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Provision of Services to Conduct Environmental Impact Study

Environmental Impact Study (Windsor & Eng Neo Avenue Forest) Final Report

Study Stage: Final

Volume 4 of 5

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9. Soil and Groundwater

9.1 Introduction

Construction and operational activities, if not managed properly, can lead to the potential contamination of soil and groundwater. Furthermore, during the land preparation and excavations for construction works there is also a potential to encounter historically contaminated soils. This section presents the assessment undertaken to define the nature and scale of the potential impacts on soil and groundwater associated with the construction and operational phase of the Project. The section will also outline appropriate control and mitigation measures.

9.2 Methodology and Assumption

This section outlines the methodology adopted for the soil and groundwater baseline analysis as well as for impact assessment for both construction and operational phases. The purpose of soil and groundwater baseline study was to determine the soil profile of the Study Area, hydrogeological conditions of the aquifer and soil and groundwater chemistry which may potentially have adverse impacts on the identified sensitive receptors. Furthermore, the baseline study should ascertain the presence of possible historical pollutants in the underlying soil that may also cause adverse impacts during construction and operational phases. Baseline conditions were established based on available secondary data, primarily Historical Land Use Survey (HLUS) report and previously soil and/ or groundwater investigation studies as detailed in Section 9.2.2.

9.2.1 Historical Land Use

Historical land use information of the study is extracted from the LTA's Historical Land Use Survey (HLUS) report [R-4, R-5] for the purpose of this report. The HLUS identifies potentially counterinitiative land uses and areas where deep excavation would occur due to the Project works. This information is analysed to produce an environmental borehole and monitoring well location plan.

9.2.2 Soil and Groundwater Baseline

Besides HLUS and publicly-available secondary data, as a part of soil and groundwater baseline study, AECOM also reviewed previously soil and/ or groundwater investigation studies carried out within the Study Area. These included both Soil Investigation (SI) reports (focusing on geotechnical characteristics of soil) [R-74] [R-75] [R-76] [R-77] [R-78] [R-79] [R-80] [R-81] [R-82] and soil and groundwater baseline studies (focusing on physico-chemical parameters of soil and groundwater) [R-70].

9.2.2.1 Soil and Groundwater Assessment Criteria

The Dutch Intervention Values (DIV) in the Dutch Environmental Guidelines Soil Remediation Circular [R-41] were adopted in this study for screening of the 12 priority pollutant metals, inorganic compounds, aromatic compounds, polycyclic aromatic hydrocarbons (PAHs), chlorinated hydrocarbons, pesticides and other pollutants in soil and groundwater. The DIV is referenced in the latest Code of Practice for Pollution Control [R-8] (COPPC) by the National Environmental Agency (NEA).

The DIVs are related to spatial parameters and define soil as being seriously contaminated if the mean soil/sediment concentration of at least one substance in at least 25 cubic metres (m^3) of soil-volume, or groundwater concentration in at least 100 m^3 of pore-saturated soil-volume, exceeds the DIV. It is noted that the intervention values for groundwater are not based on a separate risk assessment with regards to the contaminants present in the groundwater but are calculated based on partitioning of chemicals at concentrations equivalent to the intervention values in soil/sediment.

It is recognised that the Dutch Guidelines were developed to assess the acceptability of impacted soil and groundwater at housing estates in the Netherlands and is based on local Dutch ecotoxicology and soil condition (that is, soil made of 10% organic clay or 25% clay), without reference to commercial or industrial general, or similar land uses in Singapore. On that basis, exceedances of the DIVs should not necessarily be interpreted as conclusive regarding the need for remediation. Conversely, if the concentrations of COPCs were below these criteria, it would be reasonable to conclude that the concentrations are not of concern.

9.2.3 Prediction and Evaluation of Impact Assessment

The Study Area adopted for the assessment will follow the HLUS Study Area of 250 m from both sides of the alignment. Soil and groundwater impact assessment was carried out qualitatively based on the HLUS study

findings. Furthermore, where applicable, impact assessment was also based on the soil and groundwater baseline data collected as part of previously carried out soil and/ or groundwater investigations.

9.3 Identification of Soil and Groundwater Sensitive Receptors

The receptor screening for groundwater was conducted within the 250 m Study Area and classified based on methodology defined in Table 6-1.

It is understood that presently groundwater in Singapore is not directly extracted for beneficial use i.e. as a source for potable water, industrial water or irrigation purposes, and hence should be considered as Priority 3, as shown in Table 9-1 below.

Table 9-1 Classification of Receptor Sensitivity

Sensitive Receptor	Description	Receptor Sensitivity	Sensitivity Classification
Soil and Groundwater within the Project Site	The soil and groundwater within the Project site was expected not to pose unacceptable risks to future workers and human receptors.	Not sensitive groundwater (i.e. not directly extracted for any purposes such as drinking or commercial/industrial use)	Priority 3
Watercourses with biodiversity conservation significance where groundwater is partially supporting the streams ingress from the construction worksite and operational footprint	Groundwater baseflow to the watercourses near construction worksite and operational footprint to the streams was expected to be affected	Groundwater partially supporting the watercourses with biodiversity conservation significance (refer to Figure 8-1).	Priority 2

9.4 History of Land Contamination

The historical land use within the Study Area (250 m from both sides of the alignment) was reviewed in detail in the HLUS reports [R-4, R-5]. According to HLUS, there are no potential sites with contaminating historical land uses in the vicinity of Eng Neo Avenue Forest and Windsor.

Potentially contaminating activities can be deduced to have occurred based on the land use at a site, noting possible contamination at some point during the history of the land usage. Based on the HLUS reports, the hotspots and contamination severity are shown in Table 9-2 below with the respective Project worksites where HLU denotes historical land use.

Table 9-2 Land Use Hotspots

No.	Hotspot	Type	Nearest Associated Worksite	Severity of Contamination
	Pan-Island Expressway (PIE)	Existing Road	A1-W2	Low
6	SICC No 2 Substation	Utility Facilities	A1-W1	Low
	Golf courses (Island Golf Course, Bukit Golf Course)	Recreational Facilities	A1-W2/A1-W1	Medium
	Drain Upgrading for Thomson, Faber and Island Gardens Estates	Future Developments	A1-W1	Medium
	Renovation of SICC New and Millennium Golf Courses	Future Developments	A1-W1	Medium

Note:
1. HLU denotes historical land use.

No.	Hotspot	Type	Nearest Associated Worksite	Severity of Contamination
2.	The contamination severity level was extracted from the HLUS reports [R-4, R-5] where it categorises using a Contamination Severity Matrix, which considers the degree of toxicity of contaminants present on site (with respect to dermal contact and inhalation) and the spatial extent of potential contamination within HLUS's Study Area whether is it localised (1-5%), medium (6-40%) or pervasive (>40%).			

9.5 Soil and Groundwater Baseline Findings

9.5.1 Soil Profile

Based on the information obtained from the soil and groundwater investigation studies carried out within the Study Area, the encountered soil profile generally consisted of silt.

The soil profile in the vicinity of Eng Neo Avenue Forest, Site I and Site II mostly consisted of sandy silt, with intrusions of gravel and gravely silt in the western and central portions, while with intrusions of sand, sandy clay, gravelly silt and clay in the eastern portions of the Study Area. Dominant bedrock formation was observed to be granite.

The soil profile in the vicinity of Windsor generally consisted of slightly gravelly sandy silt. Besides this soil type, intrusions of silty sand, gravely and clayey sand, sandy and gravelly clay were also observed. Dominant bedrock formation was noted to be syenite. Besides syenite, diorite, granodiorite, quartz diorite, dacite, granite, basalt and dolerite were also observed as a bedrock.

9.5.2 Soil Baseline Results

As most of the available investigation studies were carried out with focus on geotechnical characteristics of soil, the available data regarding the soil baseline quality is limited. However, review of the soil analytical results of samples collected in the proximity of Site II, showed that none of the samples tested exceeded their respective DIVs. Photoionization detector (PID) readings recorded were between 0.2 and 12.1 parts per million (ppm), indicating negligible concentration of VOCs. No visual or olfactory evidence of contamination of soil was noted during field activities.

Metals, including arsenic, antimony, barium, cadmium, chromium, cobalt, copper, mercury, lead, molybdenum, nickel and zinc, were detected in most soil samples at concentrations above their respective level of reporting (LOR). TPH was detected in eleven (11) out of sixteen (16) soil samples.

These detections were all below their respective DIVs.

Vanadium has been detected in all the soil samples, ranging between 0.48 mg/kg and 21.30 mg/kg. These values are below the indicative levels for severe soil contamination as per Dutch Environmental Guidelines Soil Remediation Circular [R-41].

Other than that, phthalates, total nitrogen (TN), total phosphorous (TP), manganese and faecal coliforms were detected in limited number of soil samples.

The remaining parameters analysed for the soil samples were below their respective LORs.

The source(s) of parameters detected above their respective LORs in soil samples could not be conclusively ascertained. Presence of metals, heavy metals and TPH is a common and well-documented occurrence in urban soils that are exposed to anthropogenic activities. Also, many of the detected parameters (i.e. metals, phosphorus, nitrogen) are naturally occurring elements in the environment. However, currently there are no comprehensive studies that provide the information on the background concentrations of these parameters in soil in Singapore. The concentration of faecal coliforms is commonly used parameter to indicate the pollution of the analysed media with the faecal material of humans and/or other animal species. Considering the proximity of the Eng Neo Avenue Forest, Sites I and II, it is possible that the faecal matter originating from the surrounding fauna leached into the soil. QA/QC analysis shows that the RPD results for soil duplicate samples were at the acceptable level of precision and trip and equipment blanks did not show any detections.

9.5.3 Groundwater Baseline Results

9.5.3.1 Groundwater Elevation

Based on groundwater elevation data collected as part of soil and/ or groundwater investigations carried out in the vicinity of Eng Neo Avenue Forest, Sites I and II, the average groundwater level ranged from 17.45 mRL (i.e. west of Site II) to the to 31.05 mRL (i.e. northeast of Eng Neo Avenue Forest). The groundwater elevation in the vicinity of Windsor was found to be slightly lower, with average groundwater elevation ranging from 9.99 mRL to 21.31 mRL. Overall, the groundwater levels are estimated to be less than 5 m below ground level (m bgl) [R-77] and are expected to fluctuate as a result of rainfall percolating into the ground and due to seasonal variations.

9.5.3.2 Groundwater Flow Direction and Velocity

The hydraulic gradient was calculated using the EPA On-Line Tools for Site Assessment. Subsequently, the linear velocity of groundwater flow was calculated based on the Darcy's Equation as follows:

$$V = \frac{(Ki)}{n}$$

Where V = Groundwater flow velocity;
K = Theoretical Hydraulic Conductivity;
n = Effective porosity; and
i = Hydraulic gradient.

The average hydraulic gradient of groundwater in part of Study Area that passes through Eng Neo Avenue Forest, Sites I and II was calculated to be 0.0513 meter / meter (m/m). Theoretical hydraulic conductivity and effective porosity of the dominant soil type (i.e. sandy silt) were assumed to be 1 x 10^{-5} cm/s and 0.43, respectively. Therefore, the calculated velocity of groundwater is 0.36 m per year. It should be noted that the groundwater seepage velocity varies depending on the varying clay, silt and sand contents at a specific location and should be used as a general guide only. Based on groundwater level data collected during gauging and / or sampling events, the inferred groundwater flow direction in the west portion of the Study Area (i.e. below Sites I and II) flows westwards, while in the vicinity of A1-W2 worksite the inferred groundwater flow direction is south east, towards the watercourse. Therefore, it can be observed that the groundwater flow direction generally follows the topography of the site.

The average hydraulic gradient in the part of Study Area that passes through Windsor was calculated to be 0.0997475 m/m. Theoretical hydraulic conductivity and effective porosity of the dominant soil type (i.e. sandy silt) were assumed to be 1 x 10^{-5} cm/s and 0.43, respectively. Therefore, the calculated velocity of groundwater is 0.73 m per year. It should be noted that the groundwater seepage velocity varies depending on the varying clay, silt and sand contents at a specific location and should be used as a general guide only. Based on groundwater level data collected during gauging and / or sampling events, the inferred groundwater flow direction generally follows the topography of the site and flows towards major nearby watercourse (i.e. D/S13).

9.5.3.3 Groundwater Quality

Review of the groundwater analytical results, as presented in soil and groundwater investigation study carried out by SECS [R-70], in the vicinity of Site II showed that none of the collected samples exceeded their respective DIVs. Metals, including arsenic, antimony, barium, chromium, mercury, molybdenum and zinc, as well as TPH (only C15-C28 fraction) were detected in most groundwater samples at concentrations above their respective level of reporting (LOR). Additionally, cobalt, copper and lead were reported in certain groundwater samples (i.e. cobalt in one groundwater sample; copper and lead in one groundwater sample). The concentrations of these metals were all below their respective DIVs.

TOC was detected in majority of groundwater samples at concentrations 3.5 to 39.8 mg/L. Fluoride was only detected in one (1) groundwater sample at a concentration of 0.90 mg/L. Chloride, phosphate, sulphate and total ammoniacal nitrogen was detected in all groundwater samples, ranging between 1.60 mg/L and 34.40 mg/L, between 0.17 mg/L and 0.48 mg/L, between 4.10 mg/L and 126.10 mg/L, and between 0.03 mg/L and 8.8 mg/L, respectively. Total nitrogen (TN), TP and faecal coliform was ranging between 0.32 mg/L and 11.00 mg/L, between 0.11 mg/L and 0.18 mg/L and between 2.00 cfu/ 100 mL and 1,600.00 cfu/ 100 mL, respectively.

The remaining parameters analysed for the groundwater samples were below their respective LORs.

Groundwater samples were also tested for and compared to parameters defined in the NEA Trade Effluent Discharge limits for controlled watercourse, watercourse and public sewer. Majority of the parameters detected were below their respective trade effluent discharge limits. Out of four (4) collected groundwater samples, two (2) have reported exceedances of certain parameters. In one sample exceedance of TSS (limit for controlled watercourse) and arsenic as As (limit for watercourse) were reported, while in other groundwater sample exceedances of COD (limit for controlled watercourse), TSS (limit for watercourse and controlled watercourse), iron as Fe (limit for controlled watercourse) and manganese as Mn (limit for controlled watercourse) were reported.

The source(s) of parameters detected above their respective LORs in groundwater samples could not be conclusively ascertained. Presence of metals, chloride, phosphates, TN and TP is a common occurrence in groundwaters due to the naturally-occurring processes (e.g. leachate and migration from soil) and anthropogenic activities. The presence of faecal coliforms in certain groundwater samples is possible to have originated from faecal matter of faunal species from the surrounding environment (e.g. Eng Neo Avenue Forest). QA/QC analysis show that the RPD results for groundwater duplicate sample were at the acceptable level of precision and trip blanks did not show any detections.

Based on physicochemical measurements of groundwater during the field activities carried out as part of soil and groundwater investigation [R-70] the groundwater beneath Sites I and II can be described as generally acidic. Furthermore, during well development and sampling event, presence of non-aqueous phase liquid (NAPL) was not observed.

9.6 Potential Sources of Soil and Groundwater Impacts

Soil and groundwater can be potentially exposed to contaminants due to activities during the construction and operational phases of the Project.

9.6.1 Construction Phase

Soil and groundwater can be potentially exposed to contaminants due to the activities during the construction phase of the Project, especially within and around the cut and cover areas. The activities which could lead to contamination of the soil and groundwater during the construction phase are listed in Table 9-3.

Table 9-3 Potential Sources of Soil and Groundwater Impacts (Construction Phase)

Activity	Potential Sources of Impacts	Potential Associated Impacts
Site Clearance, levelling and land grading works Construction of shaft, facility buildings and other infrastructures	Increased runoff from hard standing surface resulting in decreased infiltration into the ground Disposal of wastewater generated from tunnelling activities Groundwater from dewatering from excavated areas	Decreased groundwater baseflow feeding into potential streams Potential groundwater drawdown due to dewatering process during tunnelling activities
Excavation of cut and cover areas Stockpiling of excavated soil from cut and cover areas and tunnel boring activities Improper management and disposal of excavated soils and/or groundwater during excavations and tunnel boring activities	Exposure of land and stockpiles from the various construction activities Contaminated excavated soils (if encountered), if not stored, handled, transported and disposed properly, can lead to direct or indirect contamination Wastewater generated from tunnelling activities	Soil erosion of exposed soil from excavation and stockpiles Potential for direct soil and/or groundwater contamination within the Study Area Potential pollution to the adjacent areas within the immediate vicinity of the Project due to migration of soil and groundwater contamination, off-site Potential contamination to the surface watercourses located in the vicinity of the construction site (its impact will be assessed in Section 8)
Improper handling, transfer and storage of toxic chemical waste	Discharge of toxic chemical waste due to spillage or leakage during storage, handling and transfer Inappropriate or inadequate design parameters for storage containers	Potential for direct soil and/or groundwater contamination within the Study Area Potential pollution to the adjacent areas within the immediate vicinity of the Project due to migration of soil and groundwater contamination, off-site

Activity	Potential Sources of Impacts	Potential Associated Impacts
Improper handling, transfer, refuelling and storage of chemicals (e.g. diesel, bentonite, lubricants, oils, grease, paints, solvents, waste treatment chemicals, etc.) generated during construction phase.	Discharge of chemical due to spillage or leakage during storage, handling, transfer and refuelling (oil, grease or other chemical substance release) Inappropriate or inadequate design parameters for storage containers	

The proposed minimum controls or stand practices commonly implemented in Singapore are discussed in Section 9.7.

9.6.2 Operational Phase

It is anticipated that there will be limited sources of impacts to soil and groundwater during the operational phase as use of chemicals and generation of toxic chemical waste is expected to be of limited quantities. Hazardous waste generated during the operational phase is associated to maintenance works on the alignment and facility buildings while non-hazardous waste generations are expected to be generated from the site office staff's general waste within the station.

The activities which could lead to contamination of the soil and groundwater during the operational phase are listed in Table 9-4.

Table 9-4 Potential Sources of Soil and Groundwater Impacts (Operational Phase)

Activity	Potential Sources of Impacts	Potential Associated Impacts
Maintenance works on the alignment and facility building	Small quantities of toxic chemical waste generated during maintenance works and operational phase (used fluorescent bulbs, used lead-batteries, used maintenance chemical containers i.e. thinner, paints, lubricants, etc.) Operation of the trains resulting in diesel oil leakage	For maintenance activities within the alignment, toxic chemicals waste leakage could occur and seep into the wastewater drainage within the alignment and/or into the soil and groundwater For general maintenance for the facility building, hazardous waste from equipment could potentially leak into drainage systems and/or into the soil and groundwater. Potential pollution within the Study Area where toxic chemicals and waste are stored.
	Improper handling of hazardous chemicals/substances during operational phase	

The proposed minimum controls or stand practices commonly implemented in Singapore are discussed in Section 9.7.

9.7 Minimum Control for Potential Impacts

This Section proposes minimum controls or standard practices commonly implemented in Singapore for similar developments that have been assumed to be implemented for the purpose of impact assessment during the construction and operational phases.

9.7.1 Construction Phase

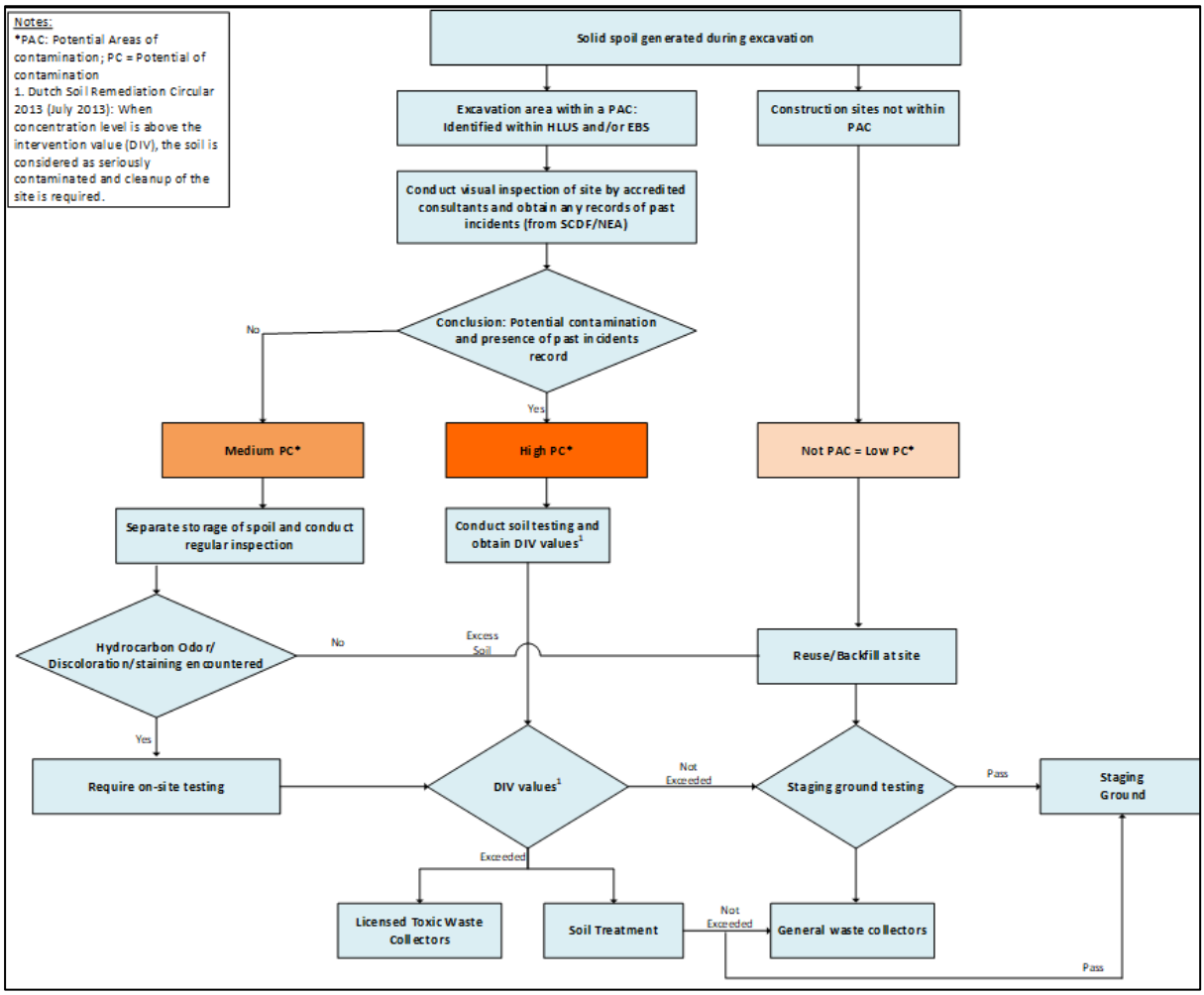
Table 9-5 sets out the minimum controls that have been identified for the Project during construction phase. Regular inspection and workers training must be conducted to ensure these measures are inculcated in the behaviour and practice of all the site staff on site.

Table 9-5 Minimum Controls during Construction Phase (Soil and Groundwater)

Potential Sources of Impacts	Minimum Controls
Decreased groundwater baseflow feeding into the streams	• Install piezometers to monitor the changes in groundwater level in compliance with Building Control Regulations 2003 as part of its

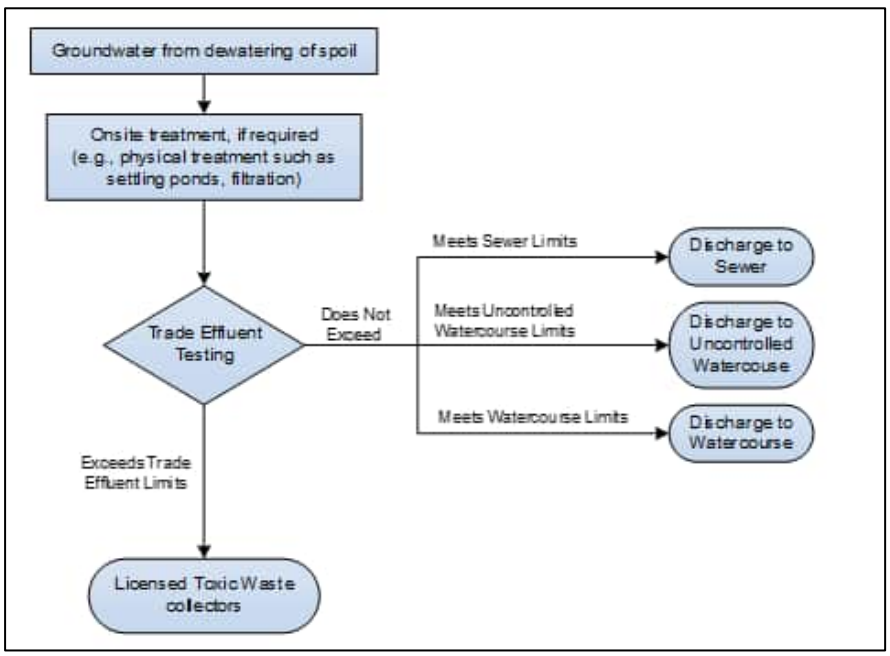
Potential Sources of Impacts	Minimum Controls
	instrumentation and monitoring plan to be endorsed by the Qualified Professional (QP). • Proper Earth Retaining Stabilising Structures (ERSS) should be selected and designed to limit groundwater settlement.
Improper management and disposal of excavated soils and/or groundwater during excavations and tunnel boring activities	• Identify all types of solid waste (e.g. tunnelling waste) and implement comprehensive waste management system at the site in order to ensure proper disposal and prevent pollution to the environment. This Contractor should conduct a construction risk assessment and prepare a comprehensive construction health, safety and environment plan. If health impacts to workers are foreseen due to the handling of such waste, necessary precautionary measures as per the safety data sheets (SDS) including personal protective equipment should be implemented on site. • Use approved materials, of the same or better quality as the surrounding area, for backfilling works. All backfilled material shall be free of debris, and of good material soil. • Handle and dispose excavated soil following the procedure shown in Figure 9-1. This flow chart explains how to handle excavated soils, and identify potential areas of contamination as well as potential of contamination (POC) in excavated soils. If the POC soils are tested for exceedance in DIVs, the soils can be disposed of to toxic waste collectors or undergo soil treatment. If contaminated soils were sent for treatment to an acceptable standard such as the DIV, the treated soil can be disposed in the staging ground or through a general waste collector, depending on the level of the contaminants during the staging ground testing. • Upon receipt of results on the tested parameters (chemicals, heavy metals) exceeding the regulatory limits, the construction Contractor should further assess the potential inhalation and dermal contact impacts of the exceeded parameters to the site workers exposed to areas where soil and/or groundwater contamination is identified. The risk assessment should be conducted before the commencement of construction activities and the findings incorporated into the Contractors' construction risk assessment and health, safety and environment plan. If health impacts to workers are foreseen, necessary precautionary measures, as per the respective chemical SDS, should be implemented on site. • A site management plan should include plans of safe handling, transfer and storage of excavated soils following the procedure in Figure 9-1. • Discharge of extracted groundwater shall be to an area approved for such disposal by the NEA and PUB and the proposed location as identified in Figure 9-1 and following the process set out in Figure 9-2. Based on the results of the soil and groundwater baseline study, the detected concentrations in groundwater do not exceed the DIVs. However, it is recommended that the construction Contractor to be vigilant of site conditions and extracted groundwater to be tested at regular intervals, especially for extracted groundwater with oily sheens or noticeable odour. If a contaminant concentration in excess of the DIV is detected, the Contractor shall assess the potential inhalation and dermal impacts of the chemical identified and assess potential health and safety considerations for exposure to groundwater before commencement of construction activities. Such contaminated wastewater may need to be disposed of to a licenced toxic waste collector. • Bentonite slurry used in the TBM will be pumped into the slurry treatment plant for recycling, cleaning and removal of native cut material. Treatment methodologies in the slurry treatment plant will include de-sanding (e.g., cyclones) and filtration. Handling and disposal of spoils for disposal after the treatment shall follow the procedure in Figure 9-1.

Potential Sources of Impacts	Minimum Controls
Toxic Chemical Waste and Wastewater Generation during Construction Phase	• Identify all types of toxic chemical waste and implement comprehensive waste management system at the site in order to ensure proper disposal and prevent pollution to the environment. This Contractor should conduct a construction risk assessment and prepare a comprehensive construction health, safety and environment plan. If health impacts to workers are foreseen due to the handling of such waste, necessary precautionary measures as per the safety data sheets (SDS) including personal protective equipment should be implemented on site. • Inspect all equipment prior to entering the site for fuel/hydraulic lines, leaking tanks, and other potential faulty parts that could potentially cause contamination to soil or groundwater. • Dispose all construction debris (under category C&D) at the gazetted Government dumping grounds or at such other sites or locations as directed by NEA. • Store generated toxic chemical waste under shelter within concrete bund walls or in storage containers with good ventilation. Spill trays shall be provided for all waste containers Spill trays shall be regularly maintained to prevent rain from washing out the pollutive substances. • Note that the Earth Control Measures (ECM) is for the containment and treatment of silty discharge due to the impact of rainwater. ECM is not meant for the treatment of wastewater due to construction activities (such as pipe-jacking and bore-piling works) which shall be treated to comply with the requirements under prevailing legislation. • Contractor will need to seek approval from relevant authorities (i.e. PUB & NEA) as per PUB Sewerage and Drainage (Trade Effluent) Regulations if the wastewater will be disposed to public sewer or NEA's Trade Effluent Discharge Limits to controlled watercourse if the treated trade effluent will be disposed to surface watercourses. If such discharges are not approved, the trade effluent will be stored, treated or recycled on site and finally disposed off-site.
Improper Handling of Hazardous Chemicals/Substances during Construction Phase	• Remove any hazardous substance or chemical if there are safer alternatives. • Ensure all hazardous substance and chemical containers are labelled its movement is recorded and returned to the designated storage areas when not in use. • Assess the SDS of all the hazardous substances and chemicals prior to its entry to site for its suitability in terms of SHE hazards and consider safer alternatives. • Ensure no trade effluent other than that of a nature or type approved by NEA Director-General shall be discharged into any watercourse or land. • Ensure all activities involving repair, servicing, engine overhaul works, etc. shall be carried out on an area which is appropriately contained (e.g. concreted area and with proper containment/sumps) and all wastes are channelled for appropriate treatment or disposal to meet the regulations. • Store chemicals stored under shelter within concrete bund walls or in storage containers with good ventilation. Spill trays shall be provided for all drums, plants and machinery and potential pollutive substances used on site. Spill trays shall be regularly maintained to prevent rain from washing out the pollutive substances. • Provide emergency spill kits on site in the event of any chemical spillages. The emergency response team shall also be competent in the use of these spill kits.



Note: DIV standards were developed to assess the acceptability of impacted sites in the Netherlands in support of the Dutch Soil Protection Act. Therefore, it is based on local Dutch ecotoxicology, soil (consisting of 10% organic clay or 25% clay) and climate conditions for residential usage which may not be applicable to conditions in Singapore.

Figure 9-1 Screening and Disposal of Excavated Soils



Note: DIVs for groundwater consider risks to human health and local ecosystems, whichever is more sensitive. When assessing risk to human health, a typical Dutch residential land use setting is considered which includes exposure via potable consumption of groundwater and consumption of home-grown produce which are not common exposure scenarios for Singapore.

Figure 9-2 Disposal of the Groundwater Generated through Dewatering or Inflow into Excavations

9.7.2 Operational Phase

Table 9-6 sets out the minimum controls that have been identified for the Project during operational phase.

Table 9-6 Minimum Controls during Operational Phase (Soil and Groundwater)

Potential Sources of Impacts	Minimum Controls
Small quantities of toxic chemical waste generated during maintenance works (used fluorescent bulbs, used lead-batteries, used maintenance chemical containers i.e. thinner, paints, lubricants, etc.)	• Store all toxic chemical waste at designated sheltered area provided with access-controlled entrance and concrete bund walls or in storage containers with good ventilation. Spill trays shall be provided for all chemical drum and potentially pollutive substances. Spill trays shall be regularly maintained to prevent rain from washing out the pollutive substances. • Dispose all toxic waste chemicals to licensed TIW collectors for treatment
Improper handling and storage of hazardous chemicals/ substances during operational phase	• Store all hazardous substances/chemicals at designated sheltered area provided with access-controlled entrance and concrete bund walls or in storage containers with good ventilation. Spill trays shall be provided for all chemical drums, plants and machinery and potential pollutive substances used on site. Spill trays shall be regularly maintained to prevent rain from washing out the pollutive substances. • Ensure all hazardous chemicals/substances are labelled its movement is recorded and returned to the designated storage areas when not in use. • Ensure all activities including repair, servicing, engine overhaul works, etc. involving the use of hazardous chemicals/substances are carried out on an area which is appropriately contained (e.g. concreted area and with proper containment/sumps). • Provide emergency spill kits on site in the event of any chemical spillages. The emergency response team shall also be competent in the use of these spill kits. • Ensure no trade effluent other than that of a nature or type approved by NEA Director-General shall be discharged into any watercourse or land.

9.8 Prediction and Evaluation of Soil and Groundwater Impacts

9.8.1 Construction Phase

9.8.1.1 Decreased Groundwater Baseflow Feeding into the Streams

The streams identified within the Study Area receive water from the upstream surface runoff, rainfall, and potentially baseflow contribution from groundwater. The pre-construction activities (e.g. site clearance, utilities diversion, levelling and land grading works) and main construction activities of shaft, station boxes, facility buildings and other infrastructures of this Project which include deep excavations and dewatering process, lead to potential impact on groundwater condition of the catchment of the existing natural stream and pond.

Based on the catchment analysis and hydrological survey for existing natural streams at Eng Neo Avenue Forest and Windsor, those streams receive considerable large amount of flow from upstream area and receive more flow from tributaries at downstream of the development. The construction worksites are proposed to not directly impact to the streams with no encroachment to the streams and buffer areas. The area of proposed worksites is considered small compared to the catchment of the streams, and the Project will be constructed phase by phase instead of whole area together, which further reduces its construction footprint by phases and reduce the potential impact on groundwater baseflow. Furthermore, it is expected that recharge wells will be used outside the excavations to limit the groundwater drawdown in the surrounding area.

Overall, minor groundwater impact from the construction worksites is expected and groundwater flow will not significantly decrease during construction phase.

Hence, the impact intensity was considered **Low** on groundwater baseflow reduction and impact consequence on groundwater baseflow feeding into the streams was assessed to be **Very Low**. Given that the occurrence of the expected decreased baseflow is probably during the dry season (i.e. **Occasional**), therefore, the impact significance of the decreased groundwater baseflow to the streams was **Minor** and no further mitigation measures were required.

9.8.1.2 Improper Management and Disposal of Excavated Soil and Groundwater

The construction method is expected to generate large amounts of spoil material. The quantity of solid waste stored on site (e.g. excavated soil, construction debris, etc.) is expected to be limited given the periodical disposal by licenced general and toxic waste Contractors as part of minimal controls (as shown in Section 9.7).

In the event that contaminated soils or groundwater are encountered during excavations, implementation of the measures detailed in Figure 9-1 and Figure 9-2 will ensure that the contaminated soil and/or groundwater is properly managed and disposed.

The overall sensitivity of the soil and groundwater receptors in the Study Area is considered as Priority 3, as specified in Section 9.3. Based on the HLUS reports [R-4, R-5], the contamination severity level from the majority of past land uses within Study Area was estimated to be low and the impact intensity was considered **Low**. Hence, the impact consequence of improper management and disposal of excavated soil and groundwater was estimated to be **Very Low** (based on the Impact Consequence Matrix as shown in Table 6-6). With the implementation of minimum controls, the likelihood of occurrence was expected to be **Occasional** during construction phase.

Therefore, the overall environmental of improper management and disposal of excavated soil and groundwater during construction phase is assessed to be **Minor**. Hence, no further mitigation measures were required.

9.8.1.3 Toxic Chemical Waste Generation

The quantity of toxic chemical waste stored on site is expected to be limited with the assumption that waste generated on-site will be periodically removed and disposed off-site by licensed Toxic Industrial Waste (TIW) Contractors during the construction phase. Based on HLUS reports [R-4, R-5], the contamination severity level was expected to be low from most of the land uses within the Study Area (refer to Table 9-2), and the impact intensity was considered **Low** (localised soil and groundwater impacts which is not likely to extend beyond the Project site and possible to remediate), with the impact consequence of soil and/or groundwater contamination was assessed to be **Very Low**.

Based upon implementation of the minimum controls and that the controls are approved by the relevant agency, where applicable, it is unlikely that discharge, spillage or leakage from toxic waste in a quantity that may adversely impact the environment will regularly occur during the construction phase. Mandatory worker training regarding environmental management and spill management and regular site inspections serves as preventative measure for such occurrences. On this basis, the expected likelihood of occurrence during construction phase was assessed to be **Occasional**.

Overall, based upon an assessment of the likelihood and consequences, and considering the routine, standard industry practices implemented during the construction phase, the potential impact of toxic chemical waste spillage or leakage to soil and/or groundwater was assessed to be **Minor**. Therefore, no further mitigation measures were required.

9.8.1.4 Improper Handling of Hazardous Chemicals/Substances

Chemicals used during the construction phase will be stored at designated sheltered area provided with access-controlled entrance and concrete bund walls or in storage containers with good ventilation or on spill pallets. In the event of chemical spillage, spill kits will be available on site to be operated by an emergency response team competent in their use. Based on HLUS reports [R-4, R-5], the contamination severity level was low to most of the land uses within the Study Area (refer to Table 9-2), Hence, the impact consequence of potential contamination (**Low** impact intensity) from chemical spillage was considered to be **Very Low** during the construction phase.

With the minimum controls being implemented, the likelihood of occurrence of a chemical spill leading to soil and/or groundwater contamination was assessed to be **Occasional** during construction phase. Therefore, the overall environmental impact of chemical spillage to soil and/or groundwater likely to occur during the construction phase was assessed to be **Minor**. Therefore, no further mitigation measures were required.

