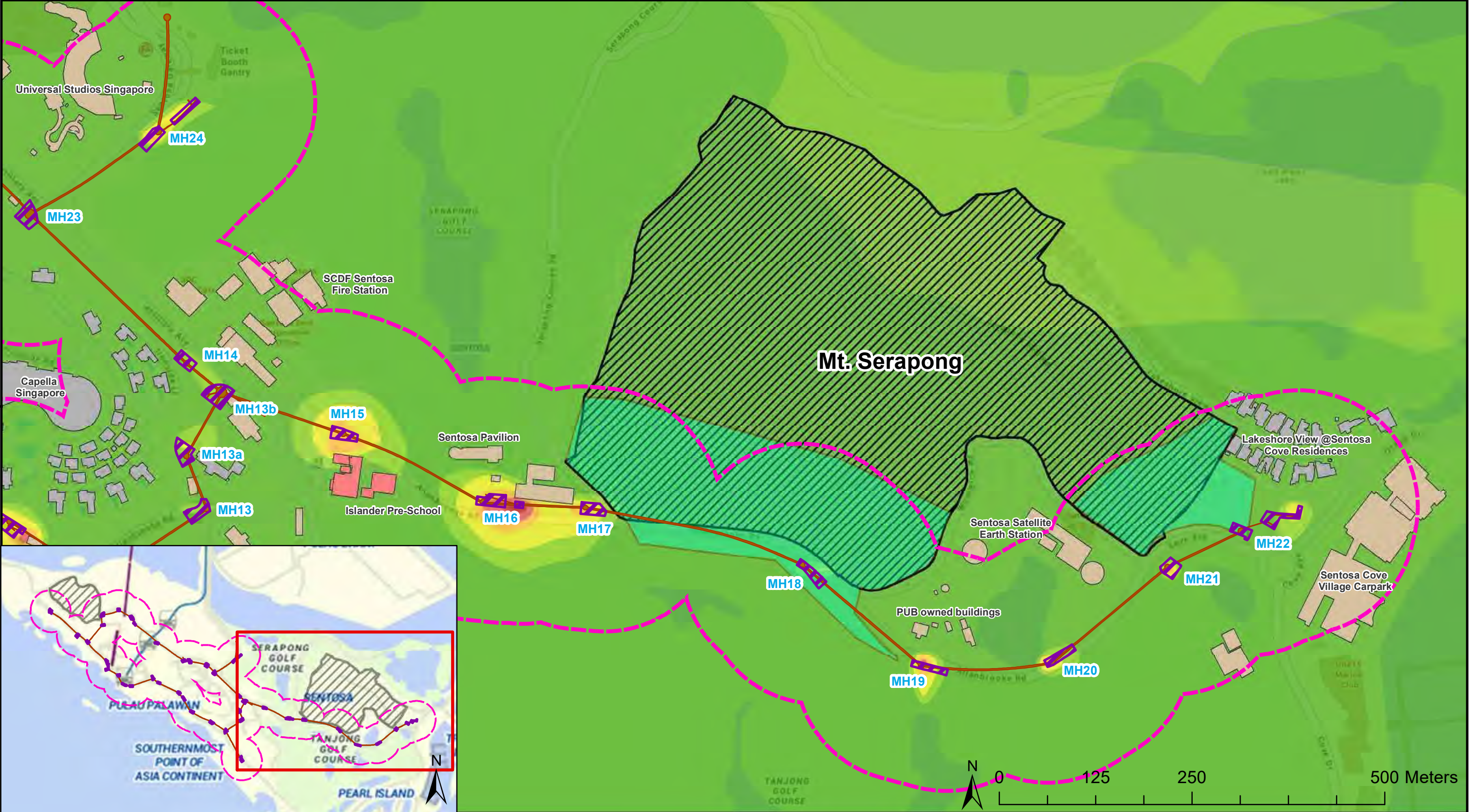
Consultant : **AECOM**

Project Title : **Contract No. SDC/21.8.2/19: Environmental Study For The Proposed Deep Gravity Sewer Project at Sentosa**

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Figure Title : **Construction Phase, Scenario 1: Ground Improvement Work, L_{Aeq} (5min) for Weekdays (7am – 7pm), South of Sentosa Island for Human Receptors**

Figure No. : 8-19	Rev. B	Sheet 3 of 4
CAD File Name : NA		A3



Legend

- Base Construction Worksites
- DGS Manholes & Pipeline
- Nature Areas
- Study Area (150m)
- Biodiversity Study Area for Mt. Imbiah and Mt. Serapong

Noise Sensitive Receptors

Human Receptors

Receptor Sensitivity	Corrected Noise Criteria (Weekdays):
Priority 1	NM05: 70 dB(A) NM02: 67 dB(A)
Priority 2	NM05: 76 dB(A) NM02: 76 dB(A)
Priority 3	NM05: 76 dB(A) NM02: 76 dB(A)

Noise level LAeq(12 hour) in dB(A)

61 <	<= 61
64 <	<= 64
67 <	<= 67
70 <	<= 70
73 <	<= 73
76 <	<= 76

							Qualified Person Endorsement : NA
							Client Endorsement : NA
B	NOV 2021	SYT	Final Report Rev B	JAG/NHT	JAG		
A	AUG 2021	SYT	Final Report Rev A	JAG/NHT	JAG		
-	MAY 2021	SYT	Final Report	JAG/NHT	JAG		
Rev.	Date	By	Description	Chk'd	App'd		