9.8.2 Operational Phase

9.8.2.1 Toxic Chemical Waste Generation during Maintenance Work

For the periodic maintenance work to be conducted along the alignment and facility building, it can be expected that toxic chemical waste might be generated in the form of used fluorescent bulbs, used lead-batteries, used maintenance chemical containers i.e. thinner, paints, lubricants, etc. These toxic wastes are expected to be of limited quantities and disposed off periodically by licensed TIW Contractors during the operational phase. The operation of the trains could also potentially result in oil leakage to the rail tracks and possibly ground surface which could potentially cause surface runoff pollution in the event of rain. If oil spill or leakage occurs, it is considered as

hazardous waste which shall be contained and cleaned properly according to the Emergency Response Plan [W-30] prepared according to NEA's requirement. Guidelines in regulating control and disposal of spills can also be referred to NEA's Management of Hazardous Waste [W-31] and Workplace Safety and Health Guidelines on Management of Hazardous Chemicals Programme [W-32].

The impact intensity was considered **Low** (localised soil and groundwater impacts which is not likely to extend beyond the Project site and possible to remediate), with the impact consequence of soil and/or groundwater contamination was assessed to be **Very Low**.

Based upon implementation of the minimum controls and that the controls are approved by the relevant agency, where applicable, it is unlikely that discharge, spillage or leakage from toxic waste in a quantity that may adversely impact the environment and will only occur during the operational phase as often as maintenance is scheduled. Mandatory worker training regarding environmental management and spill management and regular site inspections serves as preventative measure for such occurrences. For example, in the event where spillage occurs during the maintenance of the alignment, toxic chemicals could possibly enter the drainage system of the alignment and cause pollution downstream with the potential to impact the soil and groundwater. It is imperative to have preventative measures from the source to prevent pollution downstream of the drainage process. On this basis, the expected likelihood of occurrence during operational phase was assessed to be **Occasional**.

Overall, based upon an assessment of the likelihood and consequences, and considering the routine, standard industry practices implemented during the operational phase, the potential impact of toxic chemical waste spillage or leakage to soil and/or groundwater was assessed to be **Minor**. Therefore, no further mitigation measures were required.

9.8.2.2 Improper Handling of Hazardous Chemicals/Substances

Chemicals used during the operational phase will be stored at designated maintenance area provided with access-controlled entrance and concrete bund walls or in storage containers with good ventilation or on spill pallets. In the event of chemical spillage, spill kits will be available on site to be operated by an emergency response team (maintenance team) competent in their use. Based on HLUS reports [R-4, R-5], the contamination severity level are low to most of the land uses within the Study Area (refer to Table 9-2), Hence, the impact consequence of potential contamination (**Low** impact intensity) from chemical spillage was considered to be **Very Low** during the operational phase.

With the minimum controls being implemented, the likelihood of occurrence of a chemical spill leading to soil and/or groundwater contamination was assessed to be **Occasional** during operational phase. Therefore, the overall environmental impact of chemical spillage to soil and/or groundwater likely to occur during the construction phase was assessed to be **Minor**. Therefore, no further mitigation measures were required.

9.9 Recommended Mitigation Measures

In this section, no mitigation measures are proposed to further minimise the adverse impacts on the environment as there is no impact significance on sensitive receptors were assessed to be Moderate or Major.

However, it is noted that mitigation scenarios have been developed for both A1-W1 and A1-W2 mainly due to their major adverse impact on surrounding biodiversity (refer to Section 7). Both also help to further reduce their impacts on groundwater.

9.10 Residual Impacts

No residual impact assessment has been undertaken as there is no Moderate or Major impact significance on sensitive receptors were assessed.

9.11 Cumulative Impacts from Other Major Concurrent Development

9.11.1 Construction Phase

Since the construction worksite of CR14 is not located in Eng Neo Avenue Forest, the CR14 might not increase the impact on the surroundings soil and groundwater of Eng Neo Avenue Forest given the best management practices and minimum controls provided by its developer in accordance during its construction phase. The CR14 might not increase the impact on the surrounding soil and groundwater of the Site I and Site II as the waterbodies identified within Site I have artificial concrete banks with majority of inflow originating from surface flow from surrounding catchment area.

In Windsor (refer to Figure 8-18), PUB water pipeline construction at BKSR including pipelaying and permanent and reinstatement works at Shaft 4 will be carried out during the development of Cross Island Line. The PUB water pipeline construction works might slightly increase the soil and groundwater impact in Windsor due to the pipe-jacking during its construction. Hence, proper mitigation measures should be proposed by PUB to deal with the excavated groundwater and soil to minimise its adverse impact.

The concurrent Project of CR13 excavation and retrieval shaft construction works will be located exactly at CR13 retrieval shaft worksite during development of Cross Island Line. Given the existing land use is already urban development area and watercourses in the vicinity are only roadside drains, the CR13 construction work might not increase the impact on surrounding soil and groundwater given best management practices and minimum controls provided by its developer are in place during its construction.

9.11.2 Operational Phase

The CR14 will be located outside of Eng Neo Avenue Forest during operational phase as shown in Figure 8-19. Since the CR14 is not located in Eng Neo Avenue Forest, the CR14 might not increase the impact on the surroundings soil and groundwater of Eng Neo Avenue Forest given the best management practices and operation controls provided by its developer in accordance during its operational phase. The CR14 might not increase the impact on the surrounding soil and groundwater of Site I and Site II as the waterbodies identified within Site I have artificial concrete banks with majority of inflow originating from surface flow from surrounding catchment area.

In Windsor (refer to Figure 8-20), the concurrent project, PUB water pipeline's footprint at BKSR will only have manholes as the project footprint, which normally only occupy small area at the roadside. Besides, it was envisaged that maintenance works will be restricted at the manhole area, and any contamination (e.g. chemical spills, leaking, etc.) will be minimised given best management practices and minimum controls are in place. Hence, the PUB water pipeline project might not increase the soil and groundwater impact in Windsor significantly given proper management and operation of pipeline system provided by PUB during operational phase. Hence, the impact significance is estimated to be **Negligible**.

The concurrent project of CR13 will only have the station building above ground during operational phase. As long as the best management practices provided by its developer on the footprint of CR13, it might not increase the impact on surrounding soil and groundwater. Hence, the impact significance is estimated to be **Negligible**.

9.12 Summary of Key Findings

The potential impacts on soil and groundwater of historical and current land uses as well as activities associated with the construction and operational phases of the Project was discussed by using the information from LTA's HLUS reports [R-4, R-5], construction waste information and other best available data. Soil and groundwater impact study was carried out qualitatively based on HLUS study findings. Impact assessment of the A1-W2 site was also conducted based on the findings of the SECS (2021) EBS.

The soil and groundwater within the Project site was identified as Priority 3 sensitive receptors, as it is not expected for direct sensitive uses (e.g. agricultural/irrigation/drinking water purposes) or not directly extracted for industrial uses, therefore not posing unacceptable risks. Streams where groundwater is partially supported with biodiversity conservation significance were identified as Priority 2 sensitive receptors but can only be assessed with the EBS results where groundwater flow can be deduced.

The potential sources of soil and groundwater impact during construction were expected to be mainly from pre-construction activities (e.g. site clearance, levelling and land grading works) and main construction activities of this Project such as tunnelling activities, which may cause decreased groundwater baseflow feeding into the streams, potential contamination from toxic chemical waste used or generated on site, as well as potential leakage from improper handling of hazardous chemical/substances on site.

The potential sources of soil and groundwater impact during operational phase were expected to be mainly from maintenance of the alignment and facility building with potential contamination from toxic chemical waste used or generated, as well as potential leakage from improper handling of hazardous chemical/substances within the operational footprint of the Project.

Minimum control measures for soil and groundwater which are commonly implemented in Singapore have been included in this section. Regular inspection and workers training must be conducted to ensure these measures are inculcated in the behaviour and practice of all the site staff on site.

Hence, the significance from potential sources of soil and groundwater impacts during construction and operational phases such as decreased groundwater baseflow feeding into the streams, improper management and disposal of excavated soil and groundwater, toxic chemical waste generation and improper handling of hazardous chemicals/substances was assessed to be **Minor** to the sensitive receptors, and no further mitigation measures were required for CRL2 Project.

Cumulative impacts from concurrent developments identified in the vicinity of the CRL2 Project during both construction and operational phases concluded that the concurrent development, PUB water pipeline works in Windsor might increase the impact during construction phase only. Hence, appropriate mitigation measures should be proposed to minimise these adverse impacts by the project developer to avoid accidental spillage of chemicals for impacting on the quality of soil and groundwater, and to ensure surface water streams are diverted with an equivalent capacity of stream if impacted and to minimise groundwater drawdown in line with best practice measures. The impact from the rest of the concurrent developments (i.e. CR14 at Turf Road and CR13 excavation with retrieval shaft construction works) might not increase the soil and groundwater impact significantly in their construction or operational phases given best management practices and minimum controls provided by its developer are in place as both developments might only have insignificant changes on the land use in Eng Neo Avenue Forest, Site I, Site II, and Windsor.

Table 9-7 Summary of Soil and Groundwater Impact Assessment

Sensitive Receptor	Impact Significance with Minimum Controls[1]	Residual Impact Significance with Mitigation Measures (if required)
Construction Phase		
Eng Neo Avenue Forest	Minor	Minor
Site I and Site II	Minor	Minor
Windsor	Minor	Minor
Operational Phase		
Eng Neo Avenue Forest	Minor	Minor
Site I and Site II	Minor	Minor
Windsor	Minor	Minor

Note:
1. The initial impact assessment with minimum controls was considered insignificant (Negligible to Minor), no residual impact assessment was undertaken, hence the impact significance remained the same. Note that this does not indicate that impacts are completely eliminated

10. Air Quality

10.1 Introduction

This section presents the air quality impact assessment for the construction and operational phases of the Project. The key steps for conducting the air quality impact assessment are as follows:

- Review baseline monitoring data to evaluate the existing air quality in the Study Area;
- Identify and classify sensitivity of the area around the construction worksite or Project footprint;
- Conduct an impact assessment to qualitatively assess air quality impacts during construction and operation of the Project;
- Evaluate qualitative air quality impacts against nominated assessment criteria;
- Specify mitigation measures to be implemented; and
- Determine the overall significance of the residual air quality impacts after implementation of mitigation measures.

10.2 Methodology

The sections below outline the methodology used in the air quality impact assessment for both construction and operational phases, including the determination of Study Area and baseline collection methodology.

10.2.1 Study Area

The Study Area for air quality impact assessment is recommended as 50 m from the construction worksite areas for impact during construction phase in accordance with UK IAQM guidance [R-46] and 250 m around the Project Footprint for operational phase. It should be noted that the operational footprint considered in air quality impact assessment also includes existing operational roads outside or nearby the Project Site, if any. During the scoping phase for this EIS, an initial screening of receptors in the Study Area was conducted in order to determine the areas which are sensitive to potential construction and operational impacts.

It shall be noted that Peirce Secondary School and CR13 retrieval shaft worksites are located >50 m from any nearest ecologically sensitive receptors and hence, outside of the Study Area as per the IAQM Guidance. Therefore, air quality impact due to construction activities from these 2 worksites are considered insignificant and not assessed in subsequent sections.

10.2.2 Baseline Air Quality Study

Baseline air quality monitoring includes primary data collection in the form of baseline ambient air quality monitoring in the Study Area. Of the criteria pollutants generally measured as part of ambient air monitoring, such as CO, NO_2, SO_2, PM_{10} and $PM_{2.5}$, this baseline monitoring only focuses on dust levels i.e. PM_{10} and $PM_{2.5}$, since these are the major pollutants that are likely to have the largest impact on the ambient air quality as a result of the Project. The purpose of the baseline monitoring is to understand what the natural conditions of these air quality parameters are, so that in the event that a repeat monitoring event is to be conducted during the construction and/or operational phases of the Project, this monitoring data can be used as a reference of the existing baseline prior to any disturbance in the Study Area. Primary monitoring data includes monitoring equipment to be setup at the site for at least a week; while simultaneous data recorded are from nearest NEA's monitoring station from web resources. The observed site data and NEA's monitored data are compared to provide confidence in the collected data.

Air quality has both short-term and long-term targets which vary from a 1-hr target to an annual target. Owing to the timeframe of the Project, annual monitoring cannot be accommodated in this study; however, a short-term monitoring baseline was established. With varying seasonal fluctuations, it is understandable that wind flow and direction will vary throughout the year, and hence short-term baselines shall also fluctuate. However, a correlation, be it direct or indicative between the site baseline and NEA's central and western areas monitoring data, will be useful for future monitoring as it provides a reliable context for any future comparisons based on the relation between the two datasets. Hence, secondary data, such as NEA's long-term air quality data, hourly Pollution Standard Index (PSI), and meteorological data observed in the vicinity of the Study Area were collected from publicly available sources.

10.2.2.1 Desktop Assessment

10.2.2.1.1 *Secondary Data Collection (Review of Background Data)*

Desktop research consists of a review of secondary data (including existing land use and development activities, satellite images, etc.) which aids in determining the baseline air quality monitoring location. The information retrieved during the desktop research comprised of publicly available data from government and technical agencies, existing available data, relevant articles, and other online sources.

10.2.2.1.1.1 NEA Long Term Ambient Air Quality

NEA carries out routine monitoring of ambient air quality through the Telemetric Air Quality Monitoring and Management System (TAQMMS). This system comprises 22 monitoring stations (refer to Figure 10-1) which are located around Singapore and linked into a Central Control System (CCS). The air quality monitoring stations are distributed amongst urban, industrial, suburban, coastal, and roadside locations. General NEA ambient air monitoring results for Singapore over the period 2015 – 2019 have been presented and compared with Singapore Long Term Ambient Air Quality Targets in Section 10.5.1.1.1. Air pollution control in Singapore is governed by legislation listed in Section 5.

Figure 10-1 NEA Ambient Air Quality Monitoring Stations in Singapore [R-43]

10.2.2.1.1.2 Hourly Pollution Standards Index (PSI) and 24-hour PM10 and PM2.5 Concentrations

PSI (Pollutant Standards Index) is an index to provide accurate and easily understandable information about daily levels of air quality. The concentration levels of particulate matter (PM_{10}), fine particulate matter ($PM_{2.5}$), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), and carbon monoxide (CO) monitored by air monitoring locations located in different parts of Singapore are used to determine the PSI. The PSI value gives an indication of the air quality as shown in Table 10-1. 24-hr $PM_{2.5}$ and PM_{10} PSI readings were available on data.gov.sg for the Central Region of Singapore during the primary data collection period, which was on 26 March to 26 June 2020, and these are presented and discussed in Section 10.5.1.1.2.

Table 10-1 General Air Quality Descriptor Based on PSI Value [W-41]

PSI Value	Air Quality Descriptor
0 – 50	Good
51 – 100	Moderate

PSI Value	Air Quality Descriptor
101 -200	Unhealthy
201 – 300	Very unhealthy
Above 300	Hazardous

10.2.2.1.1.3 Other Parameters (Rainfall, Temperature, Wind Speed)

Rainfall, temperature, and wind speed can significantly affect the distribution of pollutants. Clementi, Upper Thomson and Lower Peirce are the nearest monitoring stations to the Study Area, located approximately 660 m, 640 m and 540 m from the alignment respectively. Clementi monitoring station recorded rainfall, temperature and wind speed data. While Upper Thomson and Lower Peirce stations only recorded rainfall data. These are discussed in Section 10.5.1.1.3.

Figure 10-2 NEA Weather Monitoring Stations in Singapore [W-42]

10.2.2.1.2 *Secondary Air Quality Monitoring Data from Concurrent Study*

Air quality monitoring services were conducted by AECOM Singapore Pte Ltd with the assistance from ALS Technichem (S) Pte Ltd as part of the concurrent study in the vicinity of the Study Area. A total of two (2) air monitoring locations were conducted as part of concurrent study for one (1) week to collect air quality samples for the following air quality parameters:

- Particulate matter smaller than 2.5 µm, $PM_{2.5}$; and
- Particulate matter smaller than 10 µm, PM_{10}.

Air quality monitoring was conducted from 23 – 30 September 2021 and 1 – 8 December 2021. The air monitoring location for the concurrent study is presented in Table 10-2 and Figure 10-3. The results for concurrent study air quality monitoring is presented in Section 10.5.1.2.

TSI Environmental DustTrak Monitoring System was used for the purpose of PM_{10} and $PM_{2.5}$ monitoring. Concentrations of PM_{10} and $PM_{2.5}$ were measured by the light scattering laser photometer principle using an Environmental DustTrak Monitoring System coupled with a heated inlet for 5-minute interval data logging over a 7-day continuous sampling period. The photometer uses an ellipsoidal reflector and simple optical components to

collect the laser-scattered light and to focus it onto a photodiode array. The mass and particle size were determined by detecting how the particles scatter light.

Table 10-2 Air Quality Monitoring Location in Concurrent Study

Monitoring ID in the Concurrent Study	Monitoring Location	Photo of Monitoring Location
AQ1	Southern portion of Eng Neo Avenue Forest	
AQ2	Within 53 Fairways Drive in the vicinity of Site I and Site II	

10.2.2.2 Primary Data Collection (Survey & Sampling)

Air quality monitoring services were provided by ALS Technichem (S) Pte. (ALS). A total of two (2) air monitoring locations were proposed (at the Inception stage), based on the following considerations:

- Identification of ASRs (hospitals, schools, childcare facilities, old age homes, residences, flora and habitats of high ecological value) nearest to the construction worksite areas / Project footprint boundary of the proposed facility building;
- Other ASRs away from the construction worksite areas / Project footprint were eliminated as these receptors are assumed to be barricaded by the first row of buildings;
- ASRs with areas having ongoing construction were avoided;
- Exclude areas where CCNR EIA has already established some air baseline in the past;
- The closest ASR to the construction worksite areas / Project footprint was selected; and
- ASRs where the owner denied permission during site walkover was excluded (e.g. past experience with terrace houses/ bungalows, embassies at Swiss valley area, heavy car park area at Grand Stand, etc).

Air quality monitoring was conducted at the monitoring locations for one week to collect air quality samples for the following air quality parameters:

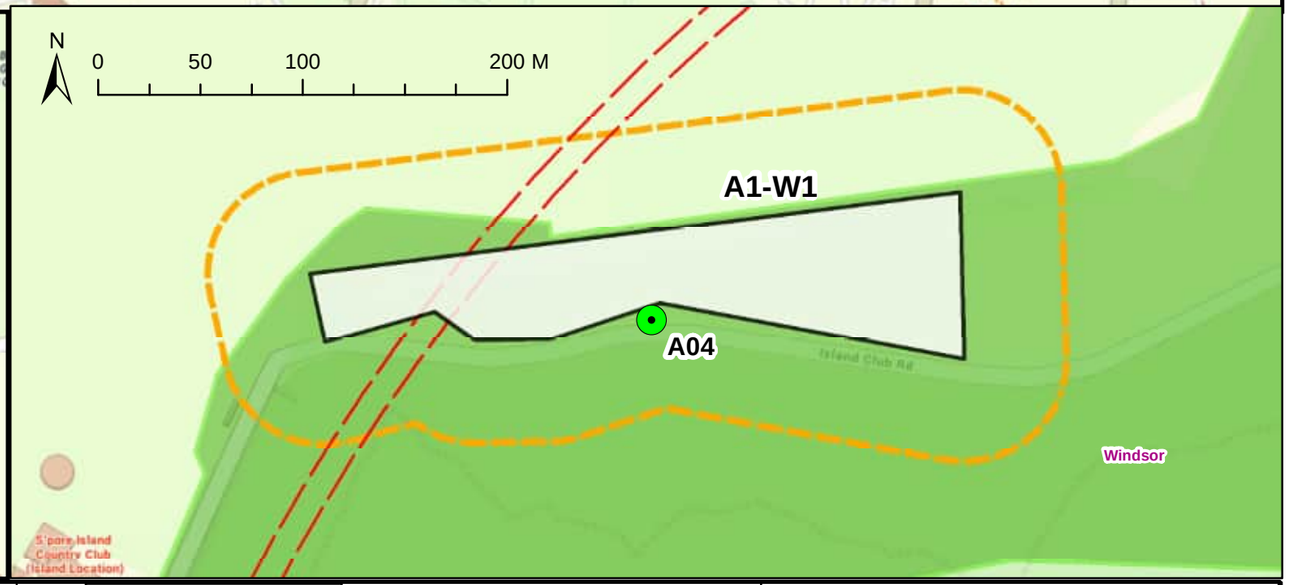
- Particulate matter smaller than 2.5 µm, $PM_{2.5}$; and
- Particulate matter smaller than 10 µm, PM_{10}.

Air quality monitoring was conducted for 1 week within the Study Area in order to establish a baseline for existing air quality levels. Following the site survey conducted on 5-6 November 2019, 25 March 2020 and 17 June 2020, two (2) monitoring locations were identified to represent the site. This has been proposed and accepted in the inception report. The monitoring location was chosen so that the equipment was more than 1 m from any buildings or structures, and not shaded by structures or trees. This is necessary to ensure adequate airflow. The air quality monitor was installed at 1.8 m from ground level in the breathing zone. Proposed air monitoring locations are provided in Table 10-3 and Figure 10-3.

TSI Environmental DustTrak Monitoring System was used for the purpose of PM_{10} and $PM_{2.5}$ monitoring. Concentrations of PM_{10} and $PM_{2.5}$ were measured by the light scattering laser photometer principle using an Environmental DustTrak Monitoring System coupled with a heated inlet for 5-minute interval data logging over a 7-day continuous sampling period. The photometer uses an ellipsoidal reflector and simple optical components to collect the laser-scattered light and to focus it onto a photodiode array. The mass and particle size were determined by detecting how the particles scatter light. For further details of the Air Quality Monitoring, please refer to Appendix M.

Table 10-3 Baseline Air Quality Monitoring Locations

Monitoring Location	Receptor Type	Nearest Construction Worksite Area/ Project Footprint	Justification	Photo of Monitoring Location
A03: Eng Neo Avenue Forest	Ecologically Sensitive Receptor	A1-W2 Worksite (Construction) A1-W2 Facility Building (Operation)	A1-W2 is located in the vicinity of Eng Neo Avenue Forest. The ambient air quality in the vicinity of A1-W2 will be affected by low traffic in the Turf Club and Saddle Club area and also the Pan Island Expressway (PIE) on the east of Eng Neo Avenue Forest. One monitoring location located in Eng Neo Avenue Forest has been chosen to represent the site in terms of existing ambient air quality in the vicinity of the Eng Neo Avenue Forest.	
A04: Windsor (within Northern Forest Fragment)	Ecologically Sensitive Receptor	A1-W1 Worksite (Construction) A1-W1 Facility Building (Operation)	A1-W1 is located at Windsor, within the Northern Forest Fragment. The ambient air quality in the vicinity of A1-W1 will be affected by low traffic along the Island Club Road. One monitoring location located north of Island Club Road has been chosen to represent the site in terms of existing ambient air quality in Windsor.	



Legend

- Baseline Air Monitoring Location
- Secondary Data [R-6]
- Air Monitoring Location - CCNR EIA [R-1]
- Construction Worksite (Base Case)
- Study Area (Air Quality)
- Proposed CRL Alignment (Base)
- Biodiversity Study Area

Note:
Site I and II: Forested area adjacent to Fairways Quarters

Rev.	Date	By	Description	Chk'd	App'd
-	APR 2022	HHL	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
BASELINE AIR QUALITY MONITORING LOCATIONS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
HHL	JAG	JAG	10-3	-	1 of 1
	Drawn HHL	Date APR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

10.2.3 Prediction and Evaluation of Impact Assessment

The air quality impact assessment included evaluation of air quality impacts from construction and operational activities.

10.2.3.1 Construction Phase

Air quality impacts were assessed using the methodology outlined in the document entitled “Guidance on the Assessment of Dust from Demolition and Construction” which was published by the UK IAQM in 2014 for impacts during construction phase. This methodology has been adapted to the general methodology outlined in this EIS.

10.2.3.1.1 *Identification of Potential Sources of Air Quality Impacts*

It is important to identify potential sources of air quality impact in the vicinity of the Study Area. While conducting the assessment, a typical construction machinery was assumed to be used during the construction equipment and activities. For air quality impacts, only above-ground areas were assessed. These have been detailed in Section 10.3.1.

10.2.3.1.2 *Identification of Sensitive Receptors*

Identification of Air Sensitive Receptors (ASRs) in the Study Area in the vicinity of above-ground construction footprint was subsequently undertaken. IAQM identifies an entire area around one continuous stretch of construction footprint as a category or sensitive receptor. It does not distinguish between each unit, household or block present in the area as a separate ASR but designates the whole area as same category of sensitivity based on an overall location, number, proximity and scale to the construction activity. This approach thereby adopts a conservative principle to air quality. A further discussion on Receptor Sensitivity was presented in Section 10.4.1.

Sensitive areas identified as Priority 1, Priority 2, and Priority 3 for air quality during the screening process have been examined in the Impact Assessment in this EIS in order to provide a more refined classification for Receptor Sensitivity. Sensitivity of the area has been determined based on the usage, number of receptors, distance from the construction footprint, and the current context of sensitive buildings in Singapore.

10.2.3.1.3 *Understanding of Baseline Air Quality*

Primary and secondary data were collected to understand the baseline air quality of the Study Area. NEA’s PSI data available from the nearest monitoring station were also reviewed for the Study Area. In addition, baseline air quality data were collected for representative location near the construction footprint. The baseline air quality review and data measured was discussed in Section 10.5.

10.2.3.1.4 *Impact Intensity Definition*

The impact intensity was determined by reviewing the scale of construction activities and classifying them as Low, Medium or High. The IAQM Guidance document provides example definitions for determining impact intensity for earthworks (based on construction footprint, heavy duty vehicles movement, formation of bunds, and material moved), for construction (based on total building volume, on-site concrete batching), for trackout (based on heavy duty vehicle outward movement, surface material, and unpaved road lengths), and for demolition (based on total demolition volume, construction material, on-site crushing of material, and height of demolition activity). The definition of parameters was defined in Table 6-5 in Section 6.4.2.1. It should be noted that in each case, not all criteria need to be met and that determination of magnitude is also based on the professional judgment of the air quality consultant. If the areas around the construction footprint are rated as High for one activity and Medium or Low for the other activities, the overall impact intensity result is classified as High for that site as those multiple activities may be occurring concurrently.

10.2.3.1.5 *Classification of Overall Consequence*

The dust impact assessment therefore evaluated the overall consequence prior to the implementation of mitigation. The worksite has been assessed by considering both the impact intensity and the Receptor Sensitivity to obtain an overall consequence rating. Since the definition of impact intensity is different for each activity, the overall consequence for each activity was explained in matrices shown in Table 10-4 to Table 10-7. Each activity for the worksite has been rated as being High, Medium, Low, or Imperceptible in terms of overall consequence based upon pre-mitigation measures but with incorporation of minimum controls.

Table 10-4 Overall Consequence of the Air Impact Analysis (Earthworks)

Receptor Sensitivity / Impact Intensity	Priority 3	Priority 2	Priority 1
Negligible	-	-	-
Low	Imperceptible	Low	Low
Medium	Low	Medium	Medium
High	Low	Medium	High

Table 10-5 Overall Consequence of the Air Impact Analysis (Construction)

Receptor Sensitivity / Impact Intensity	Priority 3	Priority 2	Priority 1
Negligible	-	-	-
Low	Imperceptible	Low	Low
Medium	Low	Medium	Medium
High	Low	Medium	High

Table 10-6 Overall Consequence of the Air Impact Analysis (Trackout)

Receptor Sensitivity / Impact Intensity	Priority 3	Priority 2	Priority 1
Negligible	-	-	-
Low	Imperceptible	Imperceptible	Low
Medium	Low	Low	Medium
High	Low	Medium	High

Table 10-7 Overall Consequence of the Air Impact Analysis (Demolition)

Receptor Sensitivity / Impact Intensity	Priority 3	Priority 2	Priority 1
Negligible	-	-	-
Low	Imperceptible	Low	Medium
Medium	Low	Medium	Medium
High	Medium	High	High

10.2.3.1.6 *Establishing Impact Significance*

Impact Significance was evaluated by considering both the overall Consequence and the Likelihood of occurrence of significant adverse impacts. The Likelihood of occurrence may be defined as unlikely, rare, occasional, regular, and continuous as per criteria listed in Table 6-7. Impact Significance has been evaluated in accordance with the matrix presented below in Table 10-8. The IAQM methodology does not differentiate between imperceptible and very low Consequences, due to the nature of air impacts as perceived by humans. In order to align the IAQM methodology with the methodology of this report, imperceptible and very low Consequences were consolidated.

Table 10-8 Impact Significance Matrix for Air Quality

Consequence / Likelihood	Imperceptible / Very Low	Low	Medium	High
Unlikely	Negligible	Negligible	Negligible	Negligible
Rare	Negligible	Minor	Minor	Minor
Occasional	Minor	Minor	Moderate	Moderate
Regular	Minor	Moderate	Moderate	Major
Continuous	Minor	Moderate	Major	Major

10.2.3.1.7 *Mitigation Measures Recommendations*

Mitigation measures were proposed for implementation when the Impact Significance is predicted to be Moderate or Major. Where mitigation measures are required, specific mitigation measures have been proposed based on the level of overall Consequence (High, Medium, and Low) as per the IAQM guidance. This is the most efficient way of prescribing dust mitigation measures so that high Consequence areas have the most comprehensive mitigation measures implemented whilst avoiding unnecessary implementation of complex mitigation measures in low Consequence areas.

10.2.3.1.8 *Establishing Residual Impact Significance*

Following implementation of mitigation measures prescribed in the EIS at the proposed construction footprint, the residual Impact Significance was evaluated using the matrix outlined in Table 10-8. Ideally, the mitigation measures required should be specified within the conditions given for planning permission and should be stipulated in construction contracts.

10.2.3.2 Operational Phase

This methodology below has been used to assess the air quality impact during operational phase of the Project.

10.2.3.2.1 *Identification of Potential Sources of Air Quality Impacts*

It is important to identify potential sources of air quality impact in the vicinity of the Study Area. While conducting the assessment, an increase in traffic volume in the vicinity of the Project during operational phase was assumed. These have been detailed in Section 10.3.2.

10.2.3.2.2 *Identification of Sensitive Receptors*

Identification of Air Sensitive Receptors (ASRs) in the Study Area within 250m around the Project Footprint was subsequently undertaken. A further discussion on Receptor Sensitivity was presented in Section 10.4.2.

Sensitive areas identified as Priority 1, Priority 2, and Priority 3 for air quality during the screening process have been examined in the Impact Assessment in this EIS in order to provide a more refined classification for Receptor Sensitivity. Sensitivity of the area has been determined based on the usage and the current context of sensitive buildings in Singapore.

10.2.3.2.3 *Understanding of Baseline Air Quality*

Primary and secondary data were collected to understand the baseline air quality of the Study Area. NEA's PSI data available from the nearest monitoring station were also reviewed for the Study Area. In addition, baseline air quality data were collected for representative location near the Project Footprint. The baseline air quality review and data measured was discussed in Section 10.5.

10.2.3.2.4 *Impact Intensity Definition*

The impact intensity was determined by reviewing the scale of increase in air quality levels due to traffic volume increase in the vicinity of the Project Footprint by comparing the baseline and predicted traffic volume. The impact intensity was then classified as Low, Medium or High.

10.2.3.2.5 *Classification of Overall Consequence*

The air quality impact assessment therefore evaluated the overall consequence prior to the implementation of mitigation. The worksite has been assessed by considering both the impact intensity and the Receptor Sensitivity to obtain an overall consequence rating. The overall consequence has been rated as being High, Medium, Low, or

Imperceptible in terms of overall consequence based upon pre-mitigation measures but after incorporation of minimum controls.

10.2.3.2.6 *Establishing Impact Significance*

Impact Significance was evaluated by considering both the overall Consequence and the Likelihood of occurrence of significant adverse impacts. The Likelihood of occurrence may be defined as unlikely, rare, occasional, regular, and continuous as per criteria listed in Table 6-7. Impact Significance has been evaluated in accordance with the matrix presented in Table 10-8.

10.2.3.2.7 *Mitigation Measures Recommendations*

Mitigation measures were proposed for implementation when for Moderate or Major Impact Significance.

10.2.3.2.8 *Establishing Residual Impact Significance*

Following implementation of mitigation measures prescribed in the EIS at the proposed Project Footprint, the residual Impact Significance was evaluated using the matrix outlined in Table 10-8. Ideally, the mitigation measures required should be specified within the conditions given for planning permission and should be stipulated in construction contracts.

10.3 Potential Sources of Air Quality Impacts

Fugitive particulate emissions from construction and operational activities have the potential to result in adverse impacts on air quality and therefore, public and ecosystem health. Particulate emissions may also generate significant nuisance to receptors near the heavy use construction footprint.

10.3.1 Construction Phase

Dust generated during construction works can have adverse effects upon vegetation restricting photosynthesis, respiration and transpiration. Furthermore, it can lead to phytotoxic gaseous pollutants penetrating the plants. The overall effect can be a decline in plant productivity, which may then have indirect effects on the quality of the affected habitats and associated fauna. Table 10-9 listed potential sources of air quality impact during construction phase of the Project.

Table 10-9 Potential Air Quality Impacts during the Construction Stage

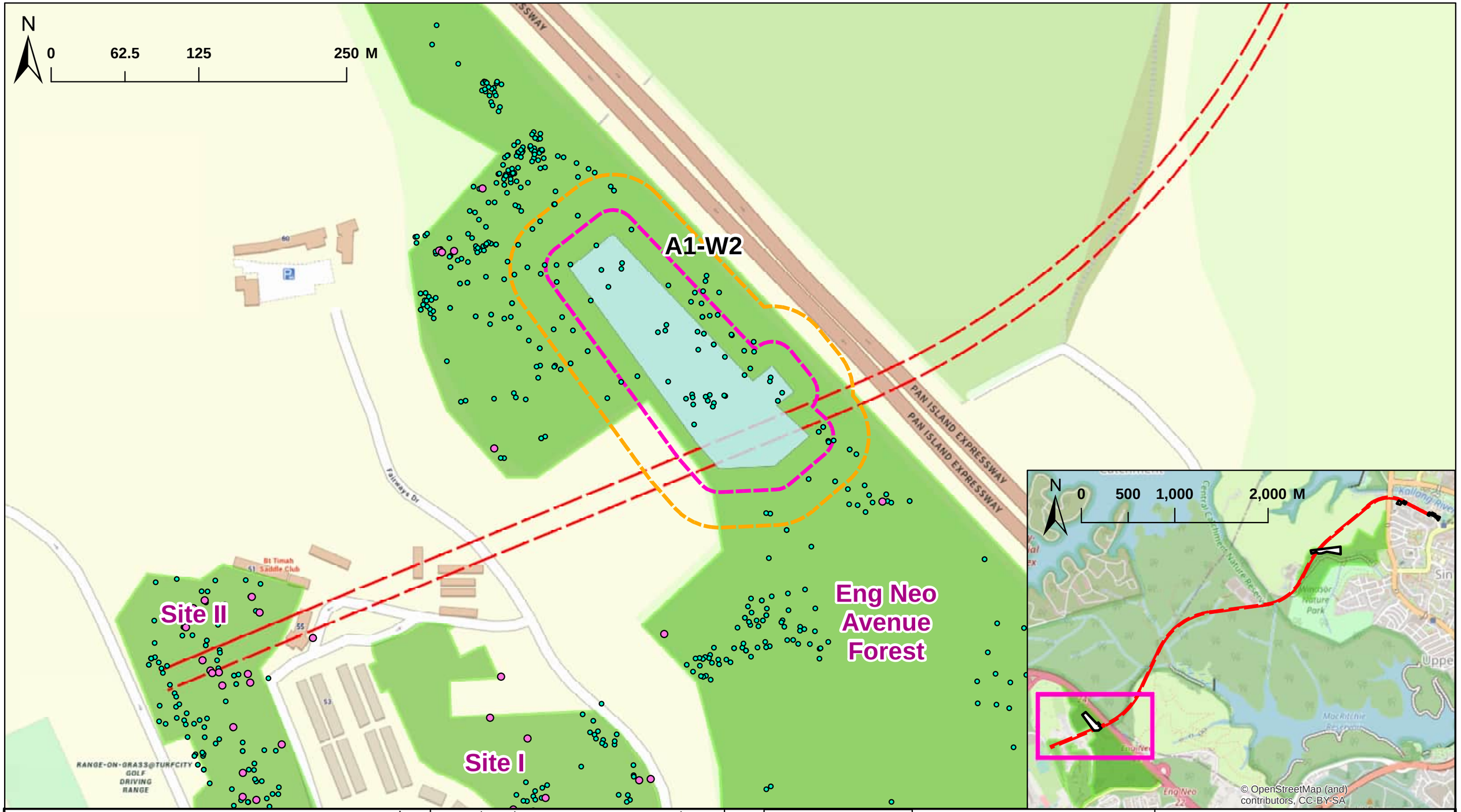
Potential Source of Impacts	Potential Associated Impacts
Dust emissions generated by earthworks processes, including land clearance, soil-stripping, ground levelling, excavation, stockpiling of spoil and landscaping at worksites A1-W1 and A1-W2.	Dust emissions could potentially result in adverse impacts on air quality and public health and may also generate significant nuisance at receptors, including the biodiversity, located nearby heavy construction worksite areas.
Dust emissions generated by the construction of new structures, such as A1-W1 and A1-W2 facility buildings.	Dust emissions could potentially result in adverse impacts on air quality and public health and may also generate significant nuisance at receptors, including the biodiversity, located nearby heavy construction worksite areas.
Dust emissions from transport of dust and dirt by dumper trucks for transporting spoil within the site and from the site onto public road network, where it may be deposited and resuspended by vehicles using the network.	Dust emissions could potentially result in adverse impacts on air quality and public health and may also generate significant nuisance at receptors nearby haulage routes.
Gaseous emissions from vehicle exhaust due to movement of construction vehicles and equipment, including spoil disposal	Exhaust emissions (NO_2, SO_2, CO, PM_{10} and $PM_{2.5}$) could potentially impact the air quality in the vicinity of construction worksites.

Potential Source of Impacts	Potential Associated Impacts
Gaseous emissions from off-road diesel engines on-site such as generators, if any	Exhaust emissions (NO_2, SO_2, CO, PM_{10} and $PM_{2.5}$) could potentially impact the air quality in the vicinity of construction worksites.

This area has been referred as earthworks footprint (refer to Figure 10-4 and Figure 10-5 for A1-W2 and A1-W1 respectively). The earthwork activity includes some extent of soil-cutting, excavation, piling and excavation works, while the construction activity includes the construction of the proposed buildings. As per the information received from LTA, it is assumed that the spoil amount will be 20,000 – 100,000 tonnes for A1-W1 and A1-W2 worksites of this EIS. At any one time, it is also assumed that <5 heavy machineries will be moving within A1-W2 and A1-W1 earthworks footprint.

The worst-case emission source for construction has been assumed to comprise the facility buildings footprint planned for development and also the temporary road access to A1-W2 worksite. This area has been referred as construction footprint (refer to Figure 10-6 and Figure 10-7 for A1-W2 and A1-W1 respectively). No concrete batching plant is expected within A1-W1 and A1-W2 construction worksite areas as the construction of facility building will require less amount of concrete. In line with the IAQM Guidance, the dust emission expected from the concrete batching plant is qualitatively assessed as part of the construction activity. The air quality impact assessment has also taken into consideration the utilities diversion work at Sin Ming Walk and A1-W1 worksite. There is no demolition expected as part of this Project construction phase hence, an assessment is not included in this section.

The trucks carrying spoil to and from the construction worksite area on access roads are also considered as a potential source of emission (referred to as trackout activity) as shown in Figure 10-8 and Figure 10-9 for A1-W2 and A1-W1 respectively. Based on the earthwork footprint for each construction worksite area, the number of outward trucks movement has been conservatively assumed to be 10-50 HDVs per day for A1-W1 and A1-W2 construction worksite areas. The road construction works are expected to be completed and paved where possible before the construction of other development commences. This is to ensure that the potential access roads are not significant dust generation sources. For a conservative trackout assessment, road material has been assumed to be Moderately Dusty and length of unpaved roads >100m. Impact prediction and evaluation is detailed in Section 10.7.1.



Legend

- 20m from Source
- 50m from Source
- Earthworks Footprint (Base)
- Large Speciemens
- Species of Conservation Significance
- Proposed CRL Alignment (Base)
- Biodiversity Study Area

Note:
Site I and II: Forested area adjacent to Fairways Quarters

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	HHL	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
We Keep Your World Moving

Project Title :
**CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)**

Figure Title :
**A1-W2 BASE SCENARIO
EMISSION SOURCES AND
RECEPTORS (EARTHWORKS)**

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
HHL	JAG	JAG	10-4	-	1 of 1
	Drawn HHL	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap and OpenStreetMap

N

0 62.5 125 250 M

A1-W1

Windsor

ISLAND GOLF COURSE

Island Club Rd

Upper Thomson Rd

Jln Rec

Island Gdns Walk P/G

Sports Island Country Club (Island Location)

180

Central Water Catchment

Kallang River

Sin Mi

Upper Th

Eng Neo

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N 0 500 1,000 2,000 M

Legend

- 20m from Source
- 50m from Source
- Earthworks Footprint (Base)
- Large Speciemens
- Species of Conservation Significance
- Proposed CRL Alignment (Base)
- Biodiversity Study Area

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	HHL	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement : NA

LTA Endorsement : NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :

CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :

A1-W1 BASE SCENARIO EMISSION SOURCES AND RECEPTORS (EARTHWORKS)

Designed	Checked	Approved
HHL	JAG	JAG
	Drawn HHL	Date MAR 2022

Figure No. : 10-5 | Rev. : - | Sheet : 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap and OpenStreetMap

N

0 50 100 200 M

A1-W2

PAN ISLAND EXPRESSWAY

PAN ISLAND EXPRESSWAY

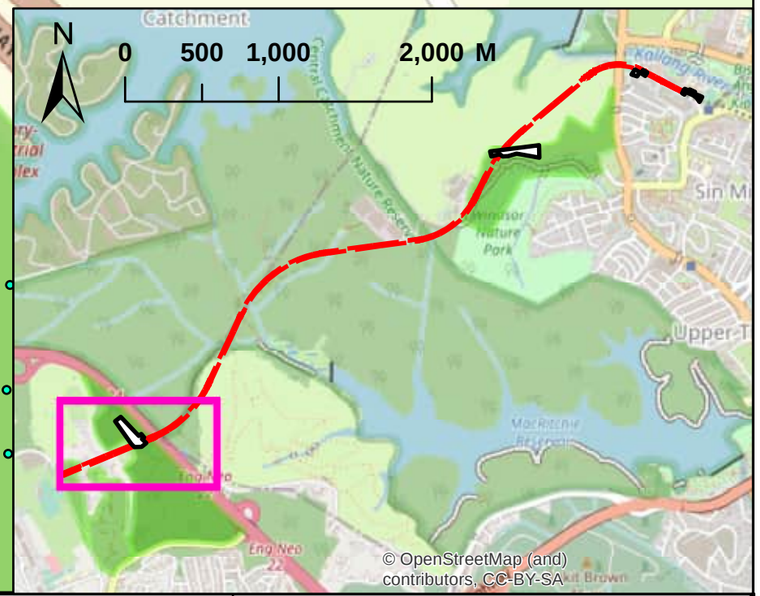
Fairways Dr

Bt Timah 51 Saddle Club

Site II

Site I

Eng Neo Avenue Forest



Legend

- 20m from Source
- 50m from Source
- Construction Footprint (Base)
- Large Speciemens
- Species of Conservation Significance
- Proposed CRL Alignment (Base)
- Biodiversity Study Area

Note:
Site I and II: Forested area adjacent to Fairways Quarters

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	HHL	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
**CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)**

Figure Title :
**A1-W2 BASE SCENARIO
EMISSION SOURCES AND
RECEPTORS (CONSTRUCTION)**

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
HHL	JAG	JAG	10-6	-	1 of 1
	Drawn HHL	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap and OpenStreetMap

N

0 50 100 200 M

ISLAND GOLF COURSE

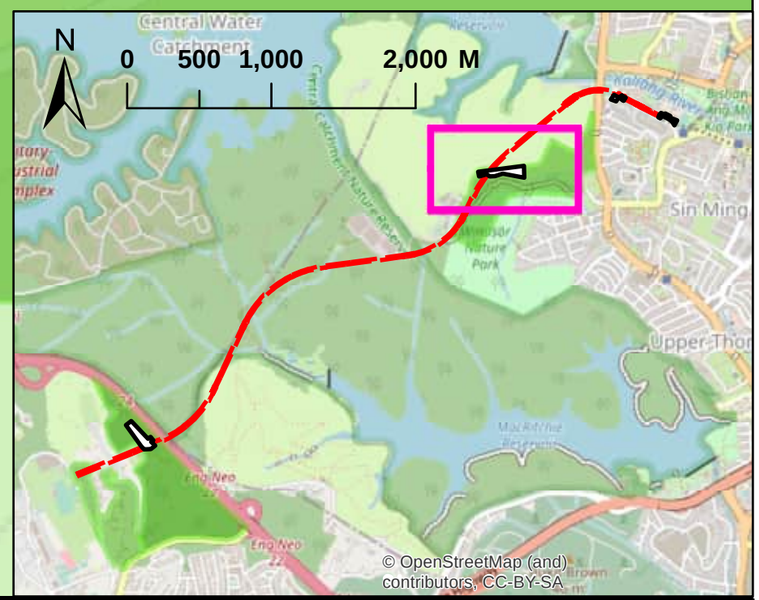
A1-W1

Windsor

S'pore Island Country Club (Island Location)

180

Island Club Rd



Legend

- 20m from Source
- 50m from Source
- Construction Footprint (Base)
- Large Speciemens
- Species of Conservation Significance
- Proposed CRL Alignment (Base)
- Biodiversity Study Area

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	HHL	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement : NA

LTA Endorsement : NA

Consultant : AECOM

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Project Title :

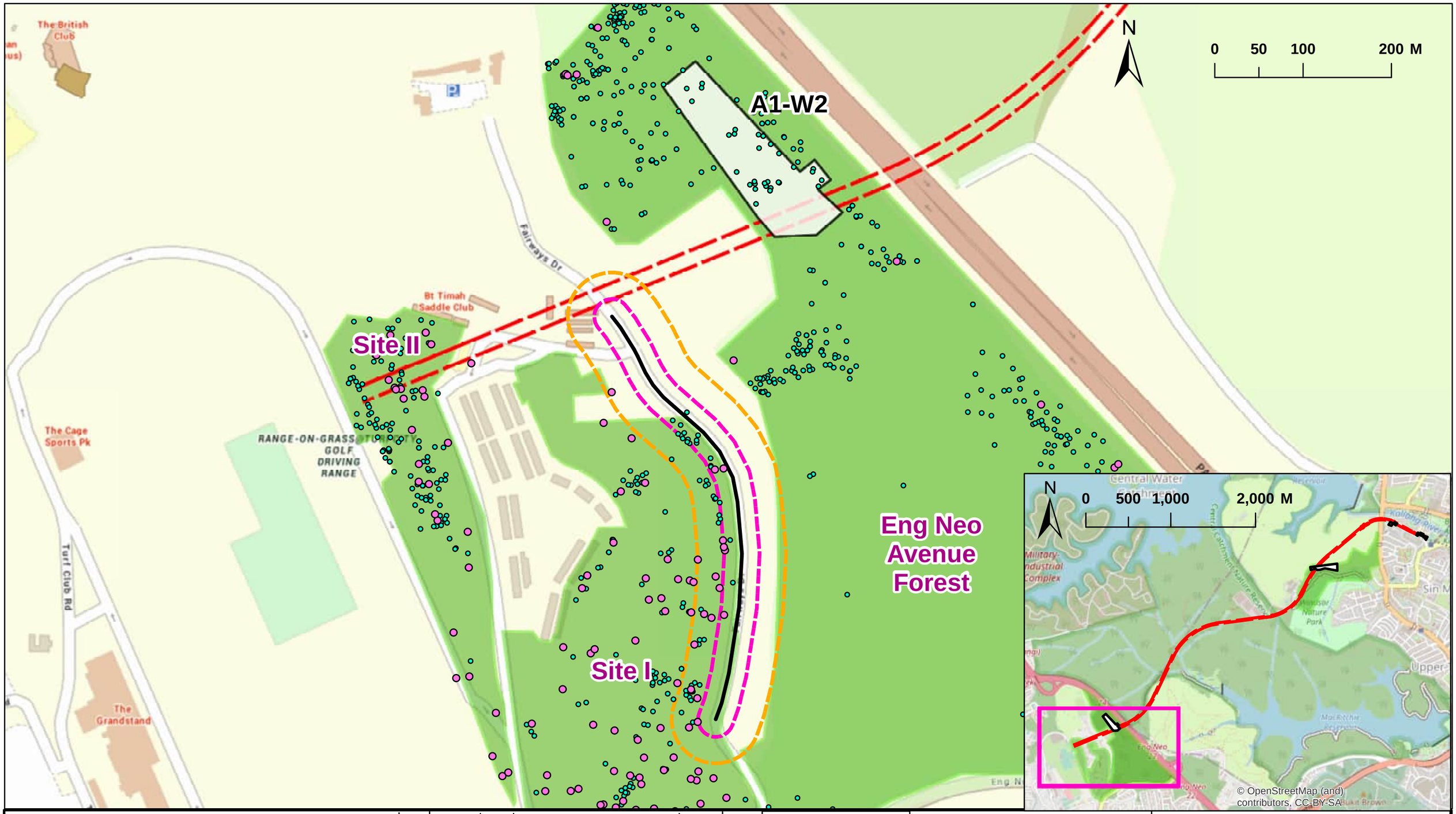
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :

A1-W1 BASE SCENARIO EMISSION SOURCES AND RECEPTORS (CONSTRUCTION)

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
HHL	JAG	JAG	10-7	-	1 of 1
	Drawn HHL	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap and OpenStreetMap



Legend

- Construction Worksite Area (Base)
- Proposed CRL Alignment (Base)
- Potential Access Road
- 20m from Source
- 50m from Source
- Large Specimens
- Species of Conservation Significance
- Biodiversity Study Area

Note:
Site I and II: Forested area adjacent to Fairways Quarters

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	HHL	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement : NA

LTA Endorsement : NA

Consultant : AECOM

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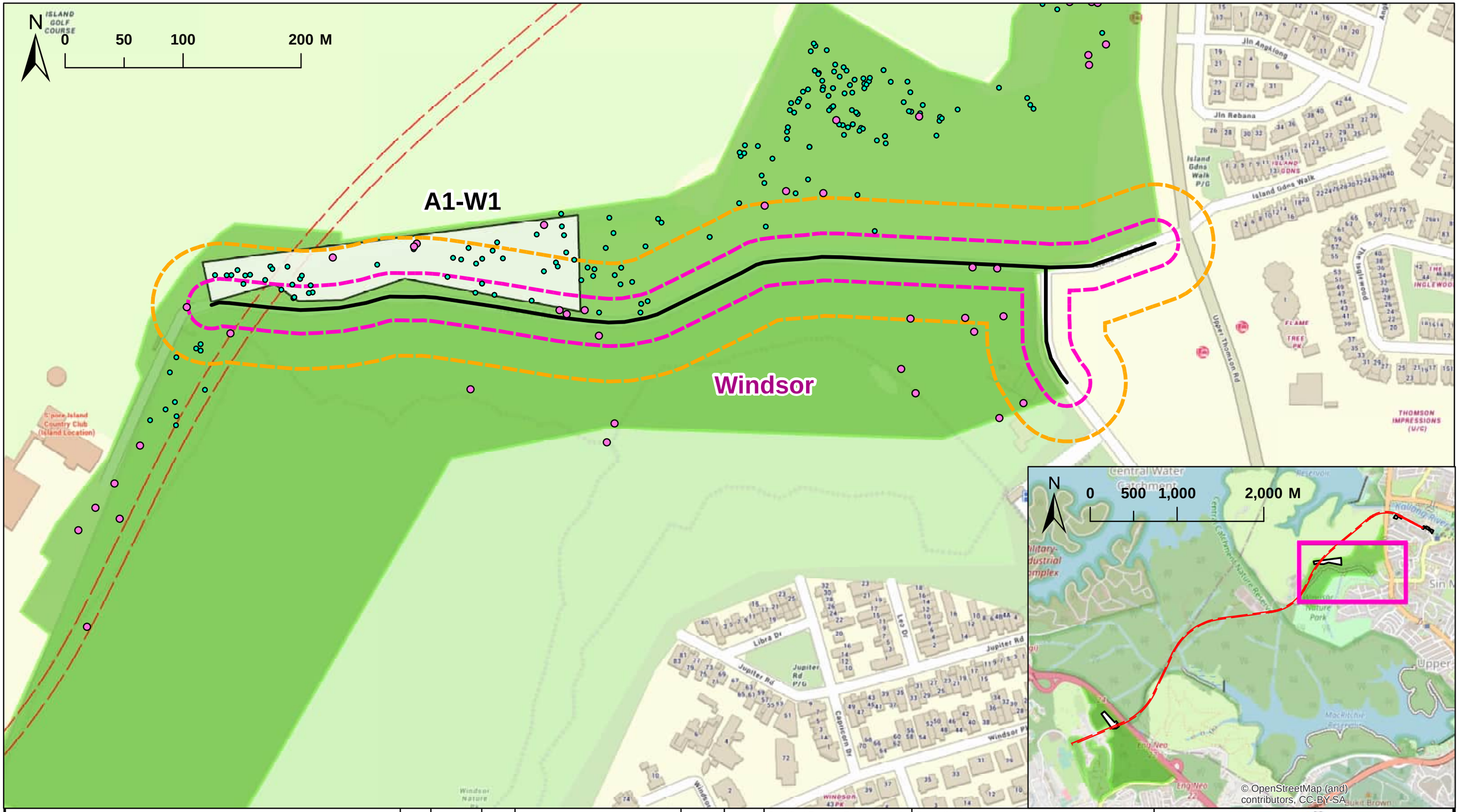
Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
A1-W2 BASE SCENARIO EMISSION SOURCES AND RECEPTORS (TRACKOUT)

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
HHL	JAG	JAG	10-8	-	1 of 1
	Drawn HHL	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap and OpenStreetMap



Legend

- Construction Worksite Area (Base)
- Proposed CRL Alignment (Base)
- Potential Access Road
- 20m from Source
- 50m from Source
- Large Specimens
- Species of Conservation Significance
- Biodiversity Study Area

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	HHL	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
A1-W1 BASE SCENARIO EMISSION SOURCES AND RECEPTORS (TRACKOUT)

Designed	Checked	Approved
HHL	JAG	JAG
	Drawn: HHL	Date: MAR 2022

Figure No. : 10-9 | Rev. : - | Sheet : 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap and OpenStreetMap

10.3.2 Operational Phase

During operational phase, since the trains are powered by electricity, they do not emit air emissions as a direct impact to environment through the facility buildings. Hence, as presented in Table 10-10, potential air quality impact during operational phase of the Project would be vehicular emissions due to increased traffic in the vicinity of the Project.

The main air pollutants affecting vegetation and ecosystems are nitrogen oxides (NOx), sulphur dioxide (SO_2) and ammonia (NH_3) [R-49]. In the context of this Project, the air pollutant of concern will be NOx which is produced from road traffic emission. SO_2 is not relevant for this Project as low sulphur content fuel will be used. NH_3 is mainly produced from agricultural activities and therefore, not relevant for the purpose of this Project. There is no published evidence for any direct toxic effect of NOx on animals and therefore effects on animals are not included in ecological impact assessment [R-49].

As per the NEA website, since 1 September 2017, all new petrol vehicles have had to meet the Euro 4 emission standard, and since 1 January 2018, all new diesel vehicles have had to meet the Euro 6 emission standard. The new standards will tighten fine particulate emissions from direct-injection petrol engines in addition to the other pollutants. Since 1 January 2018, the emission standard for all three-wheeled (Cat L5e) and large motorcycles with an engine capacity more than 200cc has been tightened to Euro 4 standard, while smaller motorcycles with an engine capacity of 200cc and below will see the Euro 4 emission standard implemented from 1 January 2020. Compared to the Euro 3 emission standard, the tighter Euro 4 emission standard will help reduce emissions of hydrocarbons and nitrogen oxides (NOx), which are precursors to ozone. The emission standards for various vehicle classes have been summarised in Table 10-11.

Table 10-10 Potential Air Quality Impacts during the Operational Stage

Potential Source of Impacts	Potential Associated Impacts
Gaseous and particulate emissions from vehicle exhaust due to the increased traffic in vicinity of A1-W1 and A1-W2 facility building due to Project operation.	Exhaust emissions (NO_2, SO_2, CO, PM_{10} and $PM_{2.5}$) could potentially impact the air quality in the vicinity of facility buildings.

Table 10-11 Emission Standard of Various Vehicle Classes

No	Implementation Date	Vehicle Classes	Emission Standard
1	1 September 2017	New petrol vehicles	Euro 6
2	1 January 2018	New diesel vehicles	Euro 6
3	1 January 2018	Three-wheeled (Cat L5e) and large motorcycles with engine capacity more than 200cc	Euro 4
4	1 January 2020	Smaller motorcycles with engine capacity of 200cc and below	Euro 4

10.4 Identification of Air Sensitive Receptors

10.4.1 Construction Phase

The construction activities at the construction worksite pose a potential risk of dust emissions that may impact upon target habitat areas lying within the zone of influence of the construction site. In line with the IAQM Guidance, a Study Area of 50 m was considered for ecological impacts during construction phase. Table 10-12 below summarises the sensitivity of each construction phase for earthworks, construction, and trackout for each construction worksite. All construction worksites are located within or in close proximity to ecologically sensitive receptors. Based on the distances of emission sources to the identified receptors presented in Figure 10-4 to Figure 10-9, the Sensitivity of the Area was determined to be Priority 1. In line with the IAQM Guidance, Priority 1 refers to construction worksites with emission source located <20 m to the nearest ecologically sensitive receptors. Flora species of high value identified within the air quality Study Area are presented in Table 10-13.

It shall be noted that Peirce Secondary School and CR13 retrieval shaft worksites are located >50 m from nearest ecologically sensitive receptors and hence, air quality impact from these 2 worksites were considered insignificant and not assessed.

Table 10-12 Receptor Sensitivity for Air Quality Impact Assessment – Construction Phase

Distance	Identified Receptors	Sensitivity of the Area
A1-W2 BASE SCENARIO CONSTRUCTION WORKSITES		
For Earthworks:		
Within 20m	Eng Neo Avenue Forest	Priority 1
Between 20m to 50m	Eng Neo Avenue Forest	
For Construction:		
Within 20m	Eng Neo Avenue Forest	Priority 1
Between 20m to 50m	Eng Neo Avenue Forest	
For Trackout:		
Within 20m	Site I	Priority 1
Between 20m to 50m	Site I Eng Neo Avenue Forest	
A1-W1 BASE SCENARIO CONSTRUCTION WORKSITE		
For Earthworks:		
Within 20m	Windsor	Priority 1
Between 20m to 50m	Windsor	
For Construction:		
Within 20m	Windsor	Priority 1
Between 20m to 50m	Windsor	
For Trackout:		
Within 20m	Windsor	Priority 1
Between 20m to 50m	Windsor	

Table 10-13 Flora species of High Value Identified within the Air Quality Study Area

Distance	Identified Species	Status	Number of Species Identified
ENG NEO AVENUE FOREST – Base Scenario Worksite: Dominated by abandoned-land forest, waste woodlands, and scrubland and herbaceous vegetation			
Conservation Species			
Within 20m from Worksite	*Bridelia stipularis* *Connarus semidecandrus*	Vulnerable Critically Endangered	3 3
Between 20m to 50m from Worksite	*Cayratia trifolia* *Centotheca lappacea* *Connarus semidecandrus* *Horsfieldia polyspherula* *Memecylon floridum* *Oncosperma tigillarium* *Piper pedicellosum*	Vulnerable Critically Endangered Critically Endangered Vulnerable Critically Endangered Vulnerable Critically Endangered	3 1 6 3 1 3 2
Large Specimens			
Within 20m from Worksite	*Ficus benjamina*	Common	2

Distance	Identified Species	Status	Number of Species Identified
Between 20m to 50m from Worksite	-	-	-
WINDSOR – Base Scenario Worksite: Dominated by abandoned-land forest, native-dominated secondary forest, managed vegetation, and scrubland and herbaceous vegetation			
Conservation Species			
Within 20m from Worksite	*Aporosa benthamiana* *Goniophlebium percussum* *Guioa pubescens* *Horsfieldia polyspherula* *Strombosia javanica* *Artabotrys suaveolens* *Connarus semidecandrus*	Vulnerable Vulnerable Vulnerable Vulnerable Vulnerable Endangered Critically Endangered	1 1 1 1 6 1 1
Between 20m to 50m from Worksite	*Goniophlebium percussum* *Strombosia javanica* *Connarus semidecandrus* *Litsea firma* *Agelaea macrophylla* *Strophanthus caudatus*	Vulnerable Vulnerable Critically Endangered Vulnerable Critically Endangered Critically Endangered	1 4 3 1 1 1
Large Specimens			
Within 20m from Worksite	*Ficus microcarpa* *Pterocarpus indicus*	Common Casual	1 2
Between 20m to 50m from Worksite	*Ficus microcarpa* *Cyrtophyllum fragrans* *Khaya senegalensis*	Common Common Cultivated Only	1 1 1

10.4.2 Operational Phase

Potential air quality impact during operational phase of the Project would be vehicular emissions due to increased traffic to the proposed development. Project footprint is located within or in the vicinity of ecologically sensitive receptors. Nearest sensitive receptors which might be impacted by the increased traffic are summarised in Table 10-14 below. As the Project is located within or in the vicinity of ecologically sensitive receptors, the Sensitivity of the Area was determined to be Priority 1.

Table 10-14 Receptor Sensitivity for Air Quality Impact Assessment – Operational Phase

Project Footprint	Identified Receptors	Sensitivity of the Area
A1-W2	Eng Neo Avenue Forest, Sites I and II	Priority 1
A1-W1	Windsor	Priority 1

10.5 Baseline Air Quality

10.5.1 Desktop Assessment

10.5.1.1 Secondary Data Collection (Review of Background Data)

10.5.1.1.1 *NEA Long Term Ambient Air Quality*

Table 10-15 provides the general NEA ambient air monitoring results for Singapore over the period 2015 – 2019 and compares them with the Singapore Long Term Ambient Air Quality Targets. The Singapore Long Term Air Quality Targets have been adopted in this report and are generally more stringent than the USEPA National Ambient Air Quality Standards (NAAQS).

It can be observed from Table 10-15 that the NEA monitoring results for background particulate matter less than 10 µm (PM_{10}), particulate matter less than 2.5 µm ($PM_{2.5}$), and ozone (O_3) have consistently exceeded the Singapore Long Term Air Quality Targets over the period 2015 - 2019. Carbon monoxide (CO) and nitrogen dioxide

(NO_2) were below the Singapore Ambient Air Quality Long Term Targets between 2015 and 2019. The elevated PM_{10}, $PM_{2.5}$, and O_3 concentrations in Singapore are partly attributable to the intermittent haze periods resulting from forest fires in neighbouring countries, although other significant contributors to the background levels may also be domestic emissions from industries, shipping and motor vehicles.

Table 10-15 NEA Long Term Ambient Air Quality Monitoring [R-48]

Pollutants	Averaging Period	2015 results ($\mu g/m^3$)	2016 results ($\mu g/m^3$)	2017 results ($\mu g/m^3$)	2018 results ($\mu g/m^3$)	2019 results ($\mu g/m^3$)	Average results 2015 – 2019 ($\mu g/m^3$)	Singapore Ambient Air Quality Long Term Targets ($\mu g/m^3$)
PM_{10}	99th %ile of 24-Hour Averages	**186**	**61**	**57**	**59**	**90**	**90.6**	50
	Annual Mean	**37**	**26**	**25**	**29**	**30**	**29.4**	20
$PM_{2.5}$	99th %ile of 24-Hour Averages	**145**	**40**	**34**	**32**	**62**	**62.6**	25
	Annual Mean	**24**	**15**	**14**	**15**	**16**	**16.8**	10
CO	Maximum 1-Hour Average	3,500	2,700	2,300	2,500	2,300	2,700	30,000
	Maximum 8-Hour Average	3,300	2,200	1,700	2,000	1,700	2,200	10,000
NO_2	Maximum 1-Hour Average	99	123	158	147	156	136.6	200
	Annual Mean	22	26	25	26	23	24.4	40
SO_2	24-Hour Average	**75**	**61**	**59**	**65**	**57**	**63.4**	50
	Annual Mean	12	13	12	9	8	10.8	15
O_3	8-Hour Average	**152**	**115**	**191**	**150**	**125**	**146.6**	100

Note: Values in **Bold** exceed the Singapore Ambient Air Quality Long Term Targets

10.5.1.1.2 *Hourly Pollution Standard Index (PSI) and 24-hour PM_{10} and $PM_{2.5}$ Concentrations Readings*

According to NEA's website [W-43], PM_{10} and $PM_{2.5}$ data are subsumed into PSI. Hourly historical PSI, 24-hr PM_{10} and $PM_{2.5}$ readings available on data.gov.sg for Central Region of Singapore were collected during primary data collection period for comparison against primary baseline monitoring results as per the details presented in Table 10-16.

The hourly PSI, 24-hr PM_{10} and $PM_{2.5}$ concentration readings recorded over these days are summarised in Table 10-16 below. The PSI readings during the primary baseline monitoring period are considered Good to Moderate. Both 24-hr PM_{10} and $PM_{2.5}$ concentrations obtained from data.gov.sg were below the target throughout the monitoring period.

Figure 10-10 to Figure 10-11 below show the variation of hourly historical PSI readings in the Central Region of Singapore during the primary data collection period as per Table 10-16. Figure 10-12 to Figure 10-13 and Figure

10-14 to Figure 10-15 show the variation of PM_{10} and $PM_{2.5}$ concentrations recorded by the NEA during the primary baseline data collection period respectively.

Table 10-16 Summary of Publicly Available Hourly PSI, 24-Hr PM_{10} and $PM_{2.5}$ Concentrations

Purpose	Monitoring Date	Region of Singapore	Hourly PSI Readings	24-hr PM_{10} Concentration ($\mu g/m^3$)	24-hr $PM_{2.5}$ Concentration ($\mu g/m^3$)	Remarks
For comparison with A03: Eng Neo Avenue Forest	26 March – 2 April 2020	Central	45 – 57	20 – 25	11 – 17	Good to Moderate PSI readings were observed during the primary baseline data collection period. Both NEA 24-hr PM_{10} and $PM_{2.5}$ concentrations readings of West Singapore were below the target throughout the monitoring period. This is in line with the primary baseline data which monitored compliance with the Singapore Ambient Air Quality Long Term Targets.
For comparison with A04: Windsor (within Northern Forest Fragment)	19 – 26 June 2020	Central	21 – 37	17 – 26	5 – 9	Good PSI readings were observed during the primary baseline data collection period. Both NEA 24-hr PM_{10} and $PM_{2.5}$ concentrations readings of West Singapore were below the target throughout the monitoring period. This is in line with the primary baseline data which monitored compliance with the Singapore Ambient Air Quality Long Term Targets.

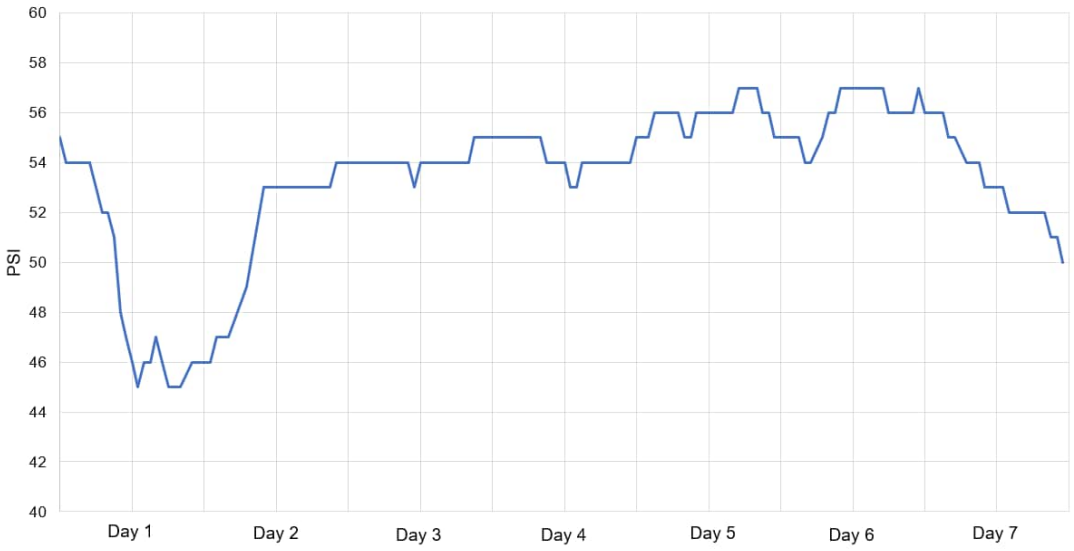


Figure 10-10 Hourly PSI reading of Central Singapore for 26 March – 2 April 2020 [W-44]

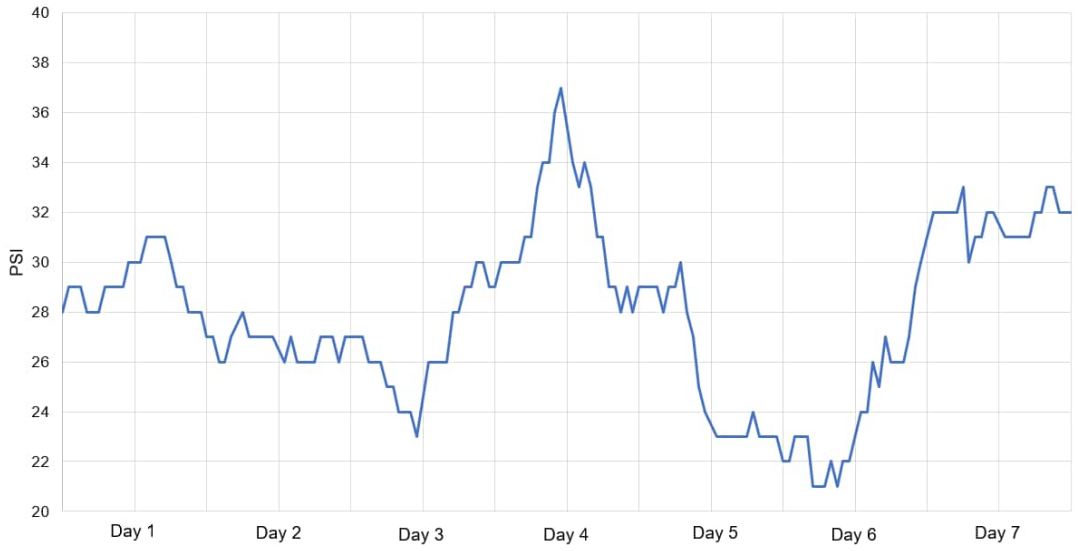


Figure 10-11 Hourly PSI Reading of Central Singapore for 19-26 June 2020 [W-44]

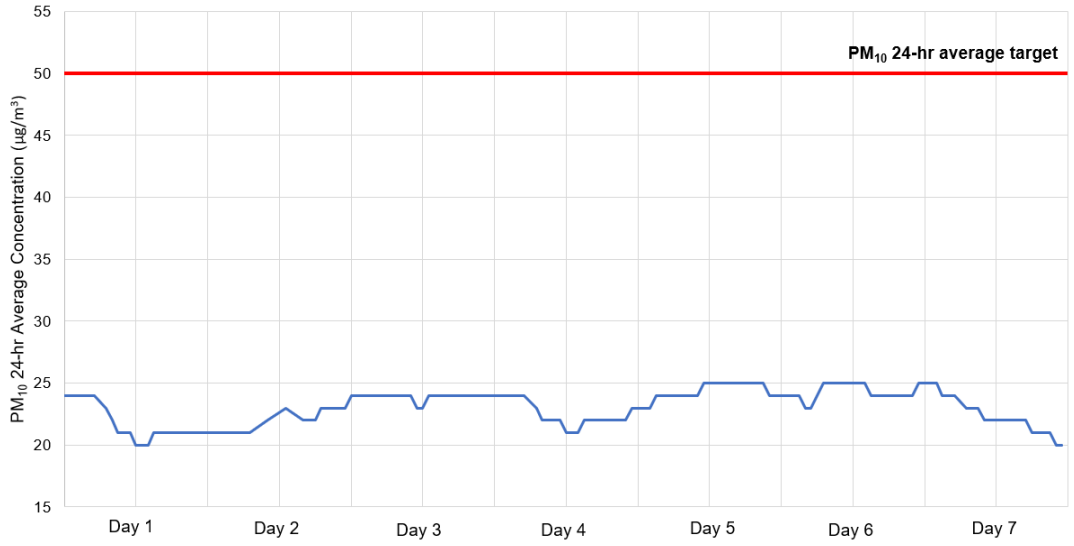


Figure 10-12 24-hr PM_{10} Concentrations of Central Singapore for 26 March – 2 April 2020 [W-44]

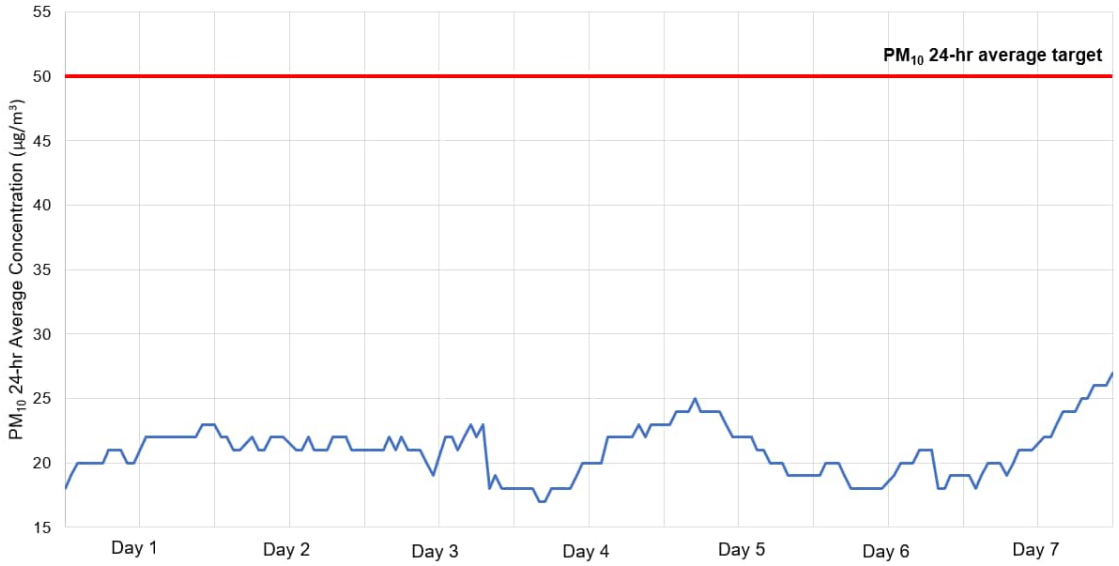


Figure 10-13 24-hr PM_{10} Concentrations of Central Singapore for 19-26 June 2020 [W-44]

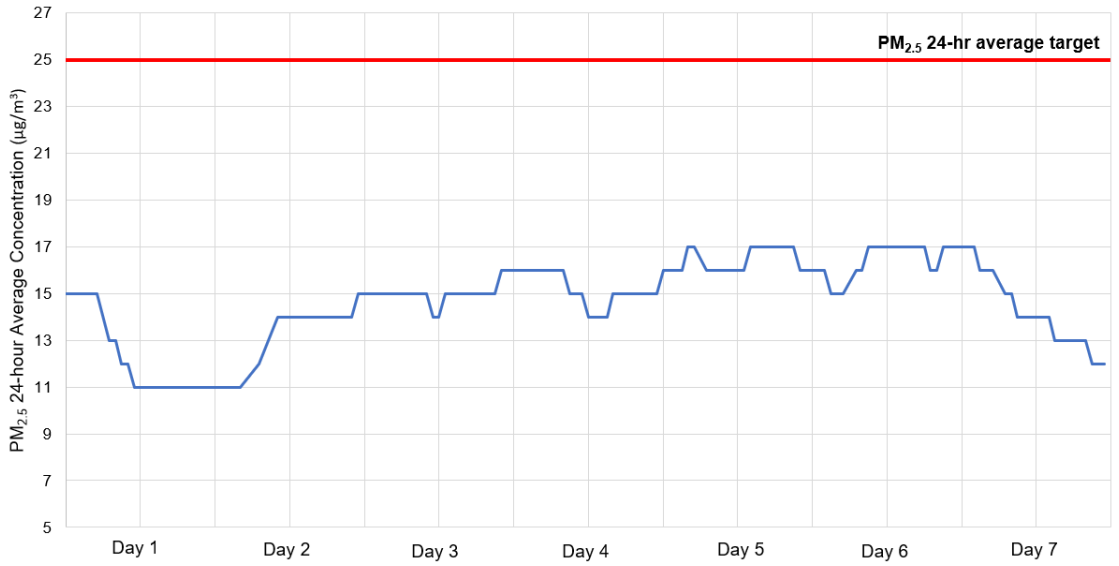


Figure 10-14 24-hr $PM_{2.5}$ Concentrations of Central Singapore for 26 March – 2 April 2020 [W-44]

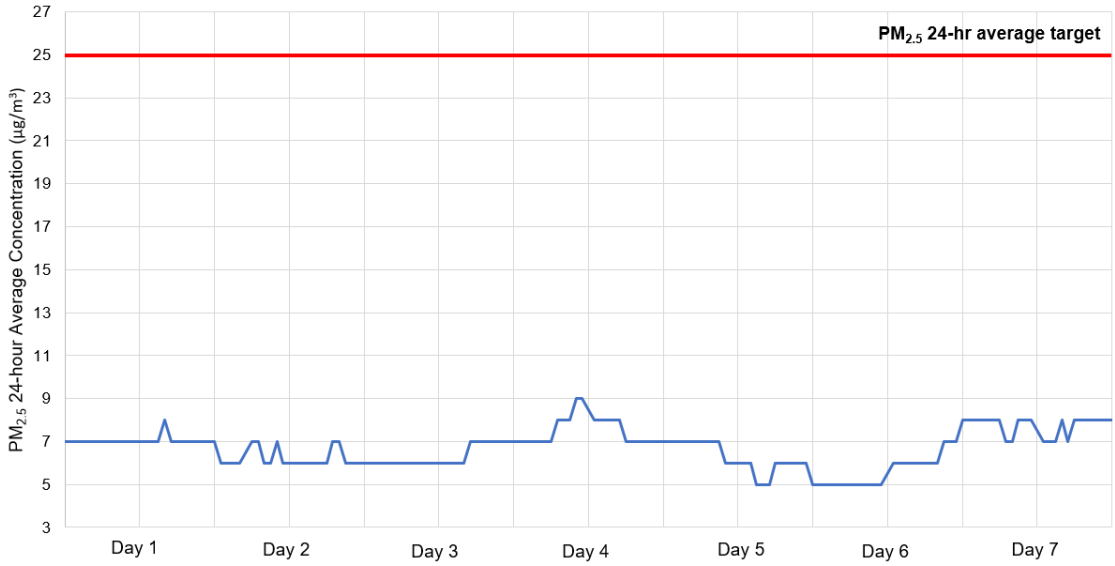


Figure 10-15 24-hr $PM_{2.5}$ Concentrations of Central Singapore for 19-26 June 2020 [W-44]

10.5.1.1.3 *Other Parameters (Rainfall, Temperature, Wind Speed)*

Figure 10-16, Figure 10-17, and Figure 10-18 below present the trend of daily total rainfall, mean temperature and mean wind speed observed at the nearest weather monitoring stations, from February 2015 to February 2020.