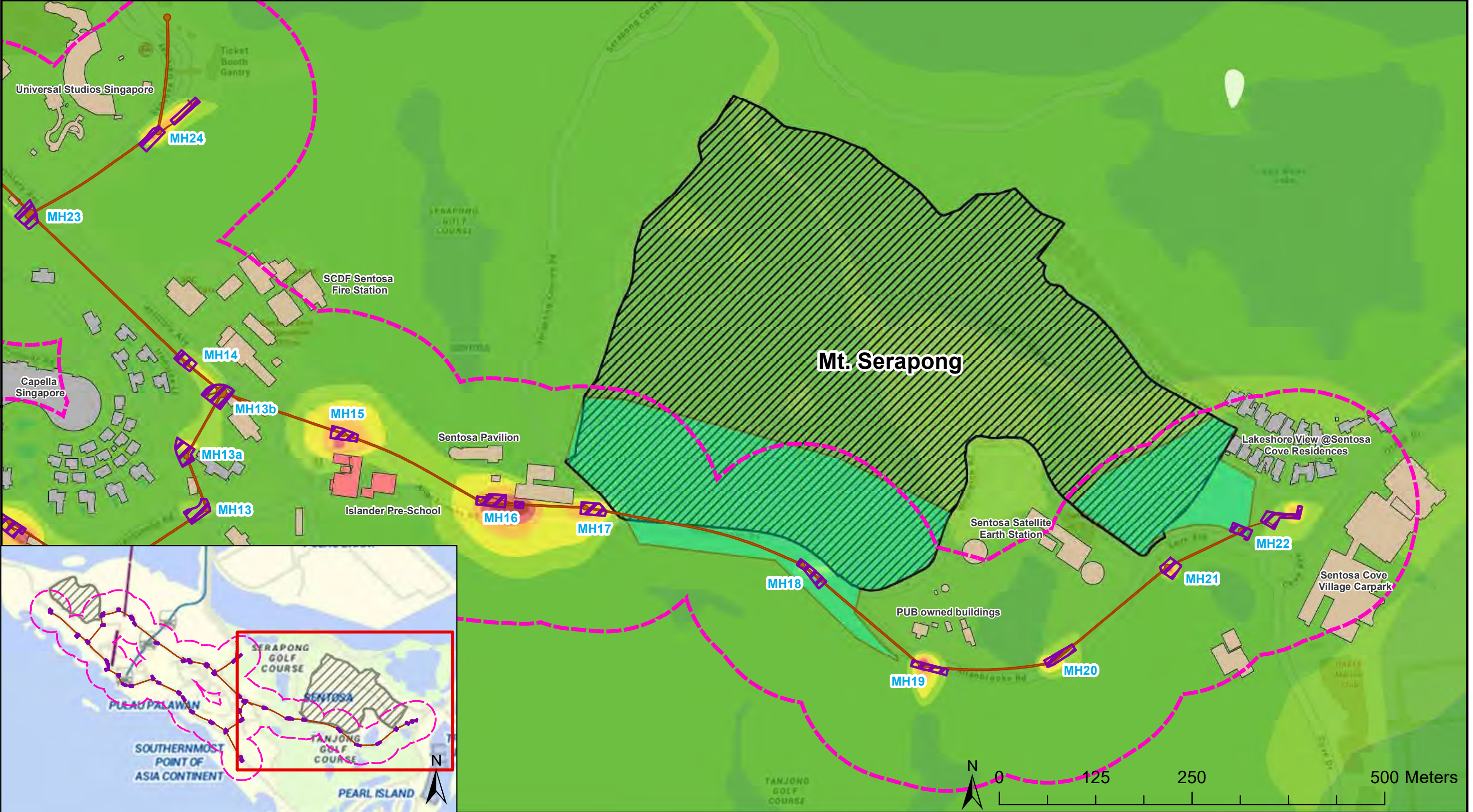
Consultant :
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Project Title :
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Sewer Project at Sentosa**

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Figure Title :
**Construction Phase,
Scenario 1: Ground Improvement Work,
LAeq (12hour) for Weekdays (7am – 7pm),
East of Sentosa Island
for Human Receptors**

Figure No. : 8-20	Rev. B	Sheet 4 of 4
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Legend

- Base Construction Worksites
- DGS Manholes & Pipeline
- Nature Areas
- Study Area (150m)
- Biodiversity Study Area for Mt. Imbiah and Mt. Serapong

Noise Sensitive Receptors

Human Receptors

Receptor Sensitivity	Corrected Noise Criteria (Weekdays):
Priority 1	NM05: 76 dB(A) NM02: 75 dB(A)
Priority 2	NM05: 90 dB(A) NM02: 90 dB(A)
Priority 3	NM05: 90 dB(A) NM02: 90 dB(A)

Noise level LAeq(5 min) in dB(A)

66 <	<= 66
69 <	<= 69
72 <	<= 72
75 <	<= 75
78 <	<= 78
81 <	<= 81

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Qualified Person Endorsement : NA

Client Endorsement : NA

Consultant : **AECOM**

Project Title : **Contract No. SDC/21.8.2/19: Environmental Study For The Proposed Deep Gravity Sewer Project at Sentosa**

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Figure Title : **Construction Phase, Scenario 1: Ground Improvement Work, LAeq (5min) for Weekdays (7am – 7pm), East of Sentosa Island for Human Receptors**

Figure No. : 8-21	Rev. B	Sheet 4 of 4
CAD File Name : NA		A3