From Figure 10-16, an average of approximately 6.31mm of daily rain was observed in the past 5 years over the 3 weather monitoring stations. This calculates to approximately 2,300mm of rain annually. As discussed in Section 4.9.1, rainfall is higher over the northern and western parts of Singapore. This means the Project is expected to receive relatively higher rainfall in the long term compared to the other parts of Singapore.

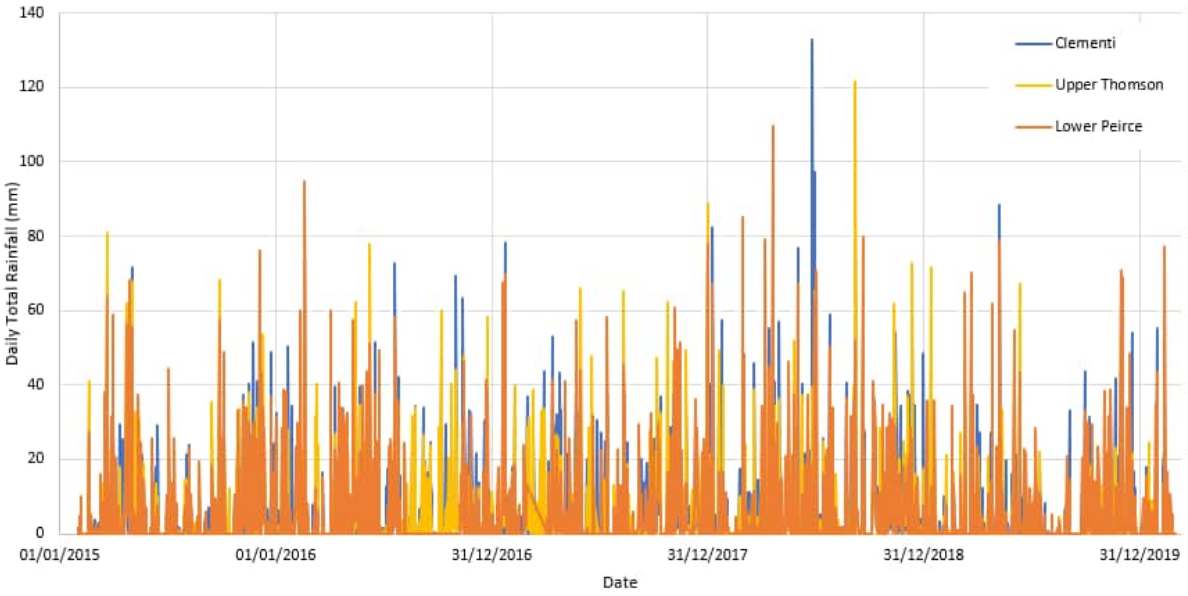


Figure 10-16 Daily Rainfall Monitored at Clementi, Upper Thomson and Lower Peirce Monitoring Stations [W-42]

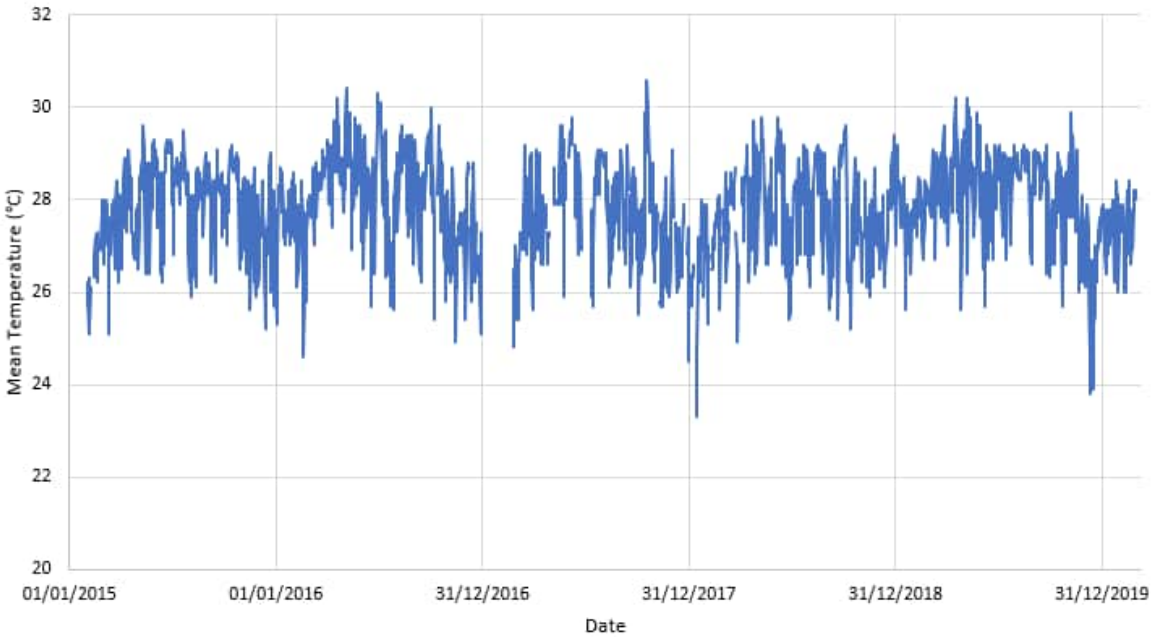


Figure 10-17 Mean Temperature Monitored at Clementi Monitoring Station [W-42]

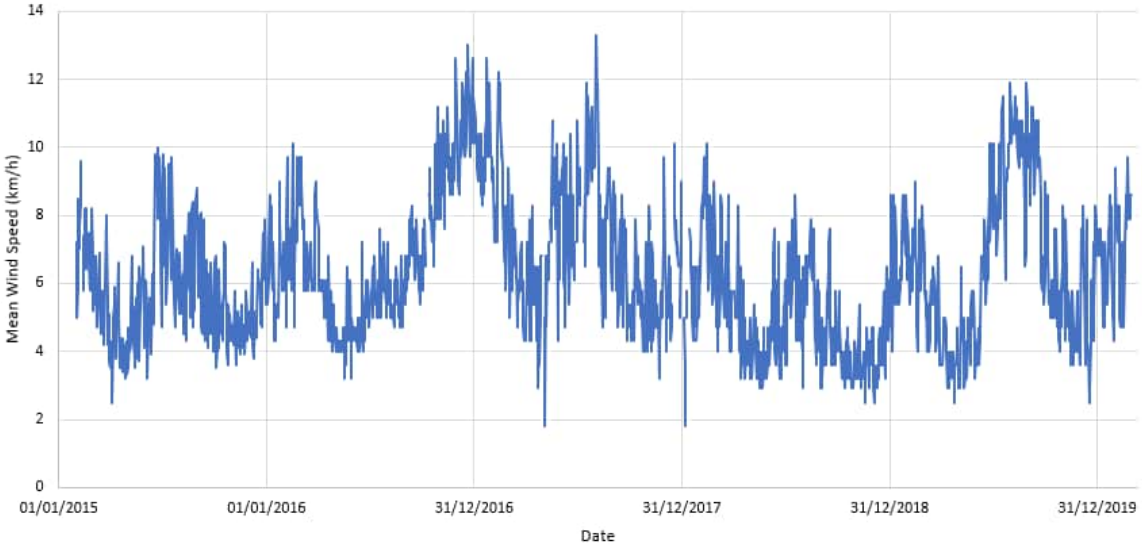


Figure 10-18 Mean Wind Speed Monitored at Clementi Monitoring Station [W-42]

10.5.1.2 Secondary Air Quality Monitoring Data from Concurrent Study Carried out by AECOM in the Vicinity

Seven (7) days of continuous ambient air quality monitoring was conducted to determine the pollutant concentrations from existing background pollutant sources. The monitoring results for each pollutant at all monitoring locations are summarised in Table 10-18 below and compared with the Singapore Ambient Air Quality Long Term Targets.

Table 10-17 Concurrent Study Air Quality Monitoring Results

Monitoring Location	Monitoring Date	Daily PM_{10} Concentration, $\mu g/m^3$			Daily $PM_{2.5}$ Concentration, $\mu g/m^3$		
		Min	Max	Average	Min	Max	Average
AQ1 – Southern portion of Eng Neo Avenue Forest	23 – 30 September 2021	14.5	24.2	20.1	8.0	16.8	12.4
AQ2 – Within 53 Fairways Drive in the vicinity of Site I and Site II	23 – 30 September 2021	14.0	24.9	20.6	7.9	16.4	12.0
Singapore Ambient Air Quality Long Term Targets		*50*			*25*		

It can be observed from Table 10-18 that all pollutant concentrations are within the Singapore Ambient Air Quality Long Term Targets at the monitoring location. It should be noted that air quality monitoring was conducted during COVID-19 pandemic. Ambient air quality in this area might be higher during normal condition.

10.5.2 Primary Data Collection (Survey & Sampling)

Seven (7) days of continuous ambient air quality monitoring was conducted at the location mentioned above to determine the pollutant concentrations from existing background pollutant sources. The monitoring results for each pollutant at all monitoring locations are summarised in Table 10-18 below and compared with the Singapore Ambient Air Quality Long Term Targets.

Table 10-18 Baseline Air Quality Monitoring Results

Monitoring Location	Monitoring Date	Daily PM_{10} Concentration, $\mu g/m^3$			Daily $PM_{2.5}$ Concentration, $\mu g/m^3$		
		Average	Max	Min	Average	Max	Min
A03: Eng Neo Avenue Forest	26 March – 2 April 2020	19.0	25.5	14.6	13.4	16.9	10.0
A04: Windsor (within Northern Forest Fragment)*	19 – 26 June 2020	10.2	13.6	6.3	6.8	9.6	3.3
Singapore Ambient Air Quality Long Term Targets		***50***			***25***		
Note: * Monitoring at A04 was conducted during the first week of Singapore's Phase 2 reopening after the Circuit Breaker measures during COVID-19 pandemic. Ambient air quality in this area might be higher during normal condition.							

It can be observed from Table 10-18 that all pollutant concentrations are within the Singapore Ambient Air Quality Long Term Targets at all monitoring locations. The Contractor is recommended to conduct air quality monitoring of PM_{10} and $PM_{2.5}$ for 1 week prior to site clearance for the re-establishment of latest baseline conditions.

10.6 Minimum Control for Potential Impacts

10.6.1 Construction Phase

This section proposes minimum controls or standard practices commonly implemented that have been assumed to be implemented for the purposes of impact assessment. The following control measures should be observed during the construction stage to reduce the noise levels:

- The construction footprint shall be hoarded on all sides;
- No demolition of permanent structure is expected as part of the Project; and

- Road construction or expansion shall be completed first and paved where possible before the construction of other development commences.

10.6.2 Operational Phase

No minimum control has been assumed for the purpose of air quality impact assessment during operational phase. Refer to Section 10.7.2 for evaluation of air quality impacts during operational phase.

10.7 Prediction and Evaluation of Air Quality Impacts

10.7.1 Construction Phase

Throughout the study a conservative but credible approach was adopted to assess potential dust impacts. This may lead to an over-estimation of the levels of pollutants that will arise in practice, but this is considered to be appropriate for planning purposes at this stage of the Project and is consistent with precautionary principles.

The assessment is conducted using the site area, hours of operation, timescale of construction, construction material, excavation quantities, surface material and number of vehicles on site as discussed in Section 10.3.1.

Dust from construction sites deposited on vegetation may create ecological stress within the local plant community. During dry periods dust can coat plant foliage adversely affecting photosynthesis and other biological functions. Rainfall removes the deposited dust from foliage and can rapidly leach chemicals into the soil. Large scale construction sites may give rise to dust deposition over an extended period of time and adversely affect vascular plants. Deposition of concrete dust has the potential to increase the surface alkalinity, which in turn can hydrolyse lipid and wax components, penetrate the cuticle, and denature proteins, finally cause the leaf to wilt [P-68]. Dust may affect photosynthesis, respiration, transpiration and allow the penetration of phytotoxic gaseous pollutants [P-69].

In line with the IAQM Guidance, the Impact Intensity was determined by reviewing the scale of construction activities and classifying them as low, medium or high for each activity type (earthworks, construction, and trackout). The amount of dust deposited, and its effects are also dependent upon weather conditions, during wet weather less dust will be generated and that which has been deposited upon foliage is more likely to be washed off. As discussed in Section 10.5.1.1.3, the Project is expected to receive relatively higher rainfall in the long term compared to the other parts of Singapore. Hence, this is expected to help to lessen the intensity of dust generated and deposited upon plant foliage. However, the IAQM methodology does not take into account the rainfall intensity in the Study Area. Therefore, the air quality assessment is expected to be conservative for the purpose of the Project.

The overall Consequence for each activity was classified by considering Impact Intensity with the Receptor Sensitivity. Without any mitigation measures in place, the Likelihood of occurrence of impacts from construction of the Project is classified as Regular as the activity would occur on a regular basis during construction. The Impact Intensity, overall Consequence and Impact Significance are outlined in Table 10-19 to Table 10-21.

Based on the assessment, the Impact Significance is predicted to be **Moderate to Major** for ecological impact. Hence, based on the assessment methodology in Section 10.2.3.1.7, Impact Significance evaluated as Moderate and Major require the adoption of management or mitigation measures.

Table 10-19 Impacts of Dust Risk Assessment – Earthworks (Before Mitigation)

Construction Worksite	Key Parameter					Impact Assessment		
	Total Site Area (m^2)	No. of Vehicles moving within the site	Total Material Moved (tonnes)	Impact Intensity	Sensitivity of the Area	Overall Consequence / Dust Risk	Likelihood	Impact Significance
A1-W2 Base Scenario	>10,000	<5	20,000 – 100,000	High	Priority 1	High	Regular	**Major**
A1-W1 Base Scenario	>10,000	<5	20,000 – 100,000	High	Priority 1	High	Regular	**Major**

Table 10-20 Impacts of Dust Risk Assessment – Construction (Before Mitigation)

Construction Worksite	Key Parameter					Impact Assessment		
	Total Building Volume (m^3)	Construction Material	No. of concrete batching plant	Impact Intensity	Sensitivity of the Area	Overall Consequence / Dust Risk	Likelihood	Impact Significance
A1-W2 Base Scenario	25,000-100,000	Concrete	0	Medium	Priority 1	Medium	Regular	**Moderate**
A1-W1 Base Scenario	25,000-100,000	Concrete	0	Medium	Priority 1	Medium	Regular	**Moderate**

Table 10-21 Impacts of Dust Risk Assessment – Trackout (Before Mitigation)

Construction Worksite	Key Parameter					Impact Assessment		
	No. of outward trucks movement per day	Road surface material	Unpaved Road Length (m)	Impact Intensity	Sensitivity of the Area	Overall Consequence / Dust Risk	Likelihood	Impact Significance
A1-W2 Base Scenario	10-50	Moderately Dusty	<100 m	Medium	Priority 1	Medium	Regular	**Moderate**
A1-W1 Base Scenario	10-50	Moderately Dusty	<100 m	Medium	Priority 1	Medium	Regular	**Moderate**

10.7.2 Operational Phase

During operational phase, since the trains are powered by electricity, they do not emit air emissions as a direct impact to environment through the facility buildings. As discussed in Section 10.3.2, emissions from vehicle exhaust due to increased traffic to the proposed Project is expected. NOx can affect plants directly or indirectly. It may directly enter a plant via the stomata, where it has phytotoxic effects. Lower plants such as lichens and bryophytes (including mosses, landworts and hornwarts) are particularly vulnerable to direct exposure to the gases in this way [W-56]. Since the biodiversity survey was focused on only vascular plants, there is limited information on the locations of these non-vascular species. However, based on empirical observation, rain trees are known to coexist with other biomes such as mosses. Numerous specimens of rain trees were recorded within the Study Area (refer to Section 7.3.2.3.3).

Indirectly, NOx can also deposit onto soil and, following transformation to nitrate, enrich the soil, leading to eutrophication. The effects of elevated NOx concentrations on vegetation can be broadly categorised as [R-50]:

- growth effects: particularly increased biomass, changes in root to shoot ratio and growth of more competitive species, but also including growth suppression of some species;
- physiological effects: e.g. CO_2 assimilation and stomatal conductivity; and
- (bio)chemical effects: e.g. changes in enzyme activity and chlorophyll content (probably through the effects of increased nitrogen).

Indirectly in the long run, accumulation of nitrogen oxides (NOx) via acidic rain causes soil and water to become more acidic and hence, reducing the nutritional value of food sources for fauna [P-70]. There is no published evidence for any direct toxic effect of NOx on animals and therefore effects on animals are not included in ecological impact assessment [R-49].

It is assumed that all new petrol and diesel vehicles will meet Euro 6 emission standard, while all motorcycles will meet Euro 4 standard going forward and slowly completely convert to these or better standards as they get phased out in 10 years from their onset. It can be observed from Table 10-22, NOx reduction from the last three Euro emission standard tier is 55.56% and 25% for diesel and gasoline passenger cars respectively. Similarly, as observed in Table 10-23, NOx reduction from the last three Euro emission standard tier is approximately 55% and 25% for diesel and gasoline commercial good vehicles respectively across all vehicle category.

Table 10-22 Euro Emission Standard for Passenger Cars [W-57]

Tier	Approval Date	Emission standard for passenger cars, g/km				
		CO	HC	NOx	HC+NOx	PM
Compression Ignition (Diesel)						
Euro 5a	September 2009	0.50	-	0.18	0.23	0.005
Euro 5b	September 2011	0.50	-	0.18	0.23	0.005
Euro 6	September 2014	0.50	-	0.08	0.17	0.005
Positive Ignition (Gasoline)						
Euro 4	January 2005	1.00	0.10	0.08	-	-
Euro 5	September 2009	1.00	0.10	0.06	-	0.005
Euro 6	September 2014	1.00	0.10	0.06	-	0.005

Table 10-23 Euro Emission Standard for Commercial Good Vehicles [W-57]

Category	Tier	Approval Date	Emission standard for commercial good vehicles, g/km				
			CO	HC	NOx	HC+NOx	PM
Compression Ignition (Diesel)							
N1, Class I ⩽ 1305 kg	Euro 5a	September 2009	0.50	-	0.18	0.23	0.005
	Euro 5b	September 2011	0.50	-	0.18	0.23	0.005
	Euro 6	September 2014	0.50	-	0.08	0.17	0.005

Category	Tier	Approval Date	Emission standard for commercial good vehicles, g/km				
			CO	HC	NOx	HC+NOx	PM
N1, Class II 1305 – 1760 kg	Euro 5a	September 2009	0.63	-	0.235	0.295	0.005
	Euro 5b	September 2011	0.63	-	0.235	0.295	0.005
	Euro 6	September 2014	0.63	-	0.105	0.195	0.005
N1, Class III 1760-3500 kg	Euro 5a	September 2009	0.74	-	0.28	0.35	0.005
	Euro 5b	September 2011	0.74	-	0.28	0.35	0.005
	Euro 6	September 2014	0.74	-	0.125	0.215	0.005
N2, 3500 – 12000 kg	Euro 5a	September 2009	0.74	-	0.28	0.35	0.005
	Euro 5b	September 2011	0.74	-	0.28	0.35	0.005
	Euro 6	September 2014	0.74	-	0.125	0.215	0.005
Positive Ignition (Gasoline)							
N1, Class I ⩽ 1305 kg	Euro 4	January 2005	1.00	0.10	0.08	-	-
	Euro 5	September 2009	1.00	0.10	0.06	-	0.005
	Euro 6	September 2014	1.00	0.10	0.06	-	0.005
N1, Class II 1305 – 1760 kg	Euro 4	January 2005	1.81	0.13	0.10	-	-
	Euro 5	September 2009	1.81	0.13	0.075	-	0.005
	Euro 6	September 2014	1.81	0.13	0.075	-	0.005
N1, Class III 1760-3500 kg	Euro 4	January 2005	2.27	0.16	0.11	-	-
	Euro 5	September 2009	2.27	0.16	0.082	-	0.005
	Euro 6	September 2014	2.27	0.16	0.082	-	0.005
N2, 3500 – 12000 kg	Euro 5	September 2009	2.27	0.16	0.082	-	0.005
	Euro 6	September 2014	2.27	0.16	0.082	-	0.005

It should also be noted that currently there is a significant traffic volume along the PIE (near A1-W2). The proposed Project has also planned the construction of future roads for maintenance access roads. Traffic near facility buildings such as A1-W1 and A1-W2 is not likely to increase as only intermittent traffic for maintenance staff will be observed. The exact numbers in terms of increase /change in volume of traffic to and from the facility buildings were not available. Without any mitigation measures in place, the Likelihood of occurrence of impacts during the operational phase is classified as Regular.

Overall it seems that given the two factors above (i.e. the implementation of Euro emission standard on new vehicles and current large traffic volume along existing roads), insignificant increase in air quality pollutant levels in the vicinity of proposed Project is expected during the operational phase. The buffer from the neighbouring high ecological sites which are not cleared (i.e. Eng Neo Avenue Forest, and Windsor) will also help in terms of providing cleaner air from the impact from the vehicles. Some green areas will also not be disturbed as part of the Project. Hence, the Impact Intensity is considered to be Negligible.

As discussed in Section 10.4.2, the Sensitivity of the receptors is classified to be Priority 1. Thus, as per Table 6-6, the Impact Consequence is calculated to be Very Low. Based on the impact significance matrix in Table 10-8, the Impact Significance is predicted to be Minor (refer to Table 10-24). No mitigation measures are required during operational phase.

Table 10-24 Impacts of Air Quality Impact Assessment – Operational Phase

Impact Intensity	Sensitivity of the Area	Overall Consequence	Likelihood	Impact Significance
Negligible	Priority 1	Very Low	Regular	**Minor**

10.8 Recommended Mitigation Measures

10.8.1 Construction Phase

10.8.1.1 Administrative Control

Based on the assessment in Section 10.7.1, the Impact Significance was determined to be **Moderate to Major**. In line with the general mitigation measures, the construction worksite areas for A1-W1 and A1-W2 have also been reduced. Refer to Figure 10-19 to Figure 10-20, Figure 10-21 to Figure 10-22, and Figure 10-23 to Figure 10-24 for earthworks, construction and trackout potential emission sources for both A1-W2 and A1-W1 Mitigated Scenario worksite area, respectively. On top of the reduction of construction worksite area, the range of dust mitigation measures to be implemented at the construction sites are outlined in Table 10-26. Upon the implementation of mitigation measures, the Impact Significance was determined to be Minor. This will be detailed in Section 10.9.1.

Table 10-25 below summarises the sensitivity of each construction phase for earthworks, construction, and trackout for each construction worksite comparing base and mitigated scenario. All construction worksites are located within or in close proximity to ecologically sensitive receptors. Based on the distances of emission sources to the identified receptors presented in Figure 10-19 to Figure 10-24, the Sensitivity of the Area was determined.

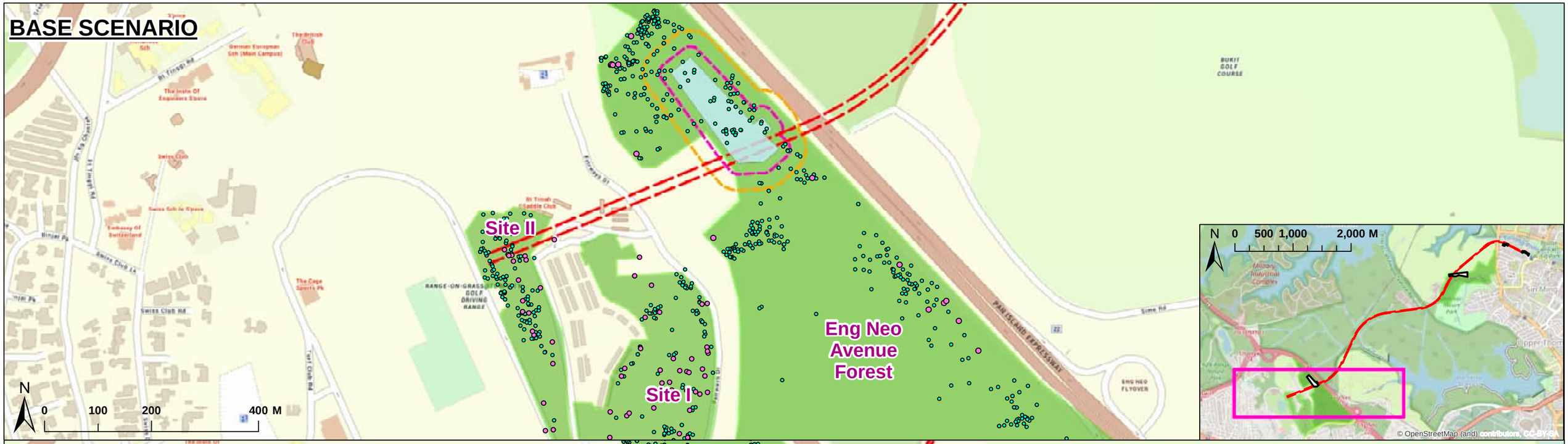
On top of the reduction of construction worksite area, a range of dust mitigation measures to be implemented at the construction sites are outlined in Table 10-26. The mitigation measures are also applicable for the utility diversion work at Sin Ming Walk and A1-W1 worksite. Upon the implementation of mitigation measures, the Impact Significance was determined to be Minor. This will be detailed in Section 10.9.1.

Table 10-25 Receptor Sensitivity for Air Quality Impact Assessment – Construction Phase (Base and Mitigated Scenarios)

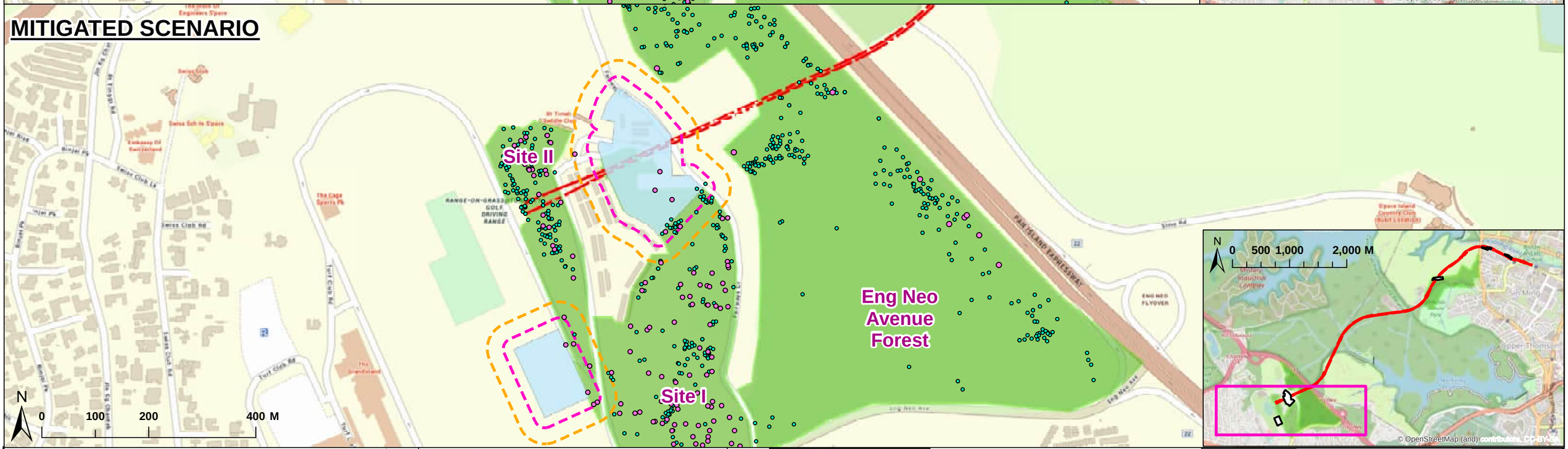
Distance	Base Scenario		Mitigated Scenario	
	Identified Receptors	Sensitivity of the Area	Identified Receptors	Sensitivity of the Area
A1-W2 CONSTRUCTION WORKSITES				
<u>For Earthworks:</u>				
Within 20m	Eng Neo Avenue Forest	Priority 1	Site I Site II	Priority 1
Between 20m to 50m	Eng Neo Avenue Forest		Site I Site II	
<u>For Construction:</u>				
Within 20m	Eng Neo Avenue Forest	Priority 1	-	-*
Between 20m to 50m	Eng Neo Avenue Forest		-	
<u>For Trackout:</u>				
Within 20m	Site I	Priority 1	Site I Site II Eng Neo Avenue Forest	Priority 1
Between 20m to 50m	Site I Eng Neo Avenue Forest		Site I Site II Eng Neo Avenue Forest	

Distance	Base Scenario		Mitigated Scenario	
	Identified Receptors	Sensitivity of the Area	Identified Receptors	Sensitivity of the Area
A1-W1 CONSTRUCTION WORKSITE				
For Earthworks:				
Within 20m	Windsor	Priority 1	Windsor	Priority 1
Between 20m to 50m	Windsor		Windsor	
For Construction:				
Within 20m	Windsor	Priority 1	Windsor	Priority 1
Between 20m to 50m	Windsor		Windsor	
For Trackout:				
Within 20m	Windsor	Priority 1	Windsor	Priority 1
Between 20m to 50m	Windsor		Windsor	
Note: * As observed from Figure 10-21, under the mitigated case, construction footprint of A1-W2 is removed. Therefore, in line with the IAQM Guidance, the Construction activities for A1-W2 mitigated scenario is expected to have insignificant impact on the ecological receptors. However, it shall be noted that impact is still expected from Earthworks and Trackout activities.				

BASE SCENARIO



MITIGATED SCENARIO



Legend

- 20m from Source
- 50m from Source
- Earthworks Footprint
- Large Specimens
- Species of Conservation Significance
- Proposed CRL Alignment
- Biodiversity Study Area

Note:
Site I and II: Forested area adjacent to Fairways Quarters

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	HHL	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
**CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)**

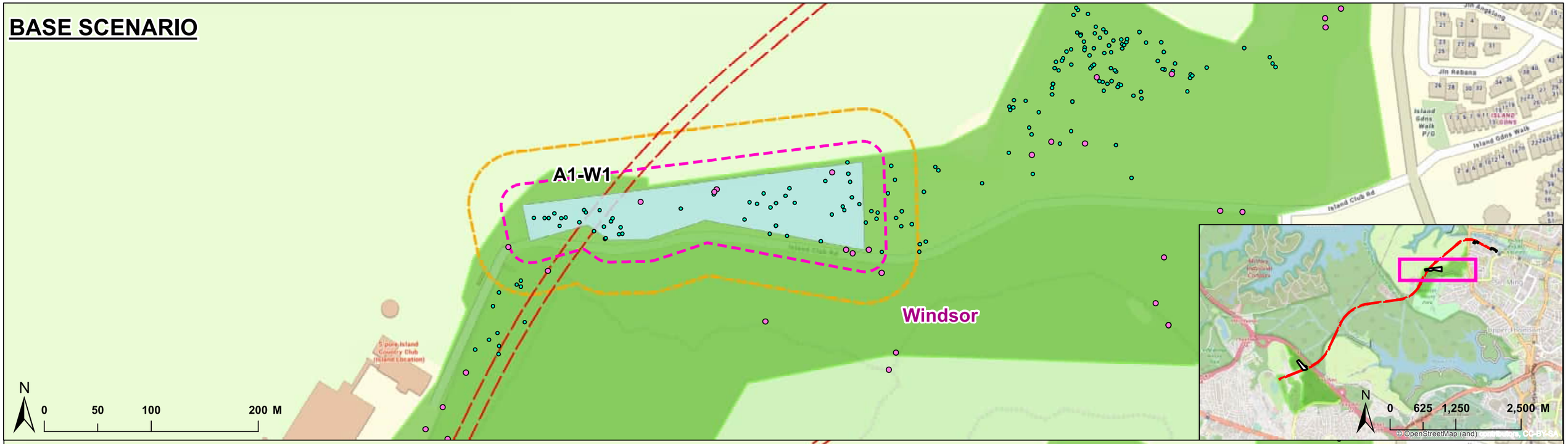
Figure Title :
**A1-W2 MITIGATED SCENARIO
EMISSION SOURCES AND RECEPTORS
(EARTHWORKS)**

Designed	Checked	Approved
HHL	JAG	JAG
	Drawn: HHL	Date: MAR 2022

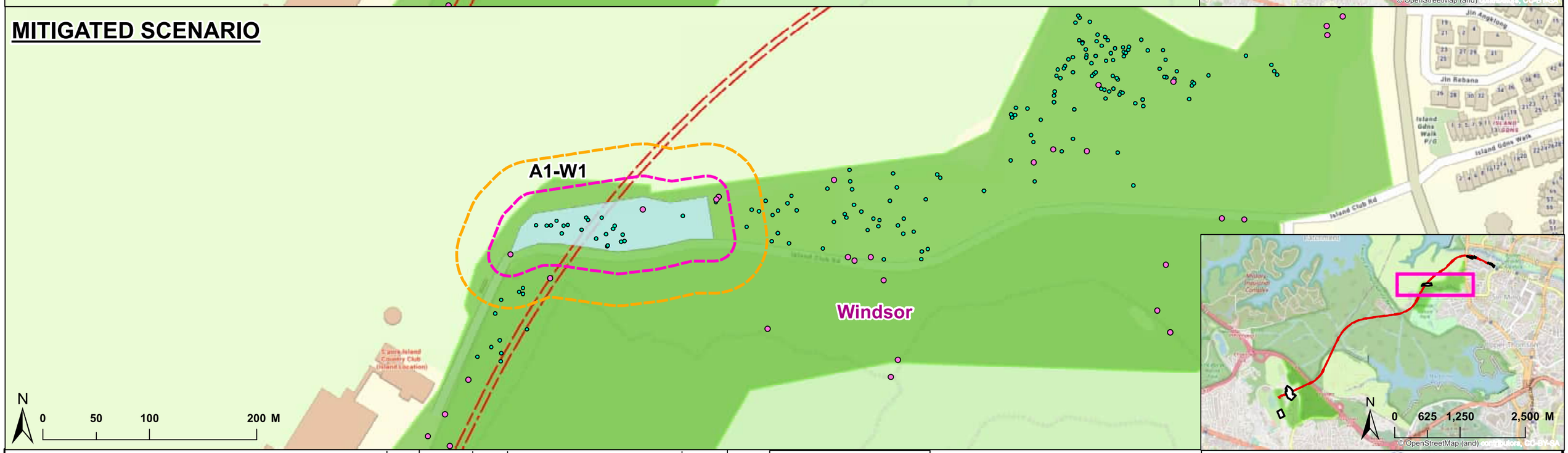
Figure No. : 10-19
Rev. : -
Sheet : 1 of 1
CAD File Name : NA
A3

Note: Source of basemap - OneMap

BASE SCENARIO



MITIGATED SCENARIO



Legend

- 20m from Source
- 50m from Source
- Earthworks Footprint
- Large Specimens
- Conservative Species
- Proposed CRL Alignment
- Biodiversity Study Area

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	HHL	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
A1-W1 MITIGATED SCENARIO EMISSION SOURCES AND RECEPTORS (EARTHWORKS)

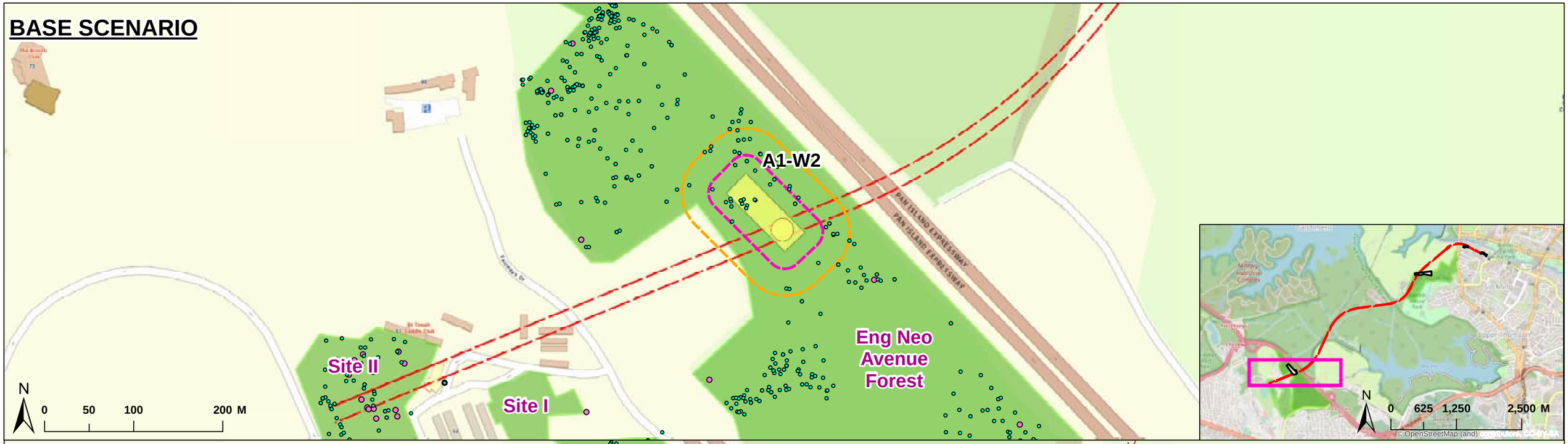
Designed	Checked	Approved
HHL	JAG	JAG
	Drawn: HHL	Date: MAR 2022

Figure No. : 10-20 | Rev. : - | Sheet : 1 of 1

CAD File Name : NA | A3

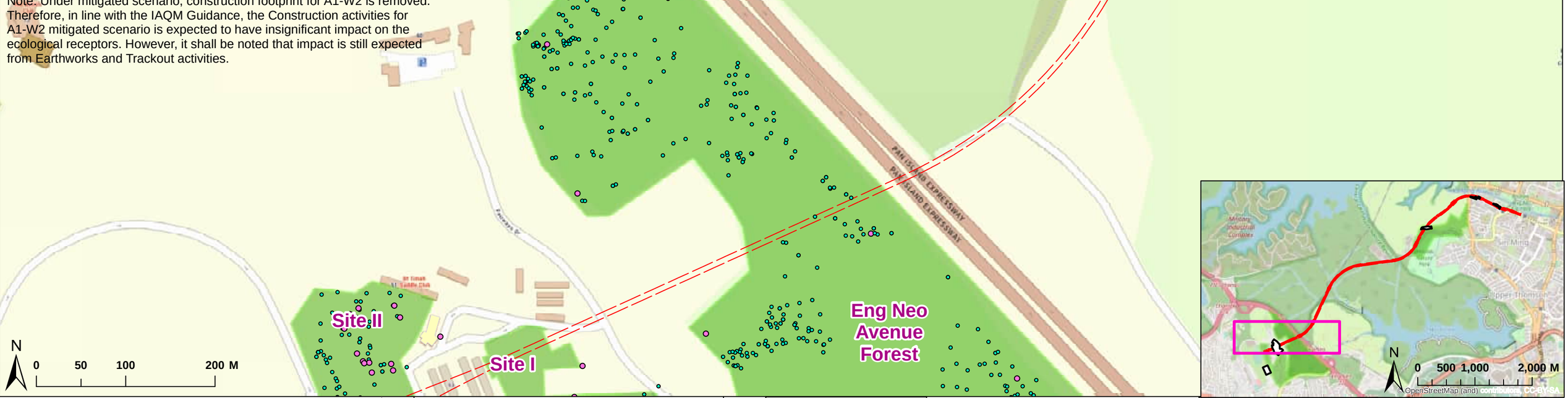
Note: Source of basemap - OneMap

BASE SCENARIO



MITIGATED SCENARIO

Note: Under mitigated scenario, construction footprint for A1-W2 is removed. Therefore, in line with the IAQM Guidance, the Construction activities for A1-W2 mitigated scenario is expected to have insignificant impact on the ecological receptors. However, it shall be noted that impact is still expected from Earthworks and Trackout activities.



Legend

- 20m from Source
- 50m from Source
- Construction Footprint
- Large Specimens
- Species of Conservation Significance
- Proposed CRL Alignment
- Biodiversity Study Area

Note:
Site I and II: Forested area adjacent to Fairways Quarters

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	HHL	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
A1-W2 MITIGATED SCENARIO EMISSION SOURCES AND RECEPTORS (CONSTRUCTION)

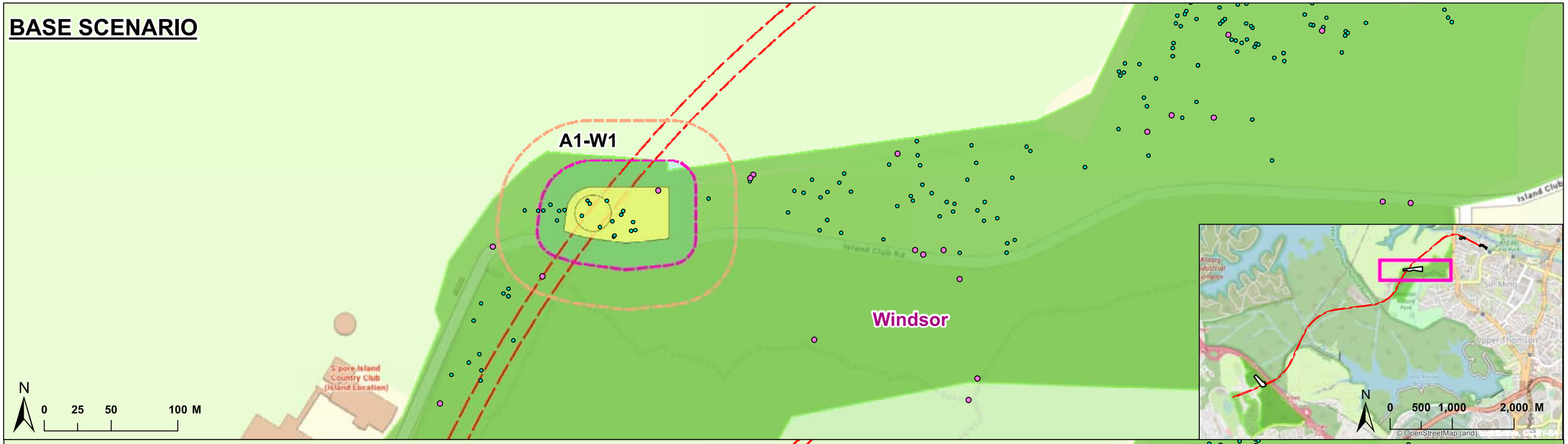
Designed	Checked	Approved
HHL	JAG	JAG
	Drawn: HHL	Date: MAR 2022

Figure No. : 10-21 | Rev. : - | Sheet : 1 of 1

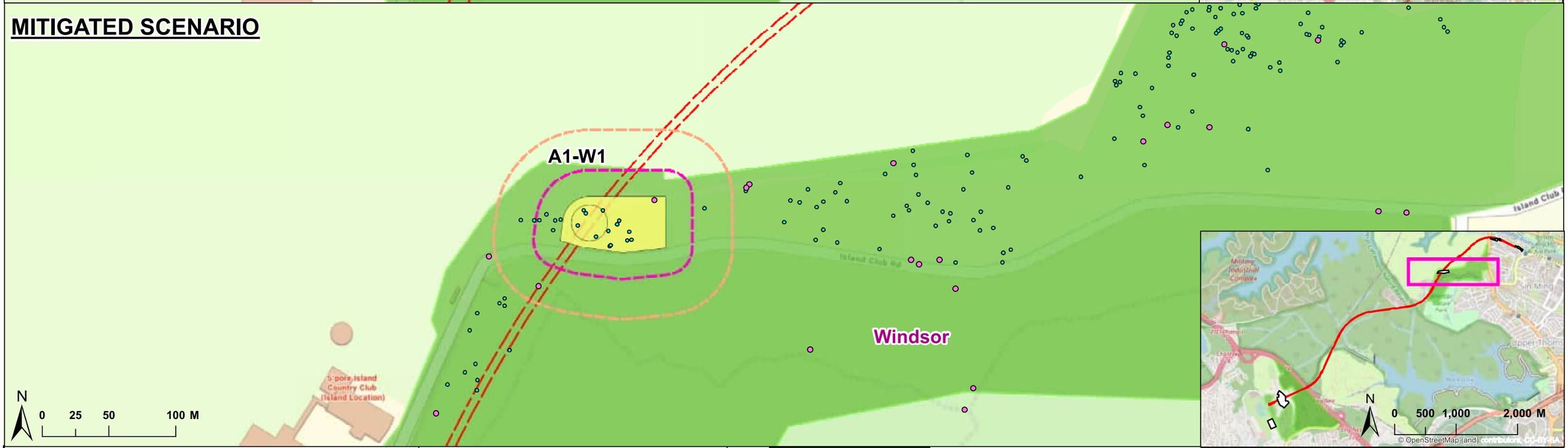
CAD File Name : NA | A3

Note: Source of basemap - OneMap

BASE SCENARIO



MITIGATED SCENARIO



Legend

- 20m from Source
- 50m from Source
- Construction Footprint
- Large Specimens
- Species of Conservation Significance
- Proposed CRL Alignment
- Biodiversity Study Area

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	HHL	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Designed	Checked	Approved
HHL	JAG	JAG
	Drawn: HHL	Date: MAR 2022

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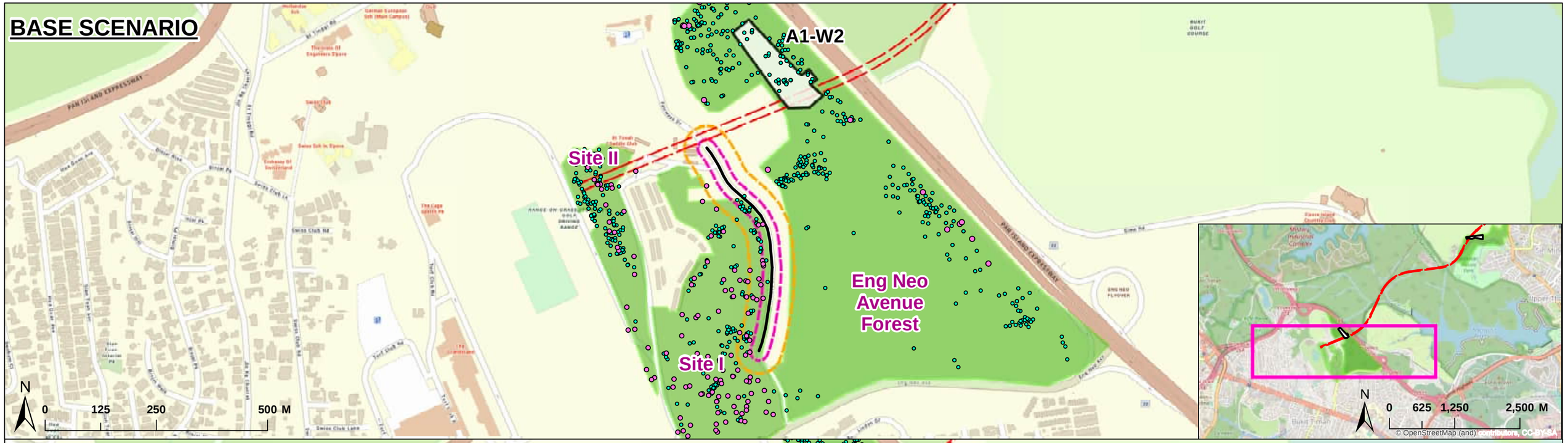
Figure Title :
A1-W1 MITIGATED SCENARIO EMISSION SOURCES AND RECEPTORS (CONSTRUCTION)

Figure No. :	Rev.	Sheet
10-22	-	1 of 1

CAD File Name : NA — A3

Note: Source of basemap - OneMap and Open StreetMap

BASE SCENARIO



MITIGATED SCENARIO

Legend

- Construction Worksite Areas
- Proposed CRL Alignment
- A1-W2 Temporary Access Roads
- Potential Access Road
- 50m from Source
- 20m from Source
- Large specimens
- Species of Conservation Significance
- Biodiversity Study Area

Note:
Site I and II: Forested area adjacent to Fairways Quarters

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	HHL	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
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Project Title :
**CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)**

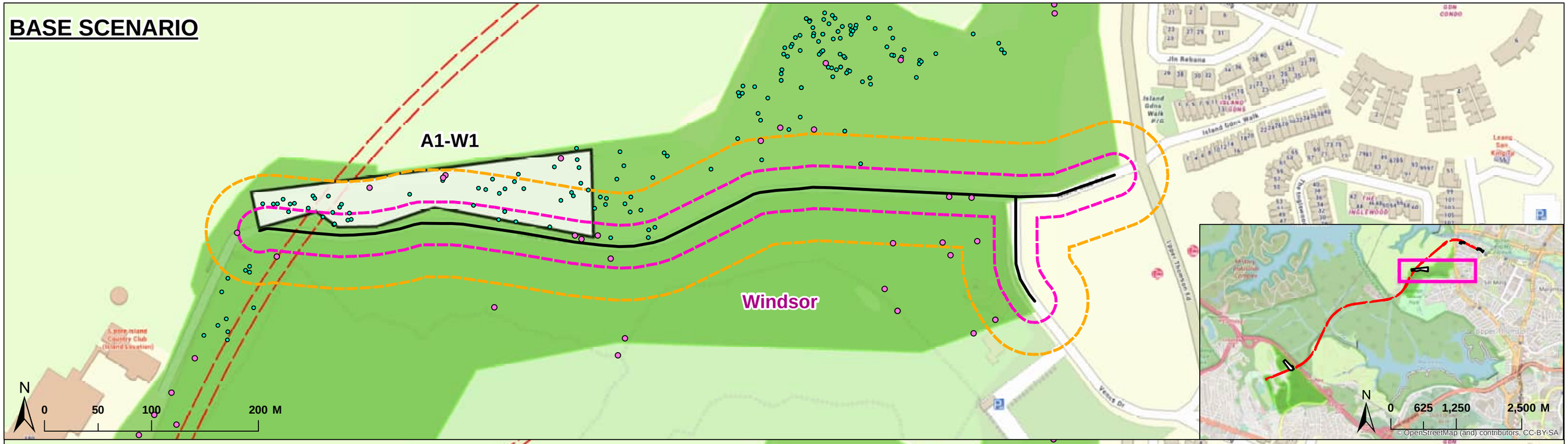
Figure Title :
**A1-W2 MITIGATED SCENARIO
EMISSION SOURCES AND RECEPTORS
(TRACKOUT)**

Designed	Checked	Approved
HHL	JAG	JAG
	Drawn	Date
	HHL	MAR 2022

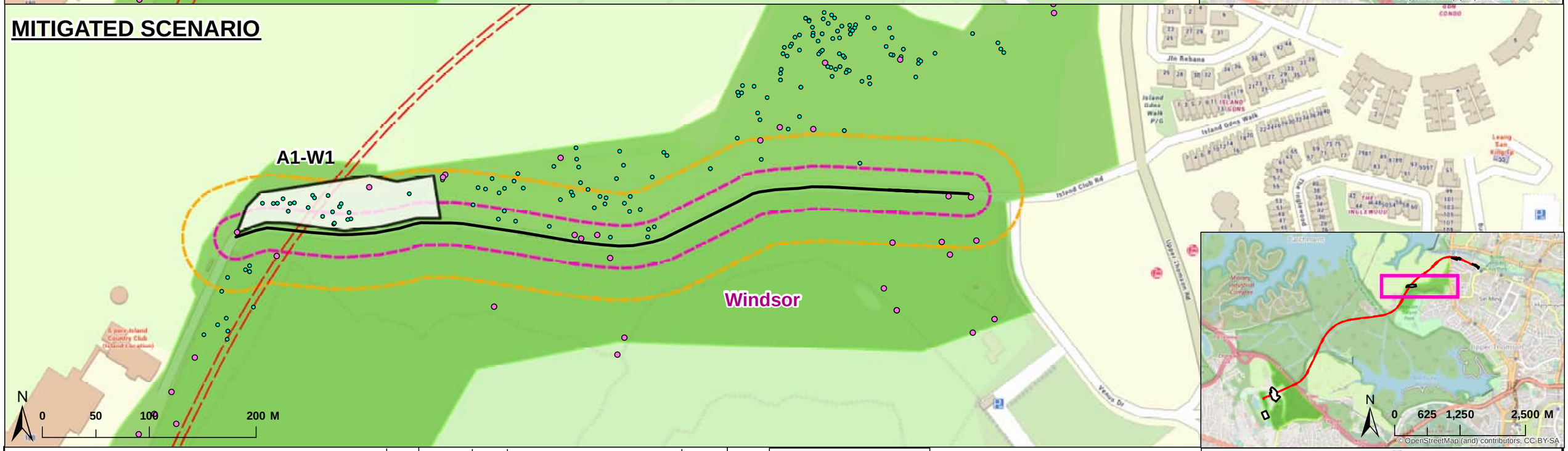
Figure No. : 10-23
Rev. : -
Sheet : 1 of 1
CAD File Name : NA
A3

Note: Source of basemap - OneMap and OpenStreetMap

BASE SCENARIO



MITIGATED SCENARIO



Legend

- Construction Worksite Areas
- Proposed CRL Alignment
- Potential Access Road
- 50m from Source
- 20m from Source
- Large specimens
- Species of Conservation Significance
- Biodiversity Study Area

Rev.	Date	By	Description	Chk'd	App'd
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Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
A1-W1 MITIGATED SCENARIO EMISSION SOURCES AND RECEPTORS (TRACKOUT)

Designed	Checked	Approved
HHL	JAG	JAG
	Drawn HHL	Date JUN 2022

Figure No. : 10-24 | Rev. : - | Sheet : 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap

Table 10-26 Air Quality Mitigation Measures (Construction Phase)

Mitigation Measures	A1-W1 Mitigated Scenario	A1-W2 Mitigated Scenario
GENERAL MITIGATION MEASURES TO BE IMPLEMENTED THROUGH OUT CONSTRUCTION PERIOD		
Communications		
Develop and implement a stakeholder communications plan that includes community engagement before work commences on site.	Mandatory	Mandatory
Display the name and contact details of person(s) accountable for air quality and dust issues on the site boundary. This may be the environment manager/engineer or the site manager.	Mandatory	Mandatory
Develop and implement an Air Pollution Control Plan (APCP) (see paragraph below for APCP details).	Mandatory	Mandatory
Site Management		
Record all dust and air quality complaints, identify cause(s), take appropriate measures to reduce emissions in a timely manner, and record the measures taken.	Mandatory	Mandatory
Make the complaints log available to the local authority when asked.	Mandatory	Mandatory
Record any exceptional incidents that cause dust and/or air emissions, either on-site or off- site, and the action taken to resolve the situation in the log book.	Mandatory	Mandatory
Hold liaison meetings with other high-risk construction sites within 500 m of the site boundary, if any, to ensure plans are co-ordinated and dust and particulate matter emissions are minimised.	Optional	Mandatory
Monitoring		
Undertake regular (daily frequency recommended) on-site and off-site inspections and record results. The log should be made available to the NEA or other Government Agencies if required. Inspections should include regular dust soiling checks of surfaces such as street furniture, cars, and window sills within 100 m of site boundary. Cleaning should be provided if necessary.	Recommended	Mandatory
Carry out regular site inspections to monitor and record compliance with the Air Pollution Control Plan.	Mandatory	Mandatory
Increase the frequency of site inspections during prolonged dry or windy conditions.	Mandatory	Mandatory
Conduct monitoring for dust deposition at suitable locations (refer to Section 13.6 for details)	Mandatory	Mandatory
Preparing and maintaining the site		

Mitigation Measures	A1-W1 Mitigated Scenario	A1-W2 Mitigated Scenario
Plan site layout so that machinery and dust causing activities are located away from receptors, where possible.	Mandatory	Mandatory
Erect hoarding around dusty activities and at the site boundary wherever possible. Boundary screens should be at least as high as any stockpiles or dust emission sources on site.	Mandatory	Mandatory
Fully enclose specific activities where there is a known high potential for dust production and the site will be active for an extensive period of time.	Mandatory	Mandatory
Keep site fencing, barriers, and scaffolding clean by cleaning regularly using wet methods (dry methods may give rise to fugitive dust).	Mandatory	Mandatory
Remove materials that have the potential to produce dust from site as soon as possible, unless being re-used on site. If they are being re-used on-site, stockpiled material should be covered, seeded, fenced or enclosed to prevent fugitive dust formation.	Mandatory	Mandatory
Operating vehicle/machinery and sustainable travel		
Ensure all vehicles and engine powered equipment comply with the legislative requirements of Singapore.	Mandatory	Mandatory
Ensure all vehicles and equipment switch off their engines when stationary – i.e. no idling vehicles or engines. Clear signs shall be erected at site entrance to inform all visitors.	Mandatory	Mandatory
Where practicable, avoid the use of diesel- or petrol-powered generators and use mains electricity or battery powered equipment.	Mandatory	Mandatory
Impose and signpost a maximum-speed-limit of 25 km/hr on paved or surfaced haul roads and 15 km/hr on unpaved haul roads and work areas.	Recommended	Mandatory
Produce a Construction Logistics Plan to manage the sustainable delivery of goods and materials.	Mandatory	Mandatory
Construction Operations		
Only use cutting, grinding or sawing equipment fitted with, or in conjunction with, suitable dust suppression techniques such as water sprays or local extraction e.g. local exhaust ventilation system.	Mandatory	Mandatory
Ensure an adequate water supply on the site for effective dust/particulate matter suppression/mitigation, using non-potable water where possible and appropriate.	Mandatory	Mandatory
Use enclosed chutes and conveyors and covered skips wherever possible.	Mandatory	Mandatory

Mitigation Measures	A1-W1 Mitigated Scenario	A1-W2 Mitigated Scenario
Minimise drop heights from conveyors, loading shovels, hoppers, and other loading or handling equipment and use fine water sprays on such equipment wherever appropriate.	Mandatory	Mandatory
A stringent “Clean as you go” Policy should be implemented on site to ensure no loose dry material is left exposed when not in use. Equipment should be readily available on site to clean any dry spillages, and cleaning should be conducted as soon as reasonably practicable after the event using wet cleaning methods.	Mandatory	Mandatory
Waste Management		
Avoid burning of waste or other materials.	Mandatory	Mandatory
MITIGATION MEASURES FOR EARTHWORKS		
Re-vegetate earthworks and exposed areas/soil stockpiles to stabilise surfaces as soon as practicable. When a particular work is finished in an area, the soil will need to be reinstated upon completion, before moving on to different areas. This will reduce dust emission. In the air assessment it refers to reinstatement as a regrown area, it does not mean replanting same trees. It only refers to vegetation plantation which prevents erosion of soil to form dust.	Recommended	Mandatory
Use Hessian, mulches or soil tackifiers where it is not possible to re-vegetate or cover with topsoil, as soon as practicable.	Recommended	Mandatory
Only remove the cover in small areas during work and not all at once.	Recommended	Mandatory
MITIGATION MEASURES FOR CONSTRUCTION		
Avoid scabbling (roughening of concrete surfaces) if possible.	Recommended	-
Sand and aggregates shall be delivered in a dampened stage and shall be re-wetted before being dumped into storage bunker.	Recommended	-
Drop heights at transfer points shall be minimised to lessen dust generation	Recommended	-
Special covered area shall be provided for loading and unloading process	Recommended	-
Water sprays or sprinklers shall be employed at conveyor transfer points	Recommended	-
Ensure sand and other aggregates are stored in bunded areas and are not allowed to dry out, unless this is required for a particular process, in which case ensure that appropriate additional control measures are in place.	Mandatory	-

Mitigation Measures	A1-W1 Mitigated Scenario	A1-W2 Mitigated Scenario
Ensure bulk cement and other fine powder materials are delivered in enclosed tankers and stored in silos with suitable emission control systems to prevent escape of material and overfilling during delivery.	Recommended	-
For smaller supplies of fine power materials ensure bags are sealed after use and stored appropriately to prevent dust.	Recommended	-
Vent shall be provided with efficient fixed filter bags to comply with the dust emissions criteria.	Mandatory	-
Silos shall not be filled up with cement more than 90% of its loading capacity, to avoid overfilling,	Recommended	-
Silos shall be equipped with overfill protection: audible high level sensor alarm and automatic shut-down switch, which could be activated to close when a problem is detected.	Mandatory	-
MITIGATION MEASURES FOR TRACKOUT		
Use water-assisted dust sweeper(s) on the access and affected local roads, to remove, as necessary, any material tracked out of the site. This may require the sweeper being continuously in use.	Mandatory	Mandatory
Avoid dry sweeping of large areas.	Mandatory	Mandatory
Ensure vehicles entering and leaving sites are covered to prevent escape of materials during transport.	Mandatory	Mandatory
Inspect on-site haul routes for integrity and instigate necessary repairs to the surface as soon as reasonably practicable.	Mandatory	Mandatory
Record all inspections of haul routes and any subsequent action in a site log book.	Mandatory	Mandatory
Install hard surfaced haul routes, which are regularly damped down with fixed or mobile sprinkler systems, or mobile water bowsers and regularly cleaned.	Mandatory	Mandatory
Implement a wheel washing system (with rumble grids to dislodge accumulated dust and mud prior to leaving the site where reasonably practicable).	Mandatory	Mandatory
Ensure there is an adequate area of hard surfaced road between the wheel wash facility and the site exit, wherever site size and layout permits.	Mandatory	Mandatory
Site access gates to be located at least 10 m from receptors where possible.	Mandatory	Mandatory

The APCP shall include the following information as a minimum:

- Summary of all work to be carried out including breakdown of phases and individual activities that may give rise to fugitive dust formation;

- Project title, Project location and area, description of the site layout and locations of areas where dust is most likely to be generated such as haulage routes, excavation areas, etc. This description shall also include the location of the water supply or chemical suppressants for applying to the dust generating areas on site;
- List of each dust generating activity, the likely schedule for each activity and the dust control measures to be implemented and frequency for their implementation. The level of detail will depend on the overall Consequence classification identified in this report and should include as a minimum the mitigation measures listed as mandatory in this document;
- Summary of the air monitoring to be undertaken including monitoring location and schedule. The air monitoring results shall be recorded, and trends observed to determine the efficacy of dust control measures over the different construction stages;
- Details and procedures on using the site log book which is used to record information on incidents such as dust episodes, the sources identified, and the action taken and its efficacy. Any complaints shall also be recorded within the log book along with the subsequent mitigation implemented and time to close out the complaint. The log book should also be used to keep track of the daily dust control measures implemented such as wheel washing, site watering, site inspections etc.;
- Details of the Superintending Officer (SO) should be included in this plan for managing dust management at the site. The responsibilities of the SO are listed in Section 13.4.3; and
- The air pollution control plan shall be reviewed at regular intervals during the construction phase to ensure the effectiveness of the procedures in place and to maintain the goal of minimisation of dust and emissions through the use of best practice and procedures.

10.8.2 Operational Phase

No mitigation measures are required during operational phase as only Minor air quality impact significance is expected during Project operational phase.

10.9 Residual Impacts

10.9.1 Construction Phase

Residual Impact Assessment assumes that the mitigation measures within Section 10.8.1 are implemented within the construction worksite area. The worksite option with smaller footprint (i.e. Mitigated Scenario) is preferred. Smaller construction footprint would reduce the potential air quality impact to the neighbouring receptors.

The Likelihood of occurrence of a significant adverse impact would be classified as Rare, subject to relevant mitigation measures identified being implemented. This Likelihood is combined with Impact Consequence to provide the residual Impact Significance results for the construction footprint. The residual Impact Significance is listed in Table 10-27 to Table 10-29 below.

Based on the assessment, by implementing the proposed mitigation measures, the Likelihood of the impact is expected to reduce from Regular to Rare, resulting in **Minor** Impact Significance.

Table 10-27 Impacts of Dust Risk Assessment – Earthworks (After Mitigation)

Construction Worksite	Key Parameter					Impact Assessment		
	Total Site Area (m^2)	No. of Vehicles moving within the site	Total Material Moved (tonnes)	Impact Intensity	Sensitivity of the Area	Overall Consequence / Dust Risk	Likelihood	Impact Significance
A1-W2 Mitigated Scenario	>10,000	<5	20,000 – 100,000	High	Priority 1	High	Rare	**Minor**
A1-W1 Mitigated Scenario	2,500-10,000	<5	20,000 – 100,000	Medium	Priority 1	Medium	Rare	**Minor**

Table 10-28 Impacts of Dust Risk Assessment – Construction (After Mitigation)

Construction Worksite	Key Parameter					Impact Assessment		
	Total Building Volume (m^3)	Construction Material	No. of concrete batching plant	Impact Intensity	Sensitivity of the Area	Overall Consequence / Dust Risk	Likelihood	Impact Significance
A1-W2 Mitigated Scenario	-	-	-	-	-	-	-	-*
A1-W1 Mitigated Scenario	25,000 – 100,000	Concrete	0	Medium	Priority 1	Medium	Rare	**Minor**
Note: As observed from Figure 10-21, under the mitigated case, construction footprint of A1-W2 is removed. Therefore, in line with the IAQM Guidance, the Construction activities for A1-W2 mitigated scenario is expected to have insignificant impact on the ecological receptors. However, it shall be noted that impact is still expected from Earthworks and Trackout activities.								

Table 10-29 Impacts of Dust Risk Assessment – Trackout (After Mitigation)

Construction Worksite	Key Parameter					Impact Assessment		
	No. of outward trucks movement per day	Road surface material	Unpaved Road Length (m)	Impact Intensity	Sensitivity of the Area	Overall Consequence / Dust Risk	Likelihood	Impact Significance
A1-W2 Mitigated Scenario	10-50	Moderately Dusty	<100 m	Medium	Priority 1	Medium	Rare	**Minor**
A1-W1 Mitigated Scenario	10-50	Moderately Dusty	<100 m	Medium	Priority 1	Medium	Rare	**Minor**

10.9.2 Operational Phase

As discussed in Section 10.7.2, the potential impact significance due to increased traffic is considered to be Minor. No mitigation measures are required during operational phase.

10.10 Cumulative Impacts from Other Major Concurrent Development

It is known that construction activities are planned to occur in the vicinity of the Project as highlighted in Section 3.4.1. Hence, cumulative impacts from other relevant major concurrent development in the vicinity of the Project shall be assessed and considered.

10.10.1 Construction Phase

Cumulative impacts for each of the construction worksite are presented in following sections.

10.10.1.1 A1-W1 Worksite

Shaft 4 as part of PUB BKSR project is collocated in the centre of A1-W1 Base Scenario worksite or at the eastern side of A1-W1 Mitigated Scenario worksite. The impact significance before mitigation for A1-W1 ranges from Moderate to Major. Due to the presence of the PUB concurrent construction site, the construction footprint in this area is expected to be larger. More vehicles moving within the site and more spoil to be moved as part of the excavation stage are also expected. With this concurrent construction activity, the overall Impact Significance is not expected to significantly increase from the project.

10.10.1.2 A1-W2 Worksite

CR14 is collocated in the western side of A1-W2 Mitigated Scenario worksite. The impact significance before mitigation for A1-W2 ranges from Moderate to Major. Due to the presence of the CR14, the construction footprint in this area is expected to be larger. More vehicles moving within the site and more spoil to be moved as part of the excavation stage are also expected. With this concurrent construction activity, the overall Impact Significance is not expected to significantly increase from the project.

10.10.2 Operational Phase

Cumulative impacts during operational phase are presented in following sections.

10.10.2.1 A1-W1 Facility Building

PUB Water Pipeline project at BKSR is collocated in the vicinity of A1-W1 facility building for both base and mitigated scenarios. The impact significance before mitigation for A1-W1 during operational phase is expected to be Negligible. Due to the presence of the PUB water pipeline, the overall Impact Significance is not expected to significantly increase from the project.

10.10.2.2 A1-W2 Facility Building

CR14 is collocated in the western side of A1-W2 Base Scenario facility building footprint. The impact significance before mitigation for A1-W2 base scenario facility building during operational phase is expected to be Negligible. Due to the presence of the CR14, the overall Impact Significance is not expected to significantly increase from the project. However, in mitigated scenario, A1-W2 facility building is no longer planned. Hence, the impact significance for A1-W2 facility building is no longer applicable in mitigated scenario.

10.11 Summary of Key Findings

Air quality impacts from the construction and operation of the proposed Project were assessed on air sensitive receptors (ASRs) in the vicinity of the Project site. Potential impacts to the neighbouring sensitive receptors during construction phase mainly include emissions from the heavy vehicular exhaust and dust emitted from the earthworks, construction and trackout activities. During the operational phase, emissions from vehicle exhaust due to increased traffic in the vicinity of the proposed development are identified as the predominant air emission source. In order to assess the current baseline air quality in the Study Area, baseline air quality data was collected at two (2) representative monitoring locations between 26 March to 26 June 2020. All pollutant concentrations were found to be within the Singapore Ambient Air Quality Long Term Targets. Secondary air monitoring data from the concurrent study carried out by AECOM in the vicinity has also been analysed. Ambient air quality was conducted at two (2) locations for 1 week. Based on the monitored results, both PM_{10} and $PM_{2.5}$ targets were met throughout the monitoring duration.

Air quality impact assessment for construction phase was undertaken in accordance with the UK IAQM Guidance on the Assessment of Dust from Demolition and Construction. Pursuant to which, a 50 m Study Area was considered for earthworks, construction and trackout activities due to ecologically sensitive receptors in the vicinity of the worksites. Dust generated during construction works can have adverse effects upon vegetation by restricting photosynthesis, respiration and transpiration. Furthermore, it can lead to phytotoxic gaseous pollutants penetrating the plants. The overall effect can be a decline in plant productivity. The results of the assessment show that unmitigated impacts were assessed as Major across all construction worksites analysed and have the potential to affect the receptors near the construction worksite area unless mitigation measures are put in place (see Section 10.7.1 for assessment details). This is mainly because of the large extent of the construction worksite located very close or within the areas with flora, fauna and habitat with high ecological value. This report, therefore, recommends mitigation measures that can be implemented by the Contractor as administrative or management measures, sourcing from best practice measures internationally, which are detailed Section 10.8.1. When these mitigation measures are applied successfully, the significance of impacts is anticipated to be reduced to **Minor** (see Section 10.9.1 for details). The key control and mitigation measures include but not limited to development of air pollution control plan, dust control measures on site, site hoarding, planning of dust causing activities-location and timing, reinstating land upon completion of works amongst several others. The mitigation measures are also applicable for the utility diversion work at Sin Ming Walk and A1-W1 worksite. In addition, the worksite option with smaller footprint (i.e. Mitigated Scenario) is preferred. Smaller construction footprint would reduce the potential air quality impact to the neighbouring receptors.

Air quality impacts were also qualitatively weighed during operational phase. Fugitive emission from vehicle exhaust due to increased traffic in the vicinity of the Project is expected. It is assumed that all new vehicles to meet their Euro emission standard. Furthermore, there is currently a large traffic volume along the PIE. The buffer from some green areas which will not be disturbed as part of the Project, will also help in terms of providing cleaner air from the impact from the vehicles. At a much higher level, trains are meant to replace substantial vehicles from roads, as passengers commute using trains, therefore in that scheme the Project may have a positive effect on road traffic. However, for immediate localised road traffic to and from the facility buildings may see some increase. In this aspect with the information assessed at this stage, the air quality impact contributed from the proposed development is anticipated to be **Minor** during the operational phase.

The Contractor is recommended to prepare an air quality management plan incorporating a range of monitoring and mitigation measures in line with Section 10.8.1, Section 13.9.1 and Section 13.13. No mitigation measures are required during operational phase as no significant air quality impact is expected from Project operation.

Cumulative impacts from other major concurrent development in the vicinity of each construction worksite are presented and detailed in Section 10.10. Due to the presence of these concurrent construction sites, the overall construction footprint is expected to be larger. With all these concurrent construction activities, the overall Impact Significance is not expected to significantly increase from the project.

Table 10-30 Summary of Air Quality Impact Assessment

Sensitive Receptor	Impact Significance with Minimum Controls[a]	Residual Impact Significance with Mitigation Measures (if required)
Construction Phase		
Eng Neo Avenue Forest	Moderate to Major	**Minor**
Site I and Site II	Negligible[2]	**Minor**
Windsor	Moderate to Major	**Minor**
Operational Phase		
Eng Neo Avenue Forest	Minor	**Minor**
Site I and Site II	Minor	**Minor**
Windsor	Minor	**Minor**

Note:
1. The initial impact assessment with minimum controls was considered insignificant (Negligible to Minor), no residual impact assessment was undertaken, hence the impact significance remained the same. Note that this does not indicate that impacts are completely eliminated

	Sensitive Receptor	Impact Significance with Minimum Controls[a]	Residual Impact Significance with Mitigation Measures (if required)
2.	The base scenario construction worksite for A1-W2 is >50m from Site I and Site II. Thus, as per IAQM guidance, the air quality impact is considered insignificant.		

11. Airborne Noise

11.1 Introduction

This section presents the detailed assessment of airborne noise impacts from the construction and operation of the Project to the identified noise ecologically sensitive receptors. Noise from construction and operational activities may be perceivable, especially to receptors in proximity and those having a direct line-of-sight to the noise sources from the Study Area. The key steps for conducting the noise impact assessment are as follows:

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

11.2 Methodology and Assumption

The sections below outline the methodology used in the noise impact assessment for construction and operational phases.

11.2.1 Baseline Airborne Noise Study

Baseline noise monitoring is used to establish the existing noise levels in the Study Area. A site survey was conducted from 5 – 6 November 2019 for up to 150m around the construction worksite areas/ Project footprint areas. A total of six (6) noise monitoring locations were proposed (at the inception stage), based on the following considerations:

- Identification of NSRs (hospitals, schools, childcare facilities, old age homes, residences, fauna and habitats of high ecological value) nearest to the construction worksite areas/ Project footprint boundary of the proposed facility building;
- Other NSRs away from the construction worksite areas/ Project footprint were eliminated as these receptors are assumed to be barricaded by the first row of buildings;
- NSRs with areas having ongoing construction were avoided;
- Areas where CCNR EIA has already established noise baseline in the past has been excluded;
- NSRs where the owner denied permission during site walkover was excluded (e.g. past experience with terrace houses/ bungalows, embassies at Swiss valley area, heavy car park area at Grand Stand, etc).
- The closest NSR to the construction worksite areas/ Project footprint was selected; and
- For a high rise residential sensitive receptor, ensure monitoring was conducted at different floor heights (e.g., mid-level, top level) to capture the terrain variation and its impact on noise levels.

The noise monitoring locations are detailed in Table 11-1 and shown in Figure 11-1. Noise monitoring was conducted for one week (weekdays and weekends), to capture baseline noise levels over time periods of 12 hours (long term), 1 hour, 15 minutes and 5 minutes (short term) at each location. Thereafter, baseline airborne noise monitoring was supplemented with secondary baseline data obtained from the concurrent study carried out by AECOM in the vicinity, to obtain the baseline noise levels for the purpose of establishing the baseline conditions within the Study Area. The Norsonic 131 Sound Level Meter was used to record the noise levels above. The method and results are detailed in the baseline noise monitoring report shown in Appendix N, calibration certificates are shown in Appendix Q and further discussed in Section 11.5.

Table 11-1 Proposed Baseline Noise Monitoring Locations

Monitoring Location	Nearest Construction Worksite Area / Project Footprint	Sensitivity of Receptor at Monitoring Location	Justification	Photo of Monitoring Location
N08: Swiss School in Singapore	A1-W2 Worksite (Eng Neo Avenue Forest)	Priority 1, 2, 3 (dependent on species sensitivity)	Representative baseline noise monitoring location within the Study Area. The baseline noise level is expected to be dominated by the operational noise from the school.	
N09: Within Eng Neo Avenue Forest	A1-W2 Worksite (Eng Neo Avenue Forest)	Priority 1, 2, 3 (dependent on species sensitivity)	Representative baseline noise monitoring location within Eng Neo Avenue Forest. Baseline noise monitoring location located east of A1-W2 Worksite.	

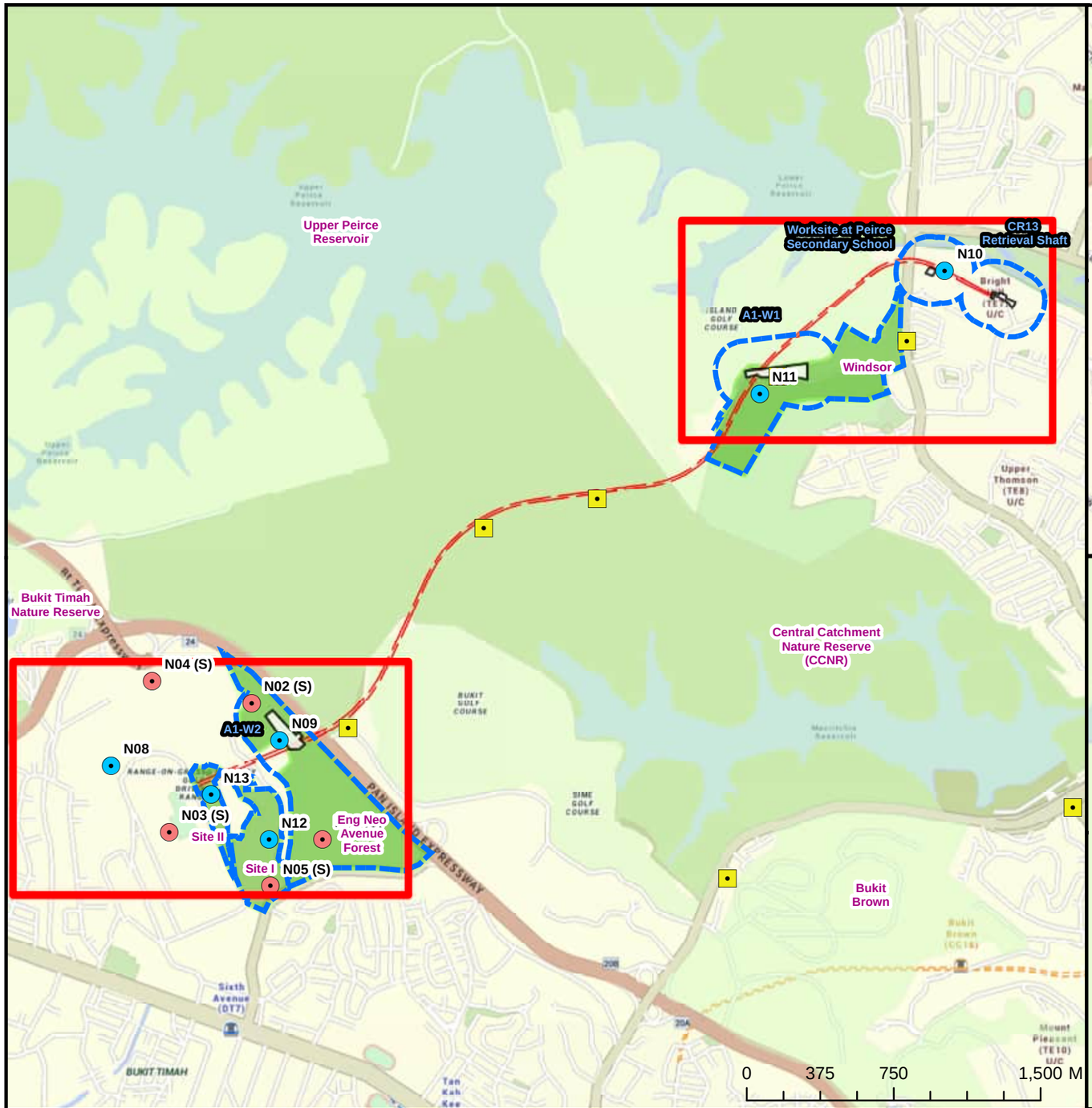
Monitoring Location	Nearest Construction Worksite Area / Project Footprint	Sensitivity of Receptor at Monitoring Location	Justification	Photo of Monitoring Location
N10: Peirce Secondary School	A1-W1 Worksite	Priority 1, 2, 3 (dependent on species sensitivity)	Representative baseline noise monitoring location within the Study Area. Baseline noise monitoring location located east of A1-W1. This location is added to monitor construction noise associated with A1-W1.	
N11: Windsor	A1-W1 Worksite	Priority 1, 2, 3 (dependent on species sensitivity)	Representative baseline noise monitoring location within Windsor. Location is south to south-west of A1-W1.	

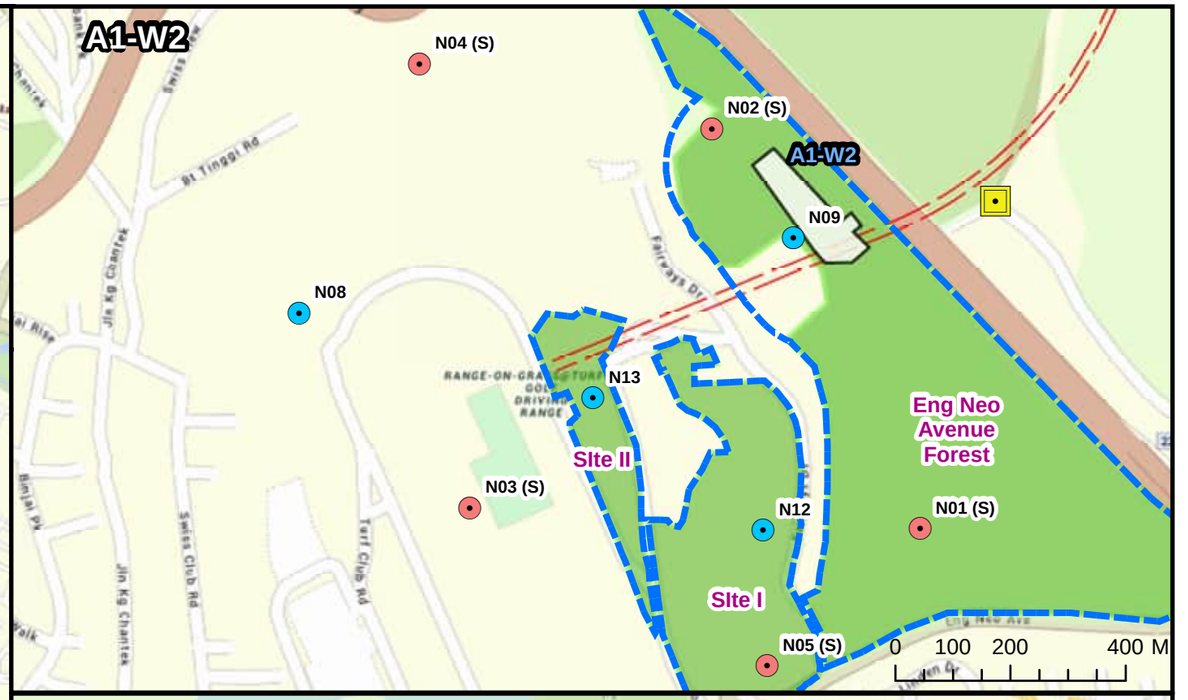
Monitoring Location	Nearest Construction Worksite Area / Project Footprint	Sensitivity of Receptor at Monitoring Location	Justification	Photo of Monitoring Location
N12: Within Site I	Site I forest area	Priority 1, 2, 3 (dependent on species sensitivity)	Representative baseline noise monitoring location within greenfield area of Site I. Baseline noise monitoring location located within northern part of Site I..	
N13: Within Site II	Site II forest area	Priority 1, 2, 3 (dependent on species sensitivity)	Representative baseline noise monitoring location within Site II. Representative baseline noise monitoring location for greenfield site-Site II, Bright Path Pre School and Saddle Club.	

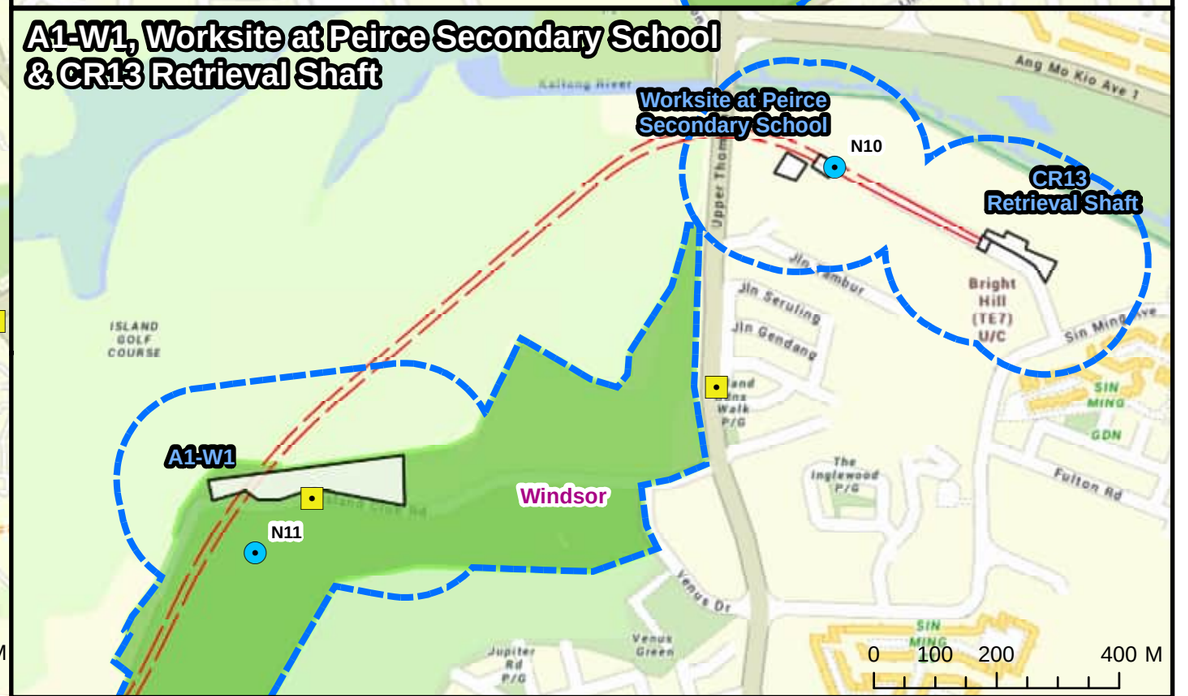
Monitoring Location	Nearest Construction Worksite Area / Project Footprint	Sensitivity of Receptor at Monitoring Location	Justification	Photo of Monitoring Location
N01(S)*	Eng Neo Avenue Forest (Southern)	Priority 1, 2, 3 (dependent on species sensitivity)	In a greenfield site within the Eng Neo Avenue Forest. The selected location represents the environment of the southern part of the Eng Neo Avenue Forest.	
N02(S)*	Eng Neo Avenue Forest (Northern)	Priority 1, 2, 3 (dependent on species sensitivity)	In a greenfield site within the Eng Neo Avenue Forest. The selected location represents the environment of the northern part of the Eng Neo Avenue Forest.	

Monitoring Location	Nearest Construction Worksite Area / Project Footprint	Sensitivity of Receptor at Monitoring Location	Justification	Photo of Monitoring Location
N03(S)*	Ravine in the centre of the former racetrack	Priority 1, 2, 3 (dependent on species sensitivity)	The selected location represents the environment of the nearest forested areas.	
N04(S)*	Forested area adjacent to The British Club/ Swiss Club	Priority 1, 2, 3 (dependent on species sensitivity)	Representative baseline noise monitoring location in the forested area adjacent to The British Club/ Swiss Club is a greenfield site. The selected location represents the environment of the nearest forested areas.	
N05(S)*	Site I (Southern)	Priority 1, 2, 3 (dependent on	Representative baseline noise monitoring location in a greenfield site within the Site I. The selected location represents the environment of the southern part of the Site I forest area.	

Monitoring Location	Nearest Construction Worksite Area / Project Footprint	Sensitivity of Receptor at Monitoring Location	Justification	Photo of Monitoring Location
		species sensitivity)		
Notes: * Secondary baseline noise monitoring locations from the concurrent study carried out by AECOM in the vicinity				







Legend

- Noise Monitoring Location
- Noise Monitoring Location - CCNR EIA [R-1]
- Noise Monitoring Locations (Secondary Data) [R-6]
- Noise Study Area
- Proposed CRL Alignment (Base)
- Construction Worksites
- Biodiversity Study Area

Note:
Site I and II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	PZ	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
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Project Title :
**CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)**

Figure Title :
**BASELINE NOISE
MONITORING LOCATIONS**

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
PZ	JAG	JAG	11-1	-	1 of 1
	Drawn PZ	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

11.2.2 Prediction and Evaluation of Impact Assessment

The airborne noise impact assessment includes the evaluation of construction noise to the sensitive noise receptors respectively.

11.2.2.1 Construction Phase

For the assessment on construction phase, the noise levels generated from the equipment used during construction detailed in Section 11.3 were predicted using SoundPLAN ver 8.2. Where topography is not available, a flat terrain based on the nearest spot height from the topography survey was taken within the Study Area. A quantitative assessment at the noise sensitive receptors (within the 150m Study Area) was carried out and compared with the stipulated *Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2008.* The identified noise sensitive receptors were assessed in accordance with the impact evaluation matrix as shown in Section 6.4.2. Noise contours were provided to the extent that topography is available. Based on the impact evaluation, mitigation to reduce airborne noise impacts was recommended for the affected noise sensitive receptors

The study on construction noise impact to the noise sensitive receptors will focus on two (2) different construction scenarios. The two scenarios are:

- Scenario 1: Cut and cover works and associated activities (non TBM/entrance construction work) – Assesses construction noise impacts from the cut and cover worksites to the sensitive receptors;
- Scenario 2: Tunnel Boring Machine (TBM) works – Assesses construction noise impacts from the TBM worksites to the sensitive receptors; and

Assumptions to the construction noise assessment are as listed below:

- Within each scenario, works are assumed to be carried out at the same time between the different worksites.

11.2.2.1.1 *Rock Breaking and Excavation and Air Overpressure*

Where common excavation techniques are not able to break down hard rocks, rock breaking and excavation can be proposed as an effective and efficient method to break down and remove rocks. For the A1-W1 worksite and A1-W2 worksite, rock breaking and excavation is proposed to break down 25m of Bukit Timah Granite rock at a depth range of 25-50m. for the construction of the facility building.

As a product of rock breaking and excavation, the major side effects on the environment includes air overpressure. When a MIC of any magnitude is detonated, air which acts as a fluid radiates from its specific work location outwards towards the surrounding environment. This radiation of energy compresses the air with diminishing pressure over distance. Air overpressure is usually measured in the form of dB (Lin). Frequency of rock breaking and excavation at A1-W1 and A1-W2 is assumed to be 1 time per day and 5 times per week for a 6-days work week over a span of 5 months.

During the writing of this report, detailed information was not available, the rock breaking and excavation works could only be carried out by an appointed Contractor at a later stage. Hence, the approach taken in this section will provide a guideline to the criteria as set out in BS5228-2:2009+A1:2014. Based on assumptions made (location, depth, method) and known information (distance to nearest receptors), this assessment will provide an estimate on the maximum amount of MIC (explosive charge mass, kg) that should be permitted in order to keep air overpressure within the stated criteria. Predictive methods in AS 2187.2-2006 Explosive – Storage and Use Part 2 will be used to predict air overpressure based on constants recommended within the guideline with formula (1) below:

$$P = K_a\left(\frac{R}{\sqrt[3]{Q}}\right)^a$$ ---------- (1)

Where

P = pressure in kilopascals

Q = explosives charge mass, in kilograms

R = distance from charge, in metres (10m)

K_a = site constant (assumed to be 100)

a = site exponent (assumed to be -1.45)

Due to the lack of information for rock breaking and excavation works in Singapore, the site constant was assumed based on AS 2187.2-2006. The site constant K_a is commonly ranging from 10 to 100 for confined explosion hole charges and hence is conservatively assumed to be 100 for the purpose of the calculation. The site exponent, *a, is* assumed to be -1.45 for confined explosion hole charges. The alternative to confined explosion hole charges would be unconfined surface charges which is usually employed in mine breaking and drilling. The distance from charge to the receptor, R, is measured from the centre of the A1-W1 worksite to the nearest boundary of Windsor which is approximately 25m

The criteria adopted from BS5228-2:2009+A1:2014 is 120 dB (Lin). Hence, the sound power level (SPL) at the receptor can be calculated based on the formula (2) below.

$$SPL = 20\ log_{10}\left(\frac{Pa}{P_o}\right)$$ ---------- (2)

Where

Pa = pressure in pascals

P_o = reference pressure of 0.00002 pa

SPL = sound pressure level in dB

11.2.2.2 Operational Phase

An airborne noise study at the boundary of facility building will be conducted in a separate study by LTA. Based on the predicted results at the boundary due to the operation of the facility building, CR2005 will assess and evaluate the impacts on the ecological receptors identified within Windsor in accordance with the impact evaluation matrix as shown in Section 6.4.2 and NEA Technical Guideline on Boundary Noise Limits for Air Conditioning and Mechanical Ventilation Systems in Non-Industrial Buildings, 2018.

A qualitative assessment will be provided to assess the increase in traffic volume due to the Project operations based on the NEA Technical Guideline for Land Traffic Noise Impact Assessment, 2016 [R-53] and assessed in accordance with impact evaluation matrix as shown in Section 6.4.2.

11.2.3 Assessment Criteria

There are currently no guidelines or standards available to assess the noise from construction and operational phases of the Project on the respective ecological receptors. The current guidelines and standards available are used to assess the respective noise impact to humans only and will be adopted for this study for the purpose of establishing the criteria and assessing noise impacts to the identified noise ecologically sensitive receptors. The ecological impacts from airborne noise is species dependent hence the assessment will be based on the species identified during site surveys at Eng Neo Avenue Forest and Windsor (see Section 11.4 for airborne noise sensitive receptors) in sync with the biodiversity section of this report. It is to be noted that for worksite A1-W1 (receptor: Windsor), Windsor ecological receptor noise impact to be assessed against the baseline noise level as the noise criterion.

Section 11.2.3.1 and Section 11.2.3.2 below details the construction and operational noise criteria adopted for this study respectively.

11.2.3.1 Construction Noise Criteria

In determining the impact of the construction noise to sensitive receptors, the baseline noise level detailed in Section 11.5 will be included in the calculation to derive a background noise correction factor to establish the maximum permitted noise level from the construction activities in accordance with the noise legislation stated in *Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2008 [R-51]*. It is to be noted that Airborne noise impacts will occur from above ground construction sites only.

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 are provided in Table 11-2 to Table 11-4 for periods of different duration, these are:

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

Table 11-2 Maximum Permissible Noise Levels for Construction Works over a Period of 12 hours

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

Table 11-3 Maximum Permissible Noise Levels for Construction Works over a Period of 1 hour

Types of affected buildings	Days of the week	Maximum Permissible $L_{Aeq\ (1\ hour)}$ (dB)		
		7am – 7pm	7pm – 10pm	10pm – 7am
Residential buildings located less than 150 m from the construction site where the noise is being emitted	Monday to Saturday	-	65	55

Table 11-4 Maximum Permissible Noise Levels for Construction Works over a Period of 5 minutes

Types of affected buildings	Days of the week	Maximum Permissible $L_{Aeq\ (5\ mins)}$ (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
	Sundays & PHs	75	55	55
(c) Buildings (other than those in paragraphs (a) and (b))	All days	90	70	70

As per the legislation, if there are other sources of noise affecting the measurement of noise emitted from the construction site, the maximum permissible noise levels for construction sites are supposed to be adjusted 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 level, and the background noise level and is presented in Table 11-5. The difference in the noise levels are 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 11-5 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 4	2
4 to 10	1
10 and above	Nil

11.2.3.1.1 *Rock Breaking and Excavation and Air Overpressure*

BS5228-2:2009+A1:2014 provides a criterion for air overpressure. Routine rock breaking and excavation can regularly generate air overpressure levels at adjacent premises of around 120 dB (Lin). This level corresponds to an excess air pressure which is equivalent to that of a steady wind velocity of 5 m·s−1 (Beaufort force 3, gentle breeze) and is likely to be above the threshold of perception. Although this criterion is usually employed for impacts on humans, it has been adopted for this study on ecological receptors (e.g. fauna within Windsor).

11.2.3.2 Operational Noise Criteria

In determining the impact of the operational noise to the ecologically sensitive noise receptors, the baseline noise level in the Study Area will be included to derive the corrected boundary noise limits in accordance with *NEA Technical Guideline on Boundary Noise Limits for Air Conditioning and Mechanical Ventilation Systems in Non-Industrial Buildings, 2018 [R-52].* Traffic noise with the *NEA Technical Guideline for Land Traffic Noise Impact Assessment, 2016 [R-53]* for noise sensitive and residential building receptors.

11.2.3.2.1 *ACMV Boundary Noise Limits*

The NEA Noise Guideline describes a non-industrial building as:

“Any permanent or temporary building or structure used for the purposes of trade, business or commerce and includes any shopping complex, financial institution, office tower, hotel, educational institution, hospital, transport infrastructures, community infrastructure, sport and recreational infrastructure but does not include any factory and residential premises.” The noise limits outlined in the NEA Noise Guideline shall, therefore, be used. These noise limits are outlined in Table 11-6.

Table 11-6 Boundary Noise Limits by NEA

Types of affected buildings	Boundary Noise Limits (reckoned as the equivalent continuous noise level over 15 minutes), dB(A)		
	Day 7am to 7pm	Evening 7pm to 11pm	Night 11pm to 7 am
Noise Sensitive Premises such as hospital, home for the aged sick, library, etc.	60	55	50
Residential Premises	65	60	55
Others	70	65	60

In accordance with the guideline, noise from the sources under consideration is measured so as to determine the impact over a continuous 15-minute period. Adjustments to the measured noise level are applied to account for the effects of duration, tonality, intermittency, and impulsiveness of the noise. The measured, adjusted 15-minute noise level is then assessed in relation to the noise limits.

Based on NEA’s Technical Guideline on Boundary Noise Limits for Air Conditioning and Mechanical Ventilation Systems in Non-Industrial Building Section 4, measurements are to be conducted as follows:

“For equipment installed at ground level, the noise measurements should be made at the site boundary. For equipment that is installed above ground level e.g. at roof-top, the noise measurements should be taken at least 1m from the noise source and at the same height as the equipment. The noise level shall be computed for a point that is at the site boundary and at the same height as the equipment.”

It shall be noted that as per the Guideline, Correction Factors shall be applied to the values in Table 11-7 to determine the final contract-specific criteria. These Correction Factors shall be determined using the background noise level measured when each equipment item is switched OFF and incorporating the values into the proposed measurement methodology detailed in the following paragraph, which is based on Section 5 of the NEA Guideline.

The maximum permissible noise levels for the Project shall be selected on the basis of the above assumption and adjusted 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 applicable permissible level, and the background noise level (as stated in the Third Schedule of the legislation) and is presented in Table 11-7.

Table 11-7 ACMV Noise Correction Factor

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

11.2.3.2.2 *Land Traffic Noise Impact Assessment Criteria*

NEA's noise requirements are as follows:

(1) The noise levels at 1 m from the façade of the new residential/noise sensitive building shall not exceed LAeq(1hr) 67 dB; and

(2) The indoor noise level of the new residential/noise sensitive building under natural ventilation shall not exceed LAeq(1hr) 57 dB.

This traffic noise assessment is typically conducted by a Noise Consultant appointed for the proposed developments for the residential and noise sensitive buildings for the Project. This study will only consider traffic noise impact to the ecological receptors qualitatively.

11.3 Potential Sources of Airborne Noise Impacts

This section discusses the potential equipment and activities which could cause noise impacts from the respective construction and operational phases of the Project.

11.3.1 Construction Phase

The construction noise impacts generated from the various construction activities will depend on the inventory adopted during each activity of the construction programme. The main source of noise will be from the Powered Mechanical Equipment (PMEs). The PMEs and the respective sound power levels used in this study are listed in Appendix Y.

Based on the construction programme proposed by CR2005, the A1-W2 worksite will follow a cut and cover construction method. For the construction at the facility building worksites of A1-W1 and original A1-W2, construction programme for a typical facility building will be adopted however it is to be noted that rock breaking and excavation has been proposed at the A1-W1 worksite and A1-W2 worksite, and this study will explore air overpressure impacts from rock breaking and excavation. The construction inventory for the respective worksites are shown in Appendix Z.

Based on the construction inventory for the concurrent project worksites, the sound power level used in the noise model are shown in Table 11-8 below. It is to be noted that rock breaking and excavation and air overpressure was not considered for noise modelling and will only be assessed semi-qualitatively due to the instantaneous nature of the noise generated from rock breaking and excavation.

Table 11-8 Effective Sound Power Level

Construction Activity	Effective Sound Power Level $L_{wA,}$ dB from overall construction inventory				
	$L_{Aeq\ (12\ hours)}$	$L_{Aeq\ (12\ hours)}$	$L_{Aeq\ (5\ min)}$	$L_{Aeq\ (5\ min)}$	$L_{Aeq\ (5\ min)}$
	7am-7pm	7pm-7am	7am-7pm	7pm-10pm	10pm-7am
CR13 Retrieval Shaft Worksite & Underpinning Works at Peirce Secondary School*					

Construction Activity	Effective Sound Power Level $L_{wA,}$ dB from overall construction inventory				
	$L_{Aeq\ (12\ hours)}$	$L_{Aeq\ (12\ hours)}$	$L_{Aeq\ (5\ min)}$	$L_{Aeq\ (5\ min)}$	$L_{Aeq\ (5\ min)}$
	7am-7pm	**7pm-7am**	**7am-7pm**	**7pm-10pm**	**10pm-7am**
1. Clearance for Construction Area	116	-	119	-	-
2. Temporary Earth Retaining System	107	105	110	108	107
3. Levelling (Cut and Fill) to Work Platform Level	109	99	114	102	101
4. Station ERSS- Installation of D Wall/SBP/Sheet Pile	107	107	108	108	-
5. Installation of Wallers & Struts/Stage excavation	108	108	110	110	110
6. TBM Receiving Shaft	114	114	115	115	115
7. Construction of Permanent Structure	102	102	105	105	105
8. Reinstatement of Work & Exiting Road	115	115	116	116	-
Note * Concurrent Project – Worst phase included in the impact calculation in the section below. .					

Based on the construction inventory for the facility building, the sound power levels used in the noise model are shown in Table 11-9 below. It is to be noted that rock breaking and excavation and air overpressure was not considered for noise modelling and will only be assessed semi-qualitatively due to the instantaneous nature of the noise generated from rock breaking and excavation.

Table 11-9 Effective Sound Power Level (Facility Building)

Construction Activity	Effective Sound Power Level $L_{wA,}$ dB from overall construction inventory				
	$L_{Aeq\ (12\ hours)}$	$L_{Aeq\ (12\ hours)}$	$L_{Aeq\ (5\ min)}$	$L_{Aeq\ (5\ min)}$	$L_{Aeq\ (5\ min)}$
	7am-7pm	**7pm-7am**	**7am-7pm**	**7pm-10pm**	**10pm-7am**
A1-W1					
1. Site Clearance and Site Preparatory Works	117	117	118	118	118
2. Piling / D-wall Works	119	119	120	120	120
3. Excavation and RC Works	115	115	116	116	116
4. Superstructure Construction	116	116	117	117	117
Utilities Diversion Works	109		110		
BKSR*					
1. Open Cut	113	-	116	-	-
2. Pipe-jacking/Shaft Construction	118	-	120	-	-
A1-W2					
1. Site Clearance and Site Preparatory Works	117	117	118	118	118
2. Piling / D-wall Works	119	119	120	120	120
3. Excavation and RC Works	115	115	116	116	116
4. Superstructure Construction	116	116	117	117	117

Construction Activity	Effective Sound Power Level L_{wA}, dB from overall construction inventory				
	$L_{Aeq\ (12\ hours)}$	$L_{Aeq\ (12\ hours)}$	$L_{Aeq\ (5\ min)}$	$L_{Aeq\ (5\ min)}$	$L_{Aeq\ (5\ min)}$
	7am-7pm	**7pm-7am**	**7am-7pm**	**7pm-10pm**	**10pm-7am**
6. TBM (Launching to CR15 and CR13 retrieval shaft) (For Scenario 2)	115	115	115	115	115
Note * Concurrent Project – Worst phase included in the impact calculation in the section below. .					

As mentioned in Section 11.2.2, two scenarios were modelled as a result of the varying construction works expected to occur at the worksites. Based on the effective sound power level generated from the worksites shown in Table 11-8 and Table 11-9, the worst-case noise levels used in the respective scenarios are shown in Table 11-10 below.

Table 11-10 Effective Sound Power Level (Noise Model Input)

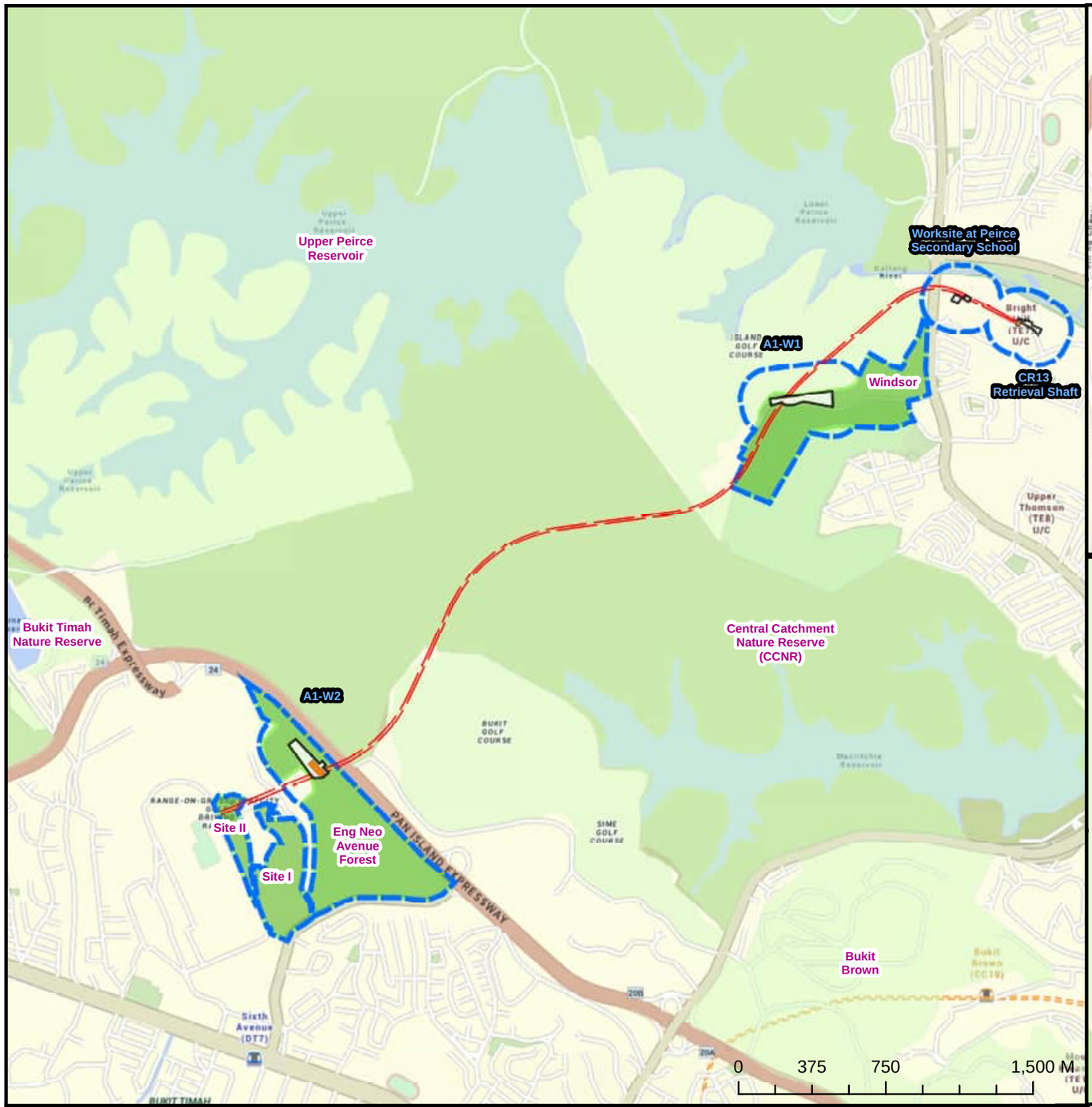
Scenario / Worksite	Effective Sound Power Level L_{wA}, dB used in the noise model				
	$L_{Aeq\ (12\ hours)}$ 7am-7pm	$L_{Aeq\ (12\ hours)}$ 7pm-7am	$L_{Aeq\ (5\ min)}$ 7am-7pm	$L_{Aeq\ (5\ min)}$ 7pm- 10pm	$L_{Aeq\ (5\ min)}$ 10pm-7am
Scenario 1: Cut and cover works and associated activitiest (From Table 11-8, Clearance for Construction Area for 7am-7pm, Reinstatement of Work & Exiting Road for LAeq (12 hours) 7pm-7am and Installation of Wallers & Struts/Stage excavation for LAeq (5mins) 10pm-7am and from Table 11-9, Piling / D-wall Works for Facility Buildings)					
CR13 Retrieval Shaft Worksite & Underpinning Works at Peirce Secondary School*	116	115	119	116	110
A1-W1 Worksite	119	119	120	120	120
A1-W2 Worksite	119	119	120	120	120
BKSR*	118	-	120	-	-
Scenario 2: TBM worksites (From Table 11-8, TBM Receiving / Launching Works)					
A1-W2 TBM Worksite (Launching)	115	115	115	115	115
CR13 TBM Receiving Shaft	114	114	115	115	115
Note * Concurrent Project – Worst phase included in the impact calculation in the section below. .					

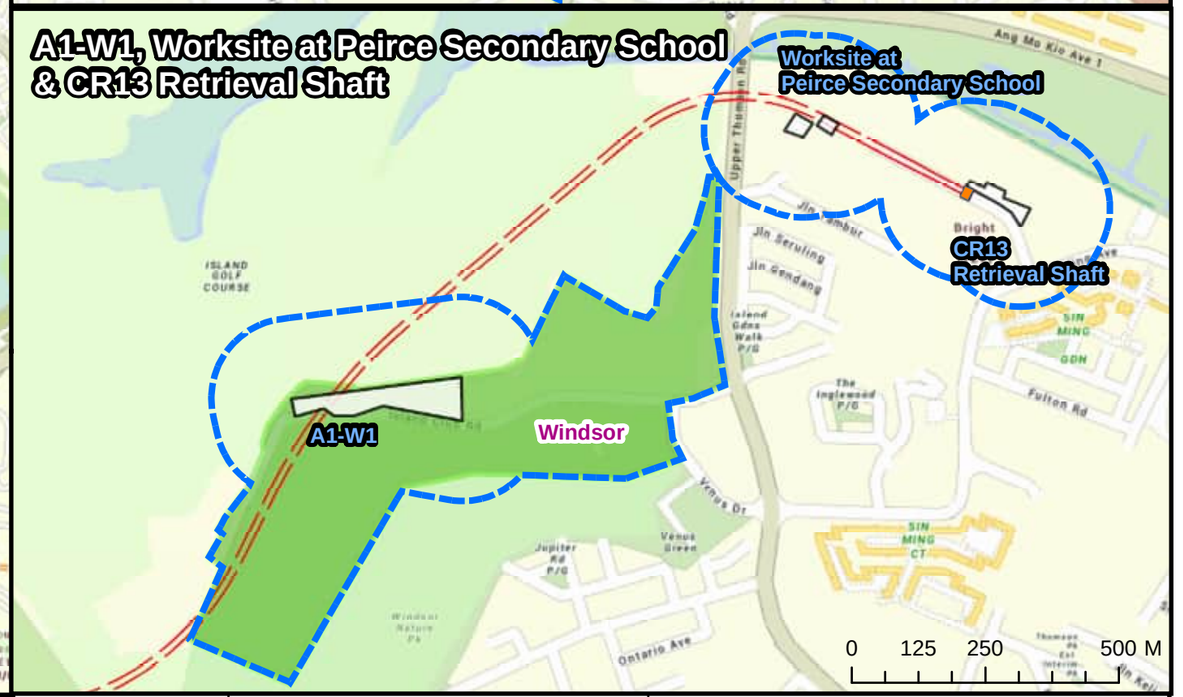
The worksites mentioned in Table 11-10 above are shown in Figure 11-2 below.

The likelihood of the assessment is based on the work period and active noise period for machinery. The two scenarios as mentioned above are deemed have an occasional likelihood. The likelihood evaluation for construction activities for the airborne noise assessment is shown in Table 11-11.

Table 11-11 Likelihood Evaluation for Construction Activities for Airborne Noise Assessment

Construction Worksite	Construction Activity	Base case	Mitigated Case
A1-W1	**Rock breaking and excavation**	Certain Likelihood Work period = 1 Active vibration period for Machinery = 1 1 x 1 = 1	Certain Likelihood Work period = 1 Active vibration period for Machinery = 1 1 x 1 = 1
A1-W1	**Scenario 1 - Cut and cover works and associated activities**	Continuous Likelihood $L_{Aeq\ (12\ hours)}$ Work period = 1 Active vibration period for Machinery = 0.8 1 x 0.8 = 0.8 Continuous Likelihood (continue work in night) $L_{Aeq\ (5\ mins)}$ Work period = 1 Active vibration period for Machinery = 1 1 x1 =1	Regular Likelihood (restricted to daytime) $L_{Aeq\ (12\ hours)}$ Work period = 0.5 Active vibration period for Machinery = 0.8 0.5 x 0.8 = 0.4 Regular Likelihood (restricted to daytime) $L_{Aeq\ (5\ mins)}$ Work period =0.5 Active vibration period for Machinery = 1 1x0.5 =0.5
A1-W2	Rock breaking and excavation	Likelihood – Certain Rock breaking and excavation - Work period = 1 Active vibration period for Machinery = 1 1 x 1 = 1	Rock breaking and excavation - Work period = 1 Active vibration period for Machinery = 1 1 x 1 = 1
A1-W2	Scenario 1 – Cut and cover works and associated activities	Likelihood- Certain $L_{Aeq\ (12\ hours)}$ Work period = 1 Active vibration period for Machinery = 0.8 1 x 0.8 = 0.8 $L_{Aeq\ (5\ mins)}$ Work period = 1 Active vibration period for Machinery = 1 1 x1 =1	Likelihood- Regular $L_{Aeq\ (12\ hours)}$ Work period = 0.5 (only day) Active vibration period for Machinery = 0.8 0.5 x 0.8 = 0.4 $L_{Aeq\ (5\ mins)}$ Work period =0.5 Active vibration period for Machinery = 1 0.5 x1 =0.5
A1-W2	Scenario 2 – TBM Works	Likelihood- Certain Work period = 1 Active vibration period for Machinery = 1 1 x 1 = 1	Likelihood- Certain Work period = 1 Active vibration period for Machinery = 1 1 x 1 = 1





Legend

- Proposed CRL Alignment (Base)
- Base Scenario Construction Worksite Footprint
- Noise Study Area
- TBM Worksite
- Biodiversity Study Area

Note:
Site I and II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	PZ	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Designed	Checked	Approved
PZ	JAG	JAG
	Drawn PZ	Date MAR 2022

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Figure Title :
AIRBORNE CONSTRUCTION NOISE SOURCES

Figure No. :	Rev.	Sheet
11-2	-	1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap

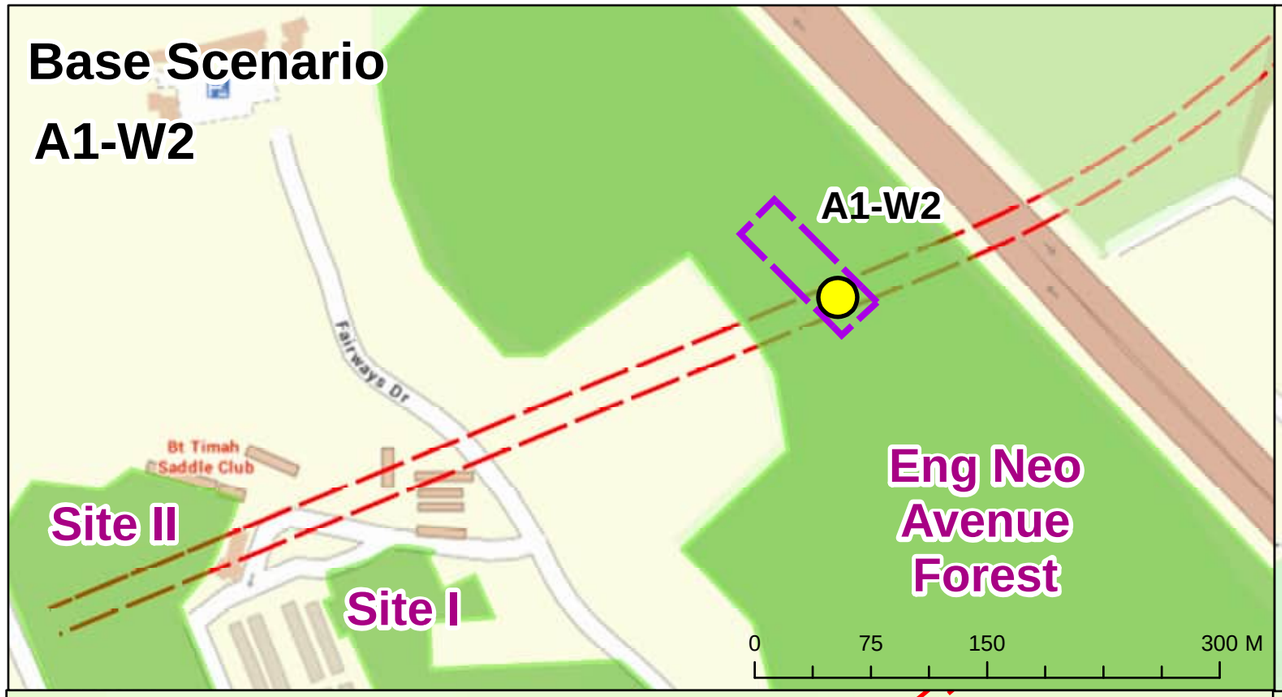
11.3.2 Operational Phase

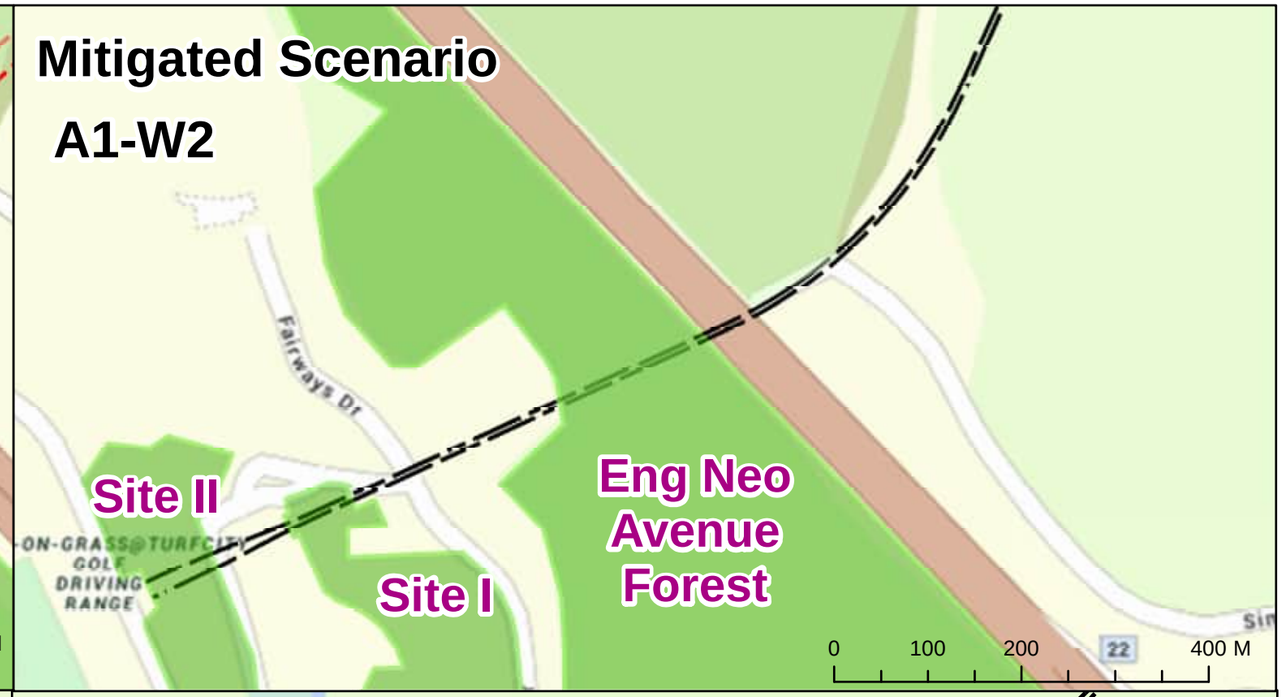
The operational footprint of the A1-W1 and A1-W2 are shown in Figure 11-3.The train alignment is underground therefore operation of train is not likely to generate airborne on the land surface. The typical noise sources during operational phase of the Project includes the following:

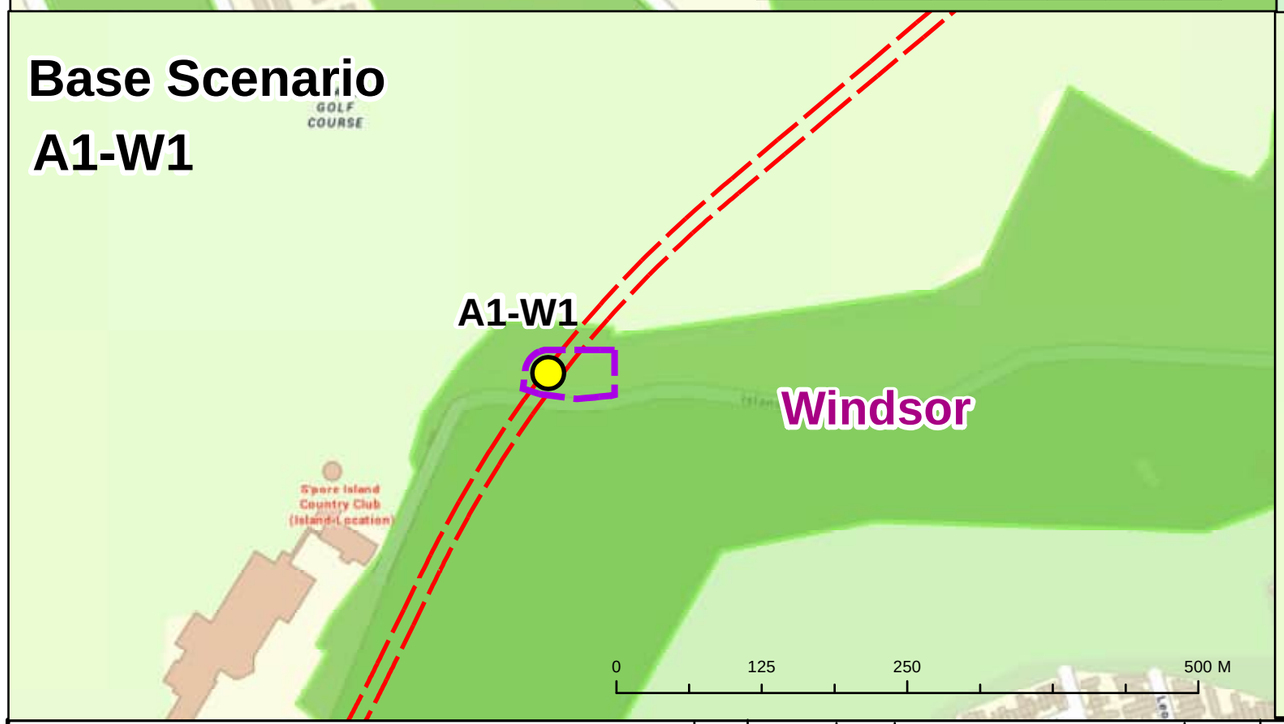
- Traffic noise due to increase in vehicular volume due to the development of the Project; and
- Air-conditioning and mechanical ventilation noise from services at the facility buildings.

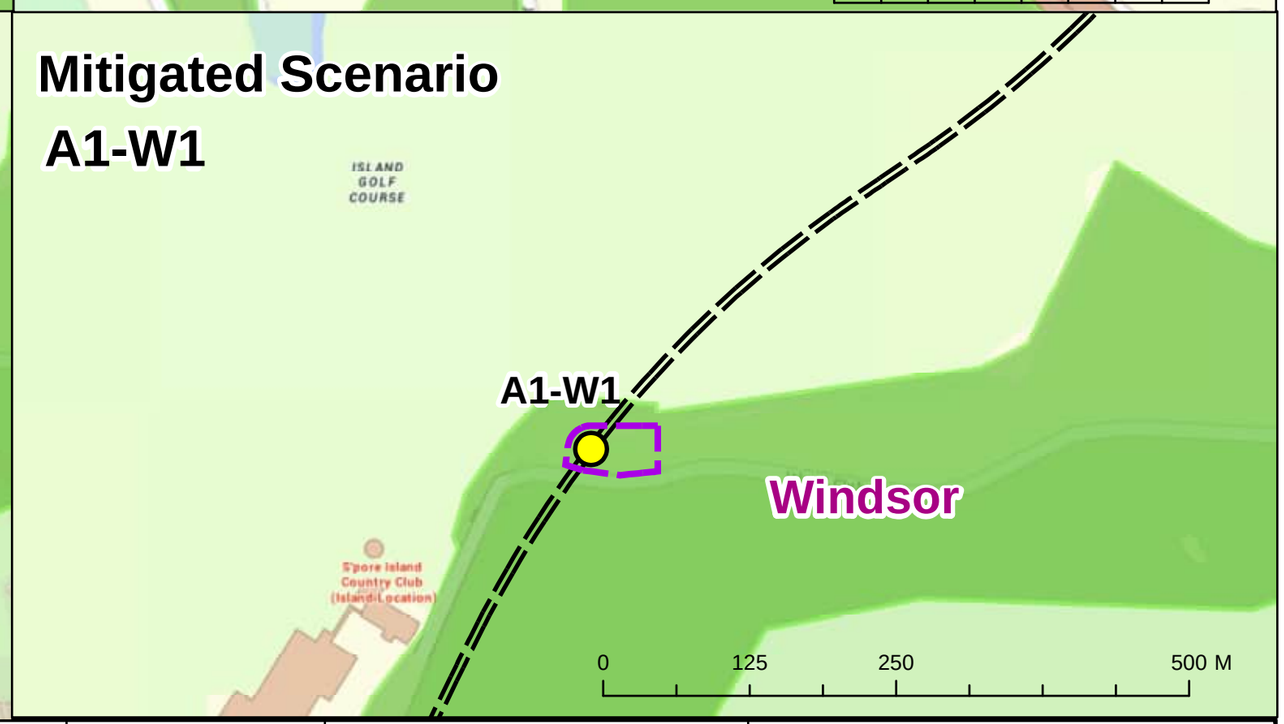
The traffic increase (if any) could potentially cause disturbance to the ecologically sensitive receptors within the respective Biodiversity Study Area. There are existing roads and its associated noise in the vicinity of the construction worksites such as Bukit Timah Road, Pan Island Expressway (PIE) and Upper Thomson Road.

Air-conditioning system noise is expected to be present for the duration of the facility building's operating hours, however, mechanical ventilation is expected to persist through the day due to maintenance work within facility building and rail alignment.









Legend

- Biodiversity Study Area

Above-Ground Structure

- Facility Building (Above-Ground)

Underground Structure

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Facility Building (Underground)

Note:
Site I and II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	PZ	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant :

Land Transport Authority
We Keep Your World Moving

Project Title :
**CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)**

Figure Title :
**OPERATIONAL FOOTPRINT
OF WORKSITES**

Designed	Checked	Approved
PZ	JAG	JAG
	Drawn: PZ	Date: MAR 2022

Figure No. : 11 - 3 | Rev. : - | Sheet : 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap

11.4 Identification of Airborne Noise Sensitive Receptors

This study focuses on the noise impacts to the Biodiversity Study Area and the respective fauna within the Study Area for the construction and operational phases. The identified ecological receptors for the construction and operational phases based on the biodiversity studies are categorised below and known habitats (where applicable) shown in Figure 11-4.

Receptor Sensitivity - Habitat

It is to be noted that both the sensitivity of both fauna and habitat are important while identifying sensitivity of noise sensitive receptors. However, during recent nature group engagement held on 23rd March 2022, for this Project, it was proposed by the members of the nature group to use habitat as the basis of sensitivity assessment for this Project. Therefore, based on the usage of the site, the habitat sensitivity maps was created as in the Figure 11-4 and used in the assessment. In addition, since there are urban patches of land nearby which may not be suitable to support the presence of fauna, this study will assess these regions as “Not Assessible”.

Receptor Sensitivity - Species

For the classification of receptor sensitivity on a species scale for assessment of mitigation measures as a secondary approach, auditory sensitivity of the respective species was used to assign receptor priority. Species that use sound for communication, foraging and breeding are known to have their behaviours disrupted by sound were assigned higher Priority status for auditory sensitivity. Species that are less affected by airborne noise but are of Conservation Significance were assigned second Priority. Species that are less affected by airborne noise and are not of Conservation Significance were assigned lowest Priority.

Species prioritisation of the ecologically sensitive receptors within the Biodiversity Study Area follows the approach listed in order below:

1. The actual presence or likely presence (from records) from faunistic field assessment conducted
2. The conservation significance or importance of the identified ecological receptors
3. The ecological receptor’s likely sensitivity to noise impacts

Literature review findings

Aculeate hymenopterans such as Bees and Wasps are capable of detecting airborne sounds despite not having ears. Due to capability to detect noise, aculeate hymenopterans are deemed to be auditory sensitive [P-79]. However, based on faunistic surveys, no Aculeate hymenopterans of conservation significance was observed. Hence, they are classified as Priority 2 ecologically sensitive receptor.

It is documented that adult odonates appear to be able to hear however sound does not appear to cause significant behavioural change [P-84]. Odonates are consequently regarded as being less auditory sensitive. Hence, they are classified as Priority 2 or 3, dependant on conservation significance.

Lepidoptera such as the butterfly and moth are known to behaviourally respond to low-frequency vibrations and sounds to avoid insect predators and parasites [P-86]. Adult butterflies are known to make use of existing airborne noise in order to avoid predators [P-75]. Hearing dependent night-flying butterflies and moths are sensitive to sounds in order to avoid predation from bats [P-88}. Based on the above, lepidopterans are considered highly auditory. Hence, classified as Priority 1 ecologically sensitive receptor.

Studies have been conducted on the transmission of noise energy across the air to water boundary. Research shows that the transmission of airborne noise energy to the water medium is low due to the difference in acoustic characteristic impedance of air to water by a ratio of 3600 [P-89]. Hence, the aquatic species within water bodies such as decapods, fishes and tadpoles are considered to be Priority 3 ecologically sensitive receptor as it cannot be determined if these species are auditory-sensitive.

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-78]. Hence, amphibians are classified as Priority 1 ecologically sensitive receptor.

Reptiles such as lizards and skinks are considered to be highly auditory sensitive due to studies showing these species exhibiting stress responses when exposed to anthropogenic noise [P-81]. Snakes are unable to hear airborne noise and are not considered noise sensitive but are however sensitive to vibrations [P-76]. Turtles and terrapins will follow the classification of aquatic species due to the ability to traverse the lands and water [P-77].

Given the wide range of species classified under reptiles, the classification for Reptiles ranges from Priority 1 to Priority 3 ecologically sensitive receptors.

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-72]. Hence, birds are 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-82]. Hence, non-volant mammals are deemed to be highly auditory sensitive and classified as Priority 1 ecologically sensitive receptors.

Anthropogenic noise is known to impact bats negatively by disrupting foraging patterns [P-87] and hence the bats are classified as highly auditory sensitive. Hence, they are classified as Priority 1 ecologically sensitive receptor.

Table 11-12 Ecological Receptor and Airborne Noise Sensitivity Classification

Receptor Number	Receptors	Sensitivity Classification
1	Aculeate hymenopterans Bee Wasp	Priority 2
2	Odonates Damselfly Dragonfly	Priority 2 / Priority 3
3	Lepidoptera Butterfly Moth	Priority 1
4	Aquatic Species Crab Shrimp Fishes Tadpoles	Priority 3
5	Amphibians Frogs	Priority 1
6	Reptiles Lizards	Priority 1
7	Reptiles Snakes	Priority 2
8	Reptiles Snakes Turtles and Terrapins	Priority 3
9	Birds	Priority 1
10	Non-volant Mammals	Priority 1
11	Bats	Priority 1

Eng Neo Avenue Forest, Site I and Site II

The fauna field survey documented 233 species, dominated by birds (72 species) and butterflies (64 species). Out of the 233 species, 15 of which are of conservation significance (3 butterflies, 8 birds, 2 non-volant mammal and 2 bats) and will be the focal of the assessment for Eng Neo Avenue Forest. In Site I and Site II, the fauna field survey documented 165 species, with 13 species of conservation significance dominated by (3 butterflies, 7 birds, 1 bat and 2 non-volant mammal). Table 11-13 shows the focal ecologically sensitive receptors within Eng Neo Avenue Forest.

Windsor

The fauna field survey documented 229 species, dominated by birds (60 species) and butterflies (51 species). Out of the 229 species, 26 of which are of conservation significance (5 odonates, 2 butterflies, 7 herpetofauna amphibians/reptiles, 7 birds and 5 non-volant mammal) and will be the focal of the assessment for Windsor. Table 11-14 shows the focal ecologically sensitive receptors within Windsor.

Based on faunistic field assessment within the Biodiversity Study Area, the full list of ecologically sensitive receptors is shown in Appendix O.

Table 11-13 Focal Ecologically Sensitive species – Eng Neo Avenue Forest

No.	Faunal Group	Species	Common name	Local status	Global status	Auditory Priority
1	Butterfly[1]	*Neptis harita*	Chocolate Sailor	Not Assessed	Vulnerable	Priority 1
2	Butterfly[1]	*Telicota colon stinga*	Common Palm Dart	Nationally Extinct (Rediscovered)	Not Assessed	Priority 1
3	Butterfly[1]	*Pachliopta aristolochiae asteris*	Common Rose	Vulnerable	Not Assessed	Priority 1
4	Butterfly[1]	*Troides helena cerberus*	Common Birdwing	Vulnerable	Not assessed; CITES protected (Appendix II)	Priority 1
5	Bird[1]	*Nisaetus cirrhatus*	Changeable Hawk-Eagle	Endangered	Least Concern	Priority 1
6	Bird[1]	*Treron curvirostra*	Thick-billed Green Pigeon	Endangered	Least Concern	Priority 1
7	Bird[2]	*Cacomantis sepulcralis*	Rusty-breasted Cuckoo	Vulnerable	Least Concern	Priority 1
8	Bird[2]	*Gallus*	Red Junglefowl	Endangered	Least Concern	Priority 1
9	Bird[1]	*Loriculus galgulus*	Blue-crowned Hanging-parrot	Endangered	Least Concern	Priority 1
10	Bird[1]	*Psittacula longicauda*	Long-tailed Parakeet	Not Assessed	Vulnerable	Priority 1
11	Bird[1]	*Pycnonotus zeylanicus*	Straw-headed Bulbul	Endangered	Endangered	Priority 1
12	Bird[2]	*Rallina fasciata*	Red-legged Crake	Vulnerable	Least Concern	Priority 1
13	Reptile[1]	*Dendrelaphis kopsteini*	Red-necked Bronzeback	Vulnerable	Least Concern	Priority 2
14	Reptile[1]	*Tropidolaemus wagleri*	Wagler's Pit Viper	Endangered	Least Concern	Priority 2
15	Mammal[2]	*Manis javanica*	Sunda Pangolin	Critically Endangered	Critically Endangered	Priority 1
16	Others (species which are not of CS and less auditory sensitive) [1 & 2]					Priority 3

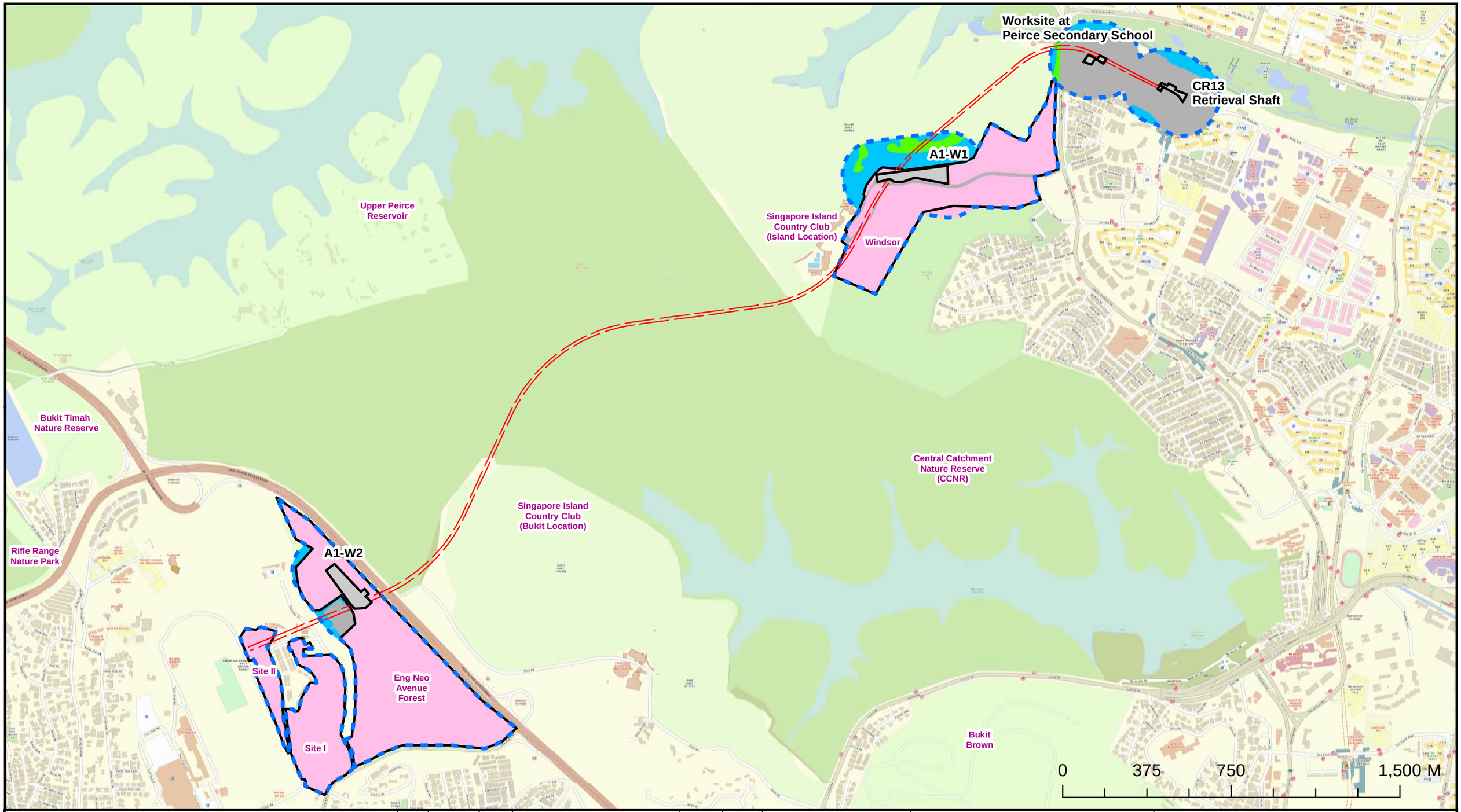
Notes:
[1] Arboreal ecological receptor
[2] Ground dwelling ecological receptor

Table 11-14 Focal Ecologically Sensitive Species – Windsor

No.	Faunal Group	Species	Common name	Local status	Global status	Auditory Priority
1	Butterfly[1]	*Borbo cinnara*	Formosan Swift	Endangered	Not Assessed	Priority 1
2	Butterfly[1]	*Catopyrops ancyra*	Ancyra Blue	Vulnerable	Not Assessed	Priority 1
3	Butterfly[1]	*Jamides alecto ageladas*	Metallic Caerulean	Nationally Extinct (Rediscovered)	Not Assessed	Priority 1
4	Butterfly[1]	*Petrelaea dana*	Dingy Line Blue	Not Assessed	Not Assessed	Priority 1
5	Butterfly[1]	*Pratapa deva relata*	White Royal	Critically Endangered	Not Assessed	Priority 1
6	Butterfly[1]	*Troides helena cerberus*	Common Birdwing	Vulnerable	Not Assessed; CITES protected (Appendix II)	Priority 1

No.	Faunal Group	Species	Common name	Local status	Global status	Auditory Priority
7	Butterfly[1]	*Eurema brigitta senna*	No Brand Grass Yellow	Nationally Extinct (Rediscovered)	Not Assessed	Priority 1
8	Amphibian[1]	*Nyctixalus pictus*	Cinnamon Bush Frog	Vulnerable	Near Threatened	Priority 1
9	Reptile[1]	*Draco melanopogon*	Black-bearded Flying Dragon	Vulnerable	Not Assessed	Priority 1
10	Reptile[1]	*Gonyosoma oxycephalum*	Red-tailed Racer	Endangered	Least Concern	Priority 2
11	Reptile[1]	*Calliophis bivirgatus*	Blue Malayan Coral Snake	Vulnerable	Least Concern	Priority 2
12	Reptile[1]	*Cnemaspis peninsularis*	Peninsular Rock Gecko	Vulnerable	Not Assessed	Priority 1
13	Reptile[1]	*Tropidolaemus wagleri*	Wagler's Pit Viper	Endangered	Least Concern	Priority 2
14	Bird[1]	*Accipiter trivirgatus*	Crested Goshawk	Critically Endangered	Least Concern	Priority 1
15	Bird[1]	*Haliaeetus ichthyaetus*	Grey-headed Fish Eagle	Critically Endangered	Near Threatened	Priority 1
16	Bird[1]	*Nisaetus cirrhatus*	Changeable Hawk-Eagle	Endangered	Least Concern	Priority 1
17	Bird[1]	*Treron curvirostra*	Thick-billed Green Pigeon	Endangered	Least Concern	Priority 1
18	Bird[2]	*Cacomantis sepulcralis*	Rusty-breasted Cuckoo	Vulnerable	Least Concern	Priority 1
19	Bird[1]	*Surniculus lugubris*	Square-tailed Drongo-Cuckoo	Critically Endangered	Least Concern	Priority 1
20	Bird[2]	*Copsychus malabaricus*	White-rumped Shama	Critically Endangered	Least Concern	Priority 1
21	Bird[1]	*Copsychus saularis*	Oriental Magpie-Robin	Endangered	Least Concern	Priority 1
22	Bird[2]	*Gallus*	Red Junglefowl	Endangered	Least Concern	Priority 1
23	Bird[1]	*Loriculus galgulus*	Blue-crowned Hanging-parrot	Endangered	Least Concern	Priority 1
24	Bird[1]	*Psittacula longicauda*	Long-tailed Parakeet	Not Assessed	Vulnerable	Priority 1
25	Bird[1]	*Psittinus cyanurus*	Blue-rumped Parrot	Critically Endangered	Near Threatened	Priority 1
26	Bird[1]	*Pycnonotus brunneus*	Asian Red-eyed Bulbul	Endangered	Least Concern	Priority 1
27	Bird[2]	*Rallina fasciata*	Red-legged Crake	Vulnerable	Least Concern	Priority 1
28	Bird[1]	*Ketupa ketupu*	Buffy Fish Owl	Critically Endangered	Least Concern	Priority 1
29	Bird[1]	*Stachyris erythroptera*	Chestnut-winged Babbler	Endangered	Least Concern	Priority 1
30	Mammal[1]	*Presbytis femoralis*	Raffles' Banded Langur	Critically Endangered	Near Threatened	Priority 1
31	Mammal[1]	*Nycticebus coucang*	Sunda Slow Loris	Critically Endangered	Vulnerable	Priority 1
32	Mammal[2]	*Manis javanica*	Sunda Pangolin	Critically Endangered	Critically Endangered	Priority 1
33	Mammal[1]	*Iomys horsfieldii*	Horsfield's Flying Squirrel	Critically Endangered	Least Concern	Priority 1
34	Mammal[2]	*Tragulus kanchil*	Lesser Mousedeer	Critically Endangered	Least Concern	Priority 1
35	Others (species which are not of CS and less auditory sensitive)					Priority 3

Notes:
1 Arboreal ecological receptor
2 Ground dwelling ecological receptor



Legend

- Proposed CRL Alignment (Base)
- Base Scenario Construction Worksite Footprint
- Noise Study Area
- Biodiversity Study Area
- Not Assessible
- Priority 1
- Priority 2
- Priority 3

Note: Site I and II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	PZ	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
We Keep Your World Moving

Project Title :
**CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)**

Figure Title :
NOISE SENSITIVE RECEPTOR - ECOLOGICAL

Designed	Checked	Approved
PZ	JAG	JAG
	Drawn PZ	Date MAR 2022

Figure No. : 11-4 | Rev. - | Sheet 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap

11.5 Baseline Airborne Noise

11.5.1 Baseline Monitoring Results

Table 11-15 and Table 11-16 summarises the $L_{Aeq(12\ hour)}$, $L_{Aeq(1\ hour)}$ and $L_{Aeq(5\ min)}$ baseline results for weekdays and Sundays/public holidays respectively. Table 11-17 summarises the $L_{Aeq(15\ min)}$ baseline results. Refer to Appendix N for the baseline noise monitoring report. It should be noted that baseline noise monitoring was conducted during COVID-19 pandemic. The ambient noise level in this area might be higher during normal conditions.

Table 11-15 Summary of Baseline Noise Monitoring Results – Weekdays (For Construction Noise Impact)

Location	Date of Monitoring	LAeq(12 hour), dB		LAeq(5 min), dB								
		7am-7pm	7pm-7am	7am – 7pm			7pm – 10pm			10pm – 7am		
		Overall		Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
N08: Swiss School in Singapore	24 Feb – 02 Mar 2020	54	47	42	69	51	39	69	49	36	55	39
N09: Within Eng Neo Avenue Forest	29 Jan – 05 Feb 2020	56	55	53	68	56	52	73	56	47	64	51
N10: Peirce Secondary School	18 Mar – 25 Mar 2020	59	51	52	74	57	50	63	53	45	57	49
N11: Windsor	30 Mar – 06 Apr 2020	59	57	44	82	55	45	75	55	44	73	53
N12: Within SIte I	13 Sep – 19 Sep 2021	55	48	43	74	52	42	56	48	39	55	46
N13: Within Site II	13 Sep – 19 Sep 2021	57	49	45	78	52	46	64	52	41	59	47
N01(S): Eng Neo Avenue Forest (Southern)*	10 Sep – 16 Sep 2021	53	50	46	60	52	47	59	51	44	56	50
N02(S): Eng Neo Avenue Forest (Northern)*	10 Sep – 16 Sep 2021	62	60	59	73	62	59	71	62	52	65	57
N03(S) : Ravine in the centre of the former racetrack*	18 Oct– 24 Oct 2021	56	55	48	74	54	47	74	56	45	67	56
N04(S): Forested area adjacent to The British Club/ Swiss Club*	24 Nov– 30 Nov 2021	54	60	49	75	53	50	83	59	43	80	52
N05(S): Site I (Southern)*	18 Oct– 24 Oct 2021	57	49	49	66	56	49	58	52	37	56	46

Notes:
* Secondary baseline noise monitoring data obtained from the concurrent study carried out by AECOM in the vicinity

Table 11-16 Summary of Baseline Noise Monitoring Results – Sunday/Public Holiday (For Construction Noise Impact)

Location	Date of Monitoring	LAeq(12 hour), dB		LAeq(5 min), dB								
		7am-7pm	7pm-7am	7am – 7pm			7pm – 10pm			10pm – 7am		
		Overall		Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
N08: Swiss School in Singapore	24 Feb – 02 Mar 2020	50	40	42	58	48	39	47	41	37	46	38
N09: Within Eng Neo Avenue Forest	29 Jan – 05 Feb 2020	55	53	53	59	55	53	59	55	48	58	51
N10: Peirce Secondary School	18 Mar – 25 Mar 2020	53	50	51	59	53	51	55	52	45	56	49
N11: Windsor	30 Mar – 06 Apr 2020	54	51	42	67	51	45	52	50	49	54	51
N12: Within SIte I	13 Sep – 19 Sep 2021	52	47	43	57	51	42	50	46	41	53	48
N13: Within Site II	13 Sep – 19 Sep 2021	57	49	46	62	52	46	50	48	42	53	48
N01(S): Eng Neo Avenue Forest (Southern)*	10 Sep – 16 Sep 2021	53	50	48	59	53	48	54	51	47	52	51
N02(S): Eng Neo Avenue Forest (Northern)*	10 Sep – 16 Sep 2021	60	59	58	67	60	60	68	62	50	62	55
N03(S) : Ravine in the centre of the former racetrack*	18 Oct– 24 Oct 2021	53	47	47	60	52	47	48	47	46	54	47
N04(S): Forested area adjacent to The British Club/ Swiss Club*	24 Nov– 30 Nov 2021	53	68	51	57	53	56	81	65	42	63	51
N05(S): Site I (Southern)*	18 Oct– 24 Oct 2021	57	49	51	63	56	49	55	52	41	55	50

Notes:
* Secondary baseline noise monitoring data obtained from the concurrent study carried out by AECOM in the vicinity

Table 11-17 Summary of Baseline Noise Monitoring Results (For Operational Noise Impact)

Location	Date of Monitoring	LAeq(15 min), dB								
		7am – 7pm			7pm-11pm			11pm-7am		
		Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
N08: Swiss School in Singapore	24 Feb – 02 Mar 2020	44	66	51	39	66	47	36	53	39
N09: Within Eng Neo Avenue Forest	29 Jan – 05 Feb 2020	53	65	56	53	72	56	47	61	51
N10: Peirce Secondary School	18 Mar – 25 Mar 2020	52	70	57	50	61	52	45	55	49
N11: Windsor	30 Mar – 06 Apr 2020	43	82	55	46	75	55	44	71	52
N12: Within Eng Neo Avenue Forest	13 Sep – 19 Sep 2021	44	73	52	43	56	48	40	54	46
N13: Within Eng Neo Avenue Forest	13 Sep – 19 Sep 2021	45	77	53	45	63	51	42	58	46

11.5.2 Corrected Construction Noise Criteria

Based on the baseline noise monitoring results, the overall noise levels for $L_{Aeq(12\ hour)}$, Average for $L_{Aeq(1\ hour)}$ and $L_{Aeq(5\ min)}$ from N08 to N11 were used to calculate the "adjusted maximum permissible noise level" in line with the directions given in Section 11.2.3 to determine the construction noise criteria for this Project.

Table 11-18 and Table 11-19 shows the corrected criteria and the calculations are shown in Appendix AA.

It is to be noted that ecological receptors noise impact in Windsor and Eng Neo Avenue Forest were assessed against the baseline noise level as the noise criterion.

Table 11-18 Corrected Construction Noise Criteria- Weekdays

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
N08	(a) Noise Sensitive	61	52	75	56	55
N09		61	56	75	59	57
N10		63	54	75	57	56
N11		63	58	75	58	57
N12		60	50	75	56	56
N13		60	50	75	57	56
N01*		61	53	75	57	56
N02*		65	61	75	63	60
N03*		62	56	75	59	56
N04*		61	61	75	61	57
N05*		62	53	75	57	56
Notes: * Secondary baseline noise monitoring data obtained from the concurrent study carried out by AECOM in the vicinity						

Table 11-19 Corrected Construction Noise Criteria - Sunday and Public Holiday

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
N08	(a) Noise Sensitive	60	50	75	55	55
N09		61	55	75	58	56
N10		61	53	75	57	56
N11		61	54	75	56	56
N12		61	52	75	56	56
N13		62	53	75	56	56
N01*		61	53	75	56	56
N02*		63	60	75	63	58
N03*		61	52	75	56	56
N04*		61	68	75	65	56
N05*		62	53	75	57	56
Notes: * Secondary baseline noise monitoring data obtained from the concurrent study carried out by AECOM in the vicinity						

11.5.3 Corrected Operational Noise Criteria

Based on the baseline noise monitoring results, the overall noise levels for $L_{Aeq(15\ Min)}$ from N08 to N11 were used to calculate the "adjusted maximum permissible noise level" in line with the directions given in Section 11.2.3 to determine the construction noise criteria for this Project.

Table 11-20 shows the corrected operational noise criteria and the calculations are shown in Appendix AA.

Table 11-20 Corrected Operational Noise Criteria

No.	Types of Affected Buildings	$L_{Aeq(15\ min),\ dB}$		
		7am-7pm	7pm-11pm	11pm-7am
N08	(a) Noise Sensitive	61	56	50
N09		61	59	54
N10		62	57	53
N11		61	58	55
N12		61	56	51
N13		61	56	52

11.6 Minimum Control for Potential Impacts

This section proposes minimum controls or standard practices commonly implemented that have been assumed to be implemented for the purposes of impact assessment.

11.6.1 Construction Noise

Mitigation measures with the following principles were developed to control construction noise levels that are predicted to exceed the Project criteria at the nearest noise sensitive receivers:

- **Elimination/ Avoidance** - Where changes to the project design and construction methodology can 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, exclusion of noisy construction phases to be conducted at evening/ night period, etc.). If full elimination is not possible, the next level of mitigation is to minimise the identified impact;

- **Minimisation (Substitution)** - Where changes to the project design and construction methodology cannot affect impact elimination; compensatory measures can be adopted to mitigate for identified impacts. For e.g., substitution of the noisier Hammer Piler with alternative Silent Piler to reduce impacts to residents. As much as possible, alternative quieter equipment shall be used for the Project construction.

- **Minimisation (Engineering controls)** - Where changes to the project design and construction cannot affect impact avoidance or minimisation via substitution, engineering controls can be adopted to further mitigate for identified impacts and possibly an enhancement measure (e.g. use of equipment enclosures wherever necessary).

- **Minimisation (Administrative controls)** - Where applicable, enhanced mitigation can 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 proper scheduling of noisier construction activities, reducing work on weekends, etc.

- **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 following control measures should be observed during the construction stage to reduce the noise levels:

- Construction prohibition period should be followed, as per fourth schedule of Environment Protection and Management regulation;

- Prepare a Construction Noise Management Plan, to establish baseline monitoring prior to site clearance, plan for monitoring during the construction phase, and procedure for complaint handling;
- The Contractor shall review the equipment to be used on site and erect localised noise barriers prior to undertaking high noise generating work;
- Machines (such as trucks) that may be in intermittent use shall be shut down between work periods or shall be throttled down to a minimum;
- Only well-maintained plants shall be utilised on-site and plants shall be serviced regularly during the entire construction period;
- The number of PMEs shall be reduced as far as practicable when construction works are carried out at areas close to the noise sensitive receivers:
- Silencers or mufflers on construction equipment shall be utilised and shall be properly maintained during the construction programme;
- Behavioural practices including no shouting, no loud stereos/ radios on site, no dropping of materials from height, no throwing of metal items shall be ensured;
- Construction respite: Restrict high noise generating drilling activities only in continuous blocks, not exceeding 3 hours each, with a minimum respite period of one hour between each block, if possible;
- Periodic noise monitoring by an independent third party, to establish compliance with requirements and to advise on equipment causing concern, and additional potential mitigation measures;
- Plan the layout of the site by considering using materials and other large structural equipment as noise barriers;
- Plant known to emit noise strongly in one direction shall, wherever possible, be orientated so that the noise is directed away from the nearby NSRs; and
- Material stockpiles and other structures shall be effectively utilised, wherever practicable, in screening noise from on-site construction activities.
- Acoustic sheds should be provided at the locations of the noise generating activity such as operation of hand-held breaker.
- Construction works at the surface and initial boring to be conducted in the daytime as far as possible.
- For A1-W1 worksite, it is now planned that the location only be used as a pass by and no TBM related works at A1-W1 worksite instead of being a site for TBM launch/ retrieval.
- The optimisation of A1-W2 worksite to be situated away from the Biodiversity Study Area as far as practicable.

11.6.2 Operation Noise

The mechanical ventilation equipment would be designed and sited appropriately during detailed design phase to ensure boundary noise levels are in compliance with the adjusted boundary noise limits derived in Section 11.5.3. Some noise sources might be located close to the boundary and might need special attention for boundary noise limits compliance, and if necessary, would be equipped with additional mitigation measures – to be provided upon assessment of the operation noise.

Minimum controls for the noise emission from the operation of the air-conditioning and mechanical ventilation systems are listed below:

- Use low air-conditioning and mechanical ventilation system equipment;
- Ensure that any exhaust outlet or intake from the mechanical ventilation system is designed to be adequately set back as far as possible from the boundary line of the development;
- Acoustic treatment for equipment to meet noise level limit at site boundary where necessary;
- AC system to be designed with the AHU units placed at appropriate locations as set back from the boundary line of the development as possible; and

  Acoustic enclosures for outdoor equipment.

11.7 Prediction and Evaluation of Airborne Noise Impacts

This section discusses the predicted construction noise impacts and operational noise impacts to the ecologically sensitive receptors from the base scenarios of all the proposed development.

11.7.1 Construction Phase (Base Scenario)

11.7.1.1 Rock Breaking and Excavation- Air Overpressure

Rock breaking and excavation events are proposed at the A1-W1 worksite with the closest Biodiversity Study Area being Windsor, as well as at the A1-W2 worksite with closest Biodiversity Study Area being Eng Neo Avenue Forest,

Site I and Site II. The approximate distance from A1-W1 worksite to the boundary of the receptor is 30m. For the of A1-W2 worksite, the approximate distance from A1-W2 worksite to the nearest boundary of the receptor is 23m.

Based on the approach mentioned in Section 11.2.2.1.1, for Priority 1 receptors the air over pressure for 2.9 kg is 156 dB at 30m distance from A1-W1 worksite. the air over pressure for 2.9 kg is 158 dB at 23m distance from A1-W2 worksite based on formula (2).

Table 11-21 Summary of Prediction and Evaluation of Airborne Noise – Rock Breaking and Excavation Impacts A1-W1 Worksite and A1-W2 Worksite

Horizontal Distance from A1-W1 Worksite, m	Ecologically sensitive Study Area	Receptor Priority	Discharge Mass (Up to)	SPL	Impact Intensity	Impact Consequence	Likelihood	Impact Significance
30	Windsor (Base)	1	2.9kg	156	Medium	Medium	Certain	Major
38		2		153	Medium	Low	Certain	Moderate
111		3		139	Low	Very Low	Certain	Minor
23	Eng Neo Avenue Forest, Sites I and II (Base)	1	2.9kg	158	Medium	Medium	Certain	Major
744		2		115	Negligible	Imperceptible	Certain	Negligible
88		3		142	Medium	Very Low	Certain	Minor

From A1-W1 Worksite, Priority 1 ecologically sensitive receptors will potentially experience medium impact intensity with medium impact consequence. Since the likelihood of rock breaking and excavation works occurring during the entire construction is regarded as **Certain**, the resulting impact significance is **Major.** Priority 2 ecologically sensitive receptors will potentially experience medium impact intensity with low impact consequence and the resulting impact significance is **Moderate.** Priority 3 ecologically sensitive receptors will potentially experience low impact intensity with very low impact consequence and the resulting impact significance is **Minor.**

From A1-W2 Worksite (Base Scenario), Priority 1 ecologically sensitive receptors will potentially experience medium impact intensity with medium impact consequence. Since the likelihood of rock breaking and excavation works occurring during the entire construction is regarded as **Certain**, the resulting impact significance is **Major.** Priority 2 ecologically sensitive receptors will potentially experience negligible impact intensity with imperceptible impact consequence and the resulting impact significance is **Negligible.** Priority 3 ecologically sensitive receptors will potentially experience medium impact intensity with very low impact consequence and the resulting impact significance is **Minor.**

11.7.1.2 Construction Scenarios 1 to 2

Based on the modelled noise levels in Table 11-10, the ecologically sensitive receptors within the Biodiversity Study Area are exposed to a wide range of noise levels from the Project site dependant on the location of the noise sensitive fauna. Hence, the assessment assumes the worst-case noise impact at the boundary of the Biodiversity Study Area fronting the receptive worksites across the scenarios.

The noise impact on ground level (1.5m) will not be same with higher elevation (10-15m) even in same location, and the response from ecological receptors will vary according to the noise levels as well as type of fauna inhabiting or experiencing the levels. It is to be noted that impacts on higher elevation receptors such as bird species are likely able to find alternative habitats in the surroundings for reasons more than just noise, including increased human presence, light, noise and other activities also. Therefore, the predicted noise levels with construction noise impact more on fauna near the ground level up to 1.5m height, hence, the predicted levels at this height were assessed in more details for Scenario 1 and Scenario 2 and is shown in Table 11-22.

Table 11-22 Summary of Construction Noise Impacts

Scenario	Ecologically sensitive Study Area	Receptor Priority	Maximum Noise Level Observed, dB(A)	Impact Intensity	Impact Consequence	Likelihood	Impact Significance
1 - Cut and cover works and associated activities	Eng Neo Avenue Forest	1	76	High	High	Certain	Major
	Site I	1	55	High	High	Certain	Major
	Site II	1	49	Low	Low	Certain	Moderate
	Site I and Site II	2	43	Negligible	Imperceptible	Certain	Negligible
		3	55	High	Low	Certain	Moderate
	Windsor	1	65	High	High	Certain	Major
		2	56	Low	Low	Certain	Moderate
		3	68	High	Low	Certain	Moderate
2 – TBM	Eng Neo Avenue Forest	1	77	High	High	Certain	Major
	Site I	1	49	Low	Low	Certain	Moderate
	Site II	1	46	Negligible	Very Low	Certain	Minor
	Site I and Site II	2	40	Negligible	Imperceptible	Certain	Negligible
		3	52	Negligible	Imperceptible	Certain	Negligible
	Windsor *	1	No Launching/ Retrieval Worksites near Windsor, TBM pass by below ground without causing any airborne noise impact.	Negligible	Very Low	NA	NA
		2		Negligible	Very Low	NA	NA
		3		Negligible	Imperceptible	NA	NA

Note
* No TBM Launching/ Retrieval Worksites near Windsor

Eng Neo Avenue Forest, Site I and Site II

Eng Neo Avenue Forest, Site I and Site II are in close proximity to the A1-W2 worksite. Across the two scenarios, the highest noise level 76 dB(A) was observed during Cut and cover works and associated activities. There was 77dB(A) was observed for ground level receptors during TBM work.

During the Cut and cover works and associated activities, Priority 1 ecologically sensitive habitats at Eng Neo Avenue Forest and Site I will potentially experience high impact intensity with high impact consequence. Since the likelihood occurring during the entire construction is regarded as **Certain**, the resulting impact significance is **Major.** But for Priority 1 ecologically sensitive receptors at Site II will potentially experience low impact intensity and the resulting impact significance is **Moderate.**

Priority 2 ecologically sensitive habitats at Site I and Site II will potentially experience negligible impact intensity and the resulting impact significance is **Negligible.**

Priority 3 ecologically sensitive habitats at Site I and Site II are closer to the worksite than the Priority 2 habitats therefore, it will potentially experience high impact intensity with low impact consequence. since the likelihood occurring during the entire construction is regarded as **Certain**, the resulting impact significance is **Moderate.**

During the TBM Work, Priority 1 ecologically sensitive habitat at Eng Neo Avenue Forest will potentially experience high impact intensity and the resulting impact significance is **Major.** Priority 1 ecologically sensitive receptors at Site I will potentially experience low impact intensity and the resulting impact significance is **Moderate.** Priority 1 ecologically sensitive receptors at Site II will potentially experience negligible impact intensity and the resulting impact significance is **Minor.**

Priority 2 and Priority 3 ecologically sensitive receptors at Site I and Site II will potentially experience negligible impact intensity and the resulting impact significance is **Negligible.**

Windsor

Windsor is in close proximity to the A1-W1 worksites. The noise impact was assessed against with the baseline noise level for the ecological receptors in Windsor. Across the two scenarios, for the ground level receptors, the highest noise level 65 dB(A) was observed) during Cut and cover works and associated activities. TBM worksites was not assessed due to A1-W1 worksite not having such construction work.

It is to be noted that the area which is closed proximity to the northern boundary of A1-W1 worksite is golf course and assumed to be Priority 3 receptors and the area between the southern boundary and the road is not applicable for assessment since that area is infrastructure.

Priority 1 ecologically sensitive receptors will potentially experience high impact intensity with high impact consequence. Since the likelihood occurring during the entire construction is regarded as **Certain**, the resulting impact significance is **Major.** Priority 2 and Priority 3 receptors are resulting impact significance as **Moderate**.

It can be expected that the fauna which are highly mobile are able to move deeper within Windsor, Site I and Site II, away from construction noise.

It is to be noted that impacted bird species are likely able to find alternative habitats in the surroundings. However, impacts were expected in the form of disturbances from noise. Impacts of disturbances to these species are unclear, but noise disturbances may affect its communication with other individuals. This site in particular has large mammals such as slow loris and langurs inhabiting the site which may be impacted for their arboreal activities and group interaction (for langurs). It was therefore likely that during the excavation period these mammals and avian species will tend to move farther away from the site.

Mitigation measures are proposed in Section 11.8 to reduce the noise impact to the ecologically sensitive receptors within the Biodiversity Study Area.

11.7.2 Operational Phase (Base Scenario)

11.7.2.1 Boundary Noise Limits for ACMV in Non-industrial Building

As mentioned in Section 11.2.2.2, an airborne noise study at the boundary of facility buildings will be conducted in a separate study by LTA. The criteria for noise at each location has been provided to the consultant and the noise at boundary is expected to meet the *NEA Technical Guideline on Boundary Noise Limits for Air Conditioning and Mechanical Ventilation Systems in Non-Industrial Buildings, 2018* and or stringent criteria as per the Table 11-23. Given that the design of this building shall be such as to meet the boundary noise requirements as stated in this report, and the design of the building shall be such as it camouflages in the surroundings; the expected noise impact during operational phase will be **negligible**.

Table 11-23 Project Criteria for Operational Noise Impact Assessment

No.	Types of Affected Buildings	$L_{Aeq(15\ min),\ dB}$		
		7am-7pm	7pm-11pm	11pm-7am
Windsor * (N11)	Noise Sensitive Premises such as hospital, home for the aged sick, library, etc.	55	55	52
Notes: *Ecological receptor noise impact to be assessed against the baseline noise level as the noise criterion				

11.7.2.2 Traffic Noise

Traffic noise around the Facility buildings is expected to be low as very rare visit to this building is expected for maintenance purposes only. Since there is no addition of new access roads to these facility buildings and they will be accessible via current existing roads, the routine traffic near Eng Neo Avenue Forest, Site I, Site II, and Windsor was expected to be much higher than the additional traffic for the building's maintenance and therefore the noise from the routine traffic shall dominate the noise levels.

At the time of writing of this report, there was no study carried out for the predicted traffic conditions at this stage near these establishments and the discussion above is based on basic understanding of the area and land use in the vicinity. In absence of specialist traffic study, there was no evaluation conducted from traffic noise in operational noise in this report; however, with current knowledge as above at this stage, the variations can only be speculated as described.

11.8 Recommended Mitigation Measures

11.8.1 Construction Phase

AECOM proposes the following recommendation to reduce the exceedance noise level

11.8.1.1 Elimination/ Avoidance

- A1-W1 weighed a design modification of worksite configuration in base scenario above, and the benefit from the mitigated/ modified scenario is that less biodiversity sensitive areas are impacted in this case due to its reduced footprint.

- It is recommended to shift the A1-W2 worksite away from Eng Neo Avenue Forest as it is currently situated on areas of high conservation value. Furthermore, the shift is recommended to avoid fragmenting the forest into two, resulting in significant impacts to loss of connectivity for both floral and faunal species.

11.8.1.2 Minimisation (Engineering Controls)

- Due to the proximity of sensitive receptors to the construction boundary, mitigation measures for noise control at the source are recommended and where possible for example, silent piling is recommended so that Cut and cover works and associated activitiesrelated noise levels can further be reduced especially for heights in trees for arboreal dwellers.
- For noisy machinery such as the Secant Pile Auger - that typically operates for long period, the soundproof baffles can be mounted directly on the machine around the engine cowling.

The implementation of noise mitigation comes about in two steps:

Step 1: The construction inventory list is analysed to pick up the equipment (PME) causing high noise levels (higher quantity of PME and longer working periods of PME can cause higher noise levels). The use of equipment with lower noise level shall be prioritised, as this is the most effective way to mitigate the noise level at the source;

Step 2: When Step 1 is not applicable or feasible, noise barriers are recommended with details in the sections below. The barrier height and placement position of a noise barrier are the prime factors determining its efficiency. Acoustic specification of the noise barrier shall be determined based on the quantitative noise impact assessment to be conducted at later stage. The following factors are to be accounted for, while erecting a barrier:

- The barrier shall be placed as close as possible to either the source or the receiver position, for maximum effectiveness;
- Materials having noise absorptive properties shall be used for the inner side of the noise barrier (facing the site); and
- It is necessary to bend the barriers around the noise source, to avoid passage of sound around the ends. Typically, the length of the barrier shall be at least ten times the height of the barrier.
- Noise Barrier of minimum STC 20 is proposed to be erected at all the locations presented in Figure 11-5 in order to mitigate the construction noise to the noise sensitive receptors. These locations are:
    - 12 m high noise barrier at the construction boundary of A1-W1 fronting noise sensitive receptors (Windsor),
    - 12m high noise barrier at the construction boundary of A1-W2 worksite fronting noise sensitive receptors (Eng Neo Avenue Forest, Site I and Site II),
    - 12 m high noise barrier at the boundary of underpinning works at Peirce Secondary School fronting noise sensitive receptors,
    - 12 high noise barriers surrounding CR13 retrieval shaft worksite and
    - LTA's standard Full TBM enclosure 15m high at boundary of A1-W2 launch shaft as marked up in the EIS Report.
- At Eng Neo Avenue Forest, Sites I and II, there is an exceedance up to 21dB without noise barrier. AECOM proposes an 12m high noise barrier to be erected at the location presented in Figure 11-5 in order to mitigate the construction noise to the noise sensitive receptors. The 12m high noise barrier is proposed to be placed where A1-W2 launch shaft worksite fronting the human and the Biodiversity Study Area along the Eng Neo Avenue Forest, Sites I and II.
- At Windsor, there is an exceedance of up to 16 dB without noise barrier. AECOM proposes an 12m-high noise barrier to be erected at the location presented in Figure 11 5 in order to mitigate the construction noise to the noise sensitive receptors. The 12m high noise barrier is proposed to be placed where A1-W1 mitigated worksites front the Biodiversity Study Area at Windsor. The exceedance dB in the Base Scenario, Mitigated Scenario and the benefit of noise barrier with 8m, 10m, 12m respectively are shown in Table 11-24.

Table 11-24 Comparison of Noise Level Exceedance (dB)

Receptor Sensitivity	Type	Nearest Noise Logger (Baseline)	Exceedance in $L_{Aeq(5\ min)}$ Criteria (7am - 7pm)				
			Base Scenario	Mitigated Scenario	Mitigated Scenario with Noise Barrier		
					8m	10m	12m
Eng Neo Avenue Forest							
Priority 1	Ecological	N9	16	6	2	1	-
Site I							
Priority 1	Ecological	N9	0	17	5	4	3
Site II							
Priority 1	Ecological	N9	0	16	9	9	9
Windsor							
Priority 1	Ecological	N11	5	4	3	3	-

Step 3: As a last resort in order to manage complaints, or mitigate further if there are intermittent noisy works, Table 11-25 provides information on methods of quietening PME to be adopted as further mitigation. These portable noise enclosures/other modes of source control specified below with reference to standards can then be implemented.

The maximum reduction level in Table 11-25 is achievable when all source control measures stated in this table are adopted. Noise enclosures should be used at the locations of the noise generating equipment at the

construction site. Acoustic sheds should be provided at the locations of the noise generating activity such as operation of hand-held breaker.

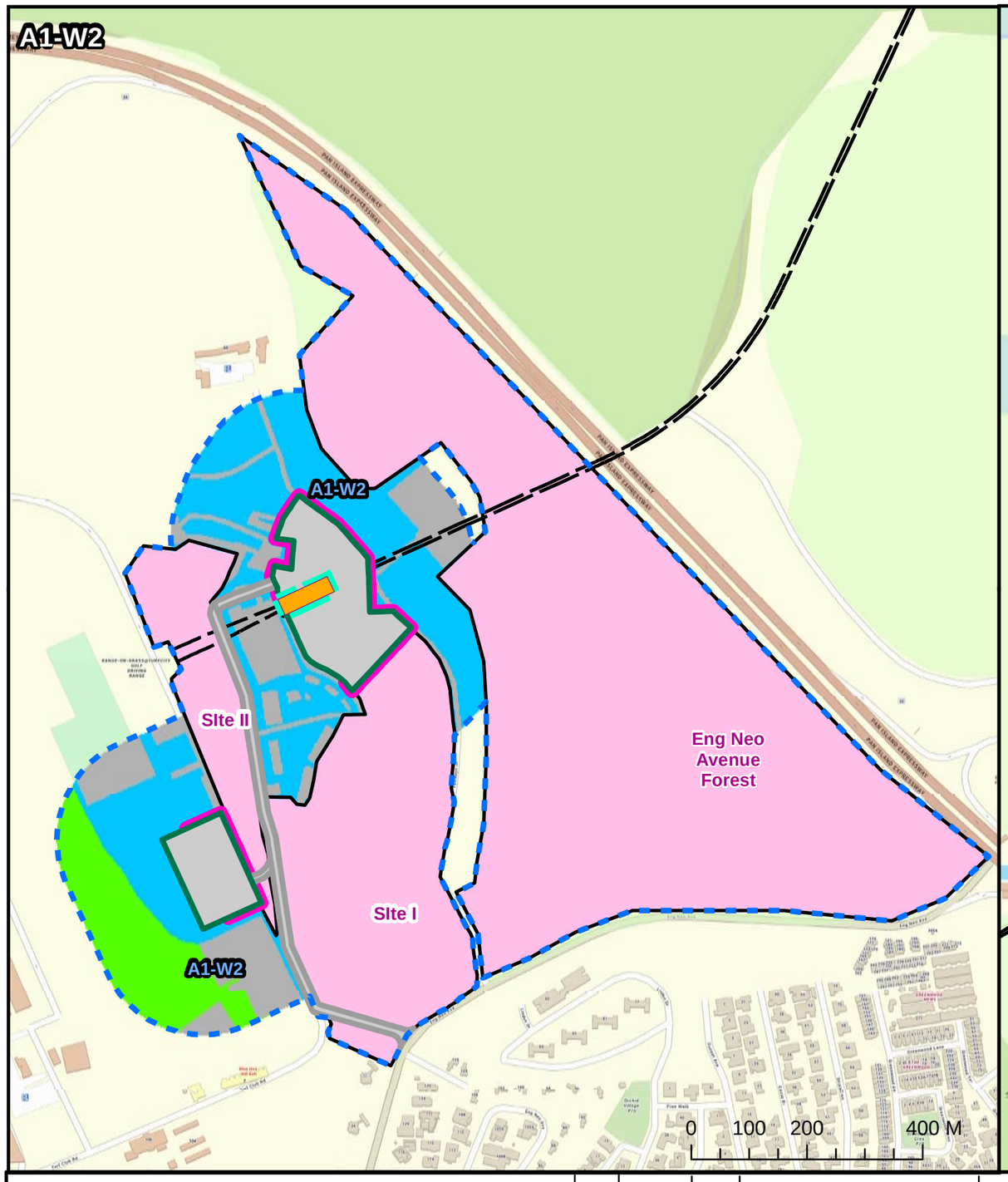
Table 11-25 Control of Noise Source from Construction Site

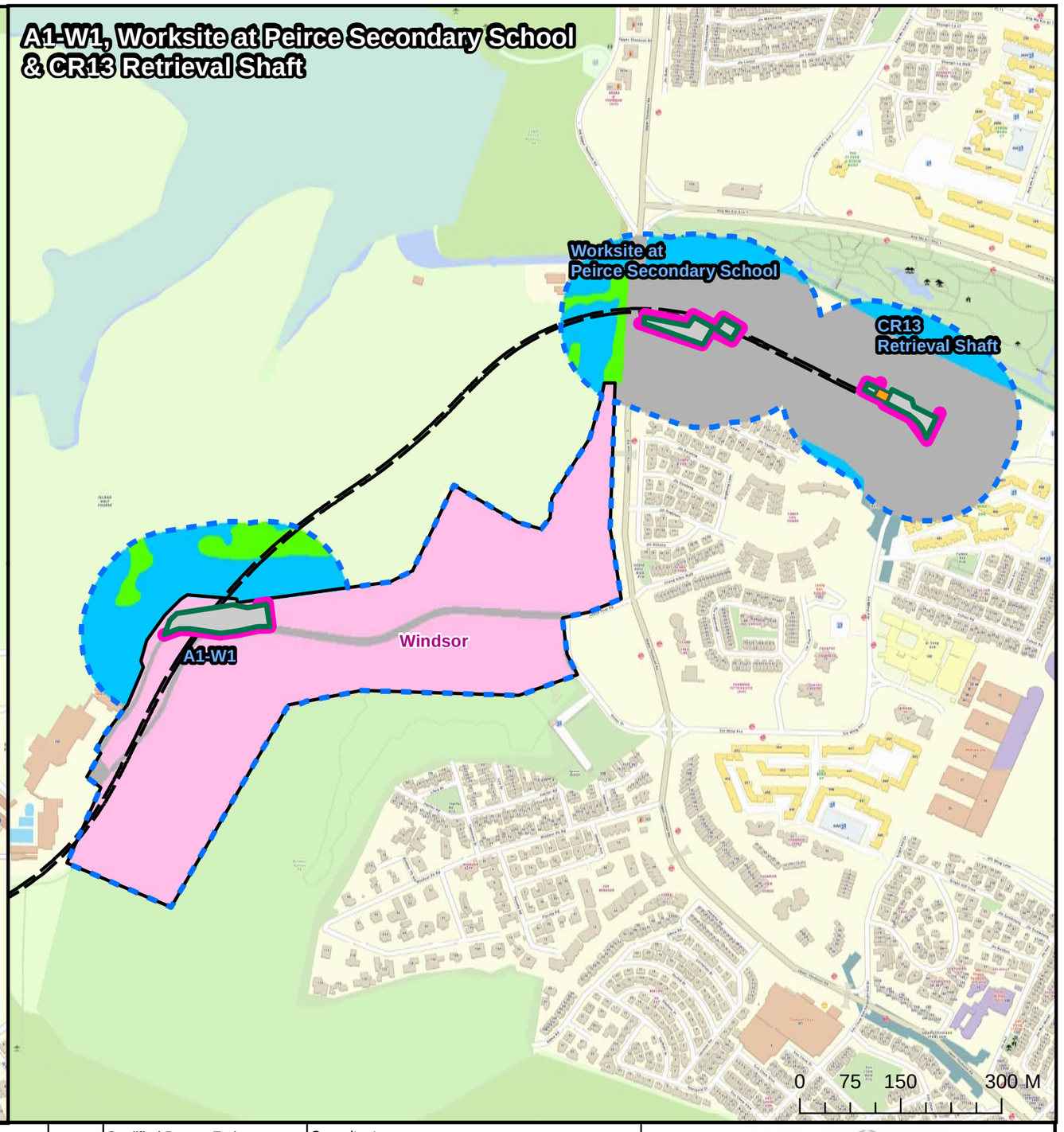
Type of Equipment	Equipment	Reduction Level, dB(A) [1]	Description of Source Control
Compressors & Generators	Generators	-20	Acoustic dampening of metal casing of body shell; acoustic enclosure or screen between the generator and receptor. The acoustic casing for the generator shall be proprietary product supplied by the generator manufacturer. The screen, if used, shall be as close as possible to the generator and it shall be of a solid construction (minimum STC 20 or surface density > 20kg/m^2) with no gaps at the bottom or in-between panels.
Hacking major structures	Excavator with Rock Breaker	-15	Use of an acoustic shed with adequate ventilation for the machine and bit.
Earth-moving Plant	Crane	-10	Manufacturers' enclosure panels to be kept closed. The engines of these vehicles shall not be exposed and clad with the manufacturers' enclosure to reduce noise break-out. Manufacturer-supplied silencers for the engine exhausts shall be installed and maintained.
	Roller	-10	
	Gantry Crane	-10	
	Dump Truck	-10	
	Excavator with Rock Breaker	-10	
	Excavator	-10	
	Concrete Mix Truck	-10	
	Lorry	-10	
	Paver	-10	
Pumps	All Pumps	-10 to -20	Use of acoustic enclosure
Piling Rig	Bore Piling Machine	-10	Acoustic dampening of panels and covers; careful alignment of pile and rig; regular cleaning, oiling and greasing of the rig. The screening shall be as close as possible to the pile-driving and extracting activities and shall be of a solid construction (minimum STC 20 or surface density > 20kg/m^2) with no gaps at the bottom or in-between panels (in the direction of the receiver cutting line-of-sight between the noise source and the receiver, on three sides as a minimum). A micropile (small diameter pile) may be used for smaller construction footprint for impact on biodiversity,

Type of Equipment	Equipment	Reduction Level, dB(A) [1]	Description of Source Control
			however, this aspect does not impact noise assessment significantly.

Note:

[1] The noise reduction level makes reference to BS 5228-1:2009 Code of practice for noise and vibration control on construction and open sites – Part 1: Noise





Legend

- Proposed CRL Alignment (Mitigated)
- Proposed Noise Barrier -12m
- Proposed Noise Barrier - Enclosed Noise Barrier (15m)
- Construction Worksites
- A1-W2 Temporary Access Road
- TBM Worksite
- Noise Study Area
- Biodiversity Study Area

- Not Assessible
- Priority 1
- Priority 2
- Priority 3

Note: Site I and II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	PZ	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
We Keep Your World Moving

Project Title :
**CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)**

Figure Title :
**PROPOSED NOISE BARRIER LOCATION
WITH MITIGATED SCENARIO**

Designed	Checked	Approved
PZ	JAG	JAG
	Drawn: PZ	Date: MAR 2022

Figure No. : 11-5 | Rev. : - | Sheet : 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap

Based on the *Singapore Standards Code of Practice for Noise Control at Construction Sites, 2014 (SS602:2014)*, the typical materials used for noise barriers and acoustic shed/enclosures are given below:

Acoustic Shed / Enclosure:

A typical machine acoustic enclosure covers the machine as fully as possible (with/without ventilation), providing adequate sound insulation that noise energy does not readily pass through it. In addition, it could also have a sound absorbing material lining, to avoid the build-up of sound energy inside. In general, an acoustic enclosure could include:

- Outer cover material made up of brickwork, fibreboard, or plasterboard. Thickness of the insulating cover depends on the material used;
- Inner lining of sound absorbing material such as glass fibre, mineral wool, straw slabs, wood wool slabs can be used. A thickness of at least 25mm is to be provided in case of high frequency sound, whereas a 12mm thick lining would suffice for low frequency sound; and
- Perforated sheet coverings can be used to protect the inner lining material, especially if it is glass wool or mineral wool-based lining.

In the case of a more permanent or substantial machine enclosure or acoustic shed, concrete breezeblock and open textured blockwork can be more effective alternatives as these are known to be durable, inexpensive, and quick to assemble, and provide a useful degree of sound absorption.

Temporary Water Barrier:

Additionally, in anticipation for high-noise events relating to rock breaking and excavation that may result in a flight-response from fauna species (e.g., wild boars) resulting in potentially road deaths, the Contractor must erect a temporary water barrier on both sides of Island Club Road (with total length of 500m and above 1m in height). Refer to Section 12.8.1 for more details regarding the implementation and placement of water barriers..

11.8.1.3 Administrative Controls

The following administrative control measures shall be observed during the construction stage to further reduce the noise levels:

- Although most of the construction activities will generate high noise level, but the birds will move out and displace to locations away from worksite eventually when noise levels are too high. Hence, only suggest to avoid site clearance during peak breeding season;
- Machines (such as trucks) that may be in intermittent use shall be shut down between work periods or shall be throttled down to a minimum;
- Only well-maintained plants shall be utilised on-site and plants shall be serviced regularly during the entire construction period;
- The number of PMEs shall be reduced as far as practicable when construction works are carried out at areas close to the noise sensitive receivers;
- Silencers or mufflers on construction equipment shall be utilised and shall be properly maintained during the construction programme;
- Behavioural practices including no shouting, no loud stereos/ radios on site, no dropping of materials from height, no throwing of metal items shall be ensured;
- Construction respite: Restrict high noise generating drilling activities only in continuous blocks, not exceeding 3 hours each, with a minimum respite period of one hour between each block, if possible;
- Periodic noise monitoring by an independent third party, to establish compliance with requirements and to advise on equipment causing concern, and additional potential mitigation measures;
- Plan the layout of the site by considering using materials and other large structural equipment as noise barriers;
- Plant known to emit noise strongly in one direction shall, wherever possible, be orientated so that the noise is directed away from the nearby noise sensitive receptors;
- Material stockpiles and other structures shall be effectively utilised, wherever practicable, in screening noise from on-site construction activities;

- All handheld percussive breakers and air compressors used on site shall comply with local legislation and LTA requirements;
- Activities may be scheduled to minimise noise generated at certain areas during periods which may be particularly sensitive to noise;
- Works using machines or vehicles that generate noise should be prohibited in the night and the dawn and no night works after 7pm for all non-safety critical activities since the site is next to the Biodiversity Study Area;
- Appropriate hearing protectors shall be used by personnel operation the plant or equipment, the hearing protector must attenuate the exposure of the user to sound pressure levels below 85 dB (A). Signage to remind personnel to put on hearing protection will be put up at work areas that emit excessive noise. Choice of hearing protector includes such as ear plugs (for < 100 dB (A)), earmuffs (for 100 dB (A) to 120 dB (A), ear plugs and earmuffs (for > 120 dB (A)) in various noise exposure level;
- Noise awareness briefing shall be conducted regularly and highlighted the noise mitigation measures such as position of machinery, making use of portable noise barriers and dos and don'ts for use of machinery at night;
- During high-noise events such as rock breaking and excavation, ecologists are to be onsite for at least the first seven rock breaking and excavation events and during the test runs in anticipation for fauna response (e.g., flee response behaviour). The ecologist is to monitor for any fauna behaviour (e.g., dashing onto road) resulting in roadkill incidents for at least 30 minutes after each rock breaking event. In addition, during rock breaking and excavation events, there shall be ecologists present to observe fauna movements, and the appointed Contractor should take note to restrict the entry of visitors into the trails of Windsor (Refer to Section 12.8.1);
- Above-ground works not critical for safety reasons to be restricted to weekdays (avoiding works on Sunday and Public holidays); and
- Works will be halted immediately and mitigation measures adjusted to prevent future occurrence of roadkill incidents upon any observed signs of fauna seen trying to dash onto the road.

In addition to the above measures, an EMMP for noise has been prepared, for management of potential impacts from noise during construction phase. Details of the same are provided in **Section 13**.

11.8.2 Operational Phase

11.8.2.1 Minimum Controls for ACMV Noise

Minimum Controls below should be applied at the detailed design stage of the development by the appointed M&E consultants. An appointed Noise consultant should validate the noise in accordance with *NEA's Technical Guideline on Boundary Noise Limits for Air Conditioning and Mechanical Ventilation Systems in Non-Industrial Building*. In addition, mitigation measures will be provided by the appointed Noise Consultants during the detailed design stage.

- Use low air-conditioning and mechanical ventilation system equipment;
- Ensure that any exhaust outlet or intake from the mechanical ventilation system is designed to be adequately set back as far as possible from the boundary line of the development;
- Acoustic treatment for equipment to meet noise level limit at site boundary where necessary;
- AC system to be designed with the AHU units placed at appropriate locations as set back from the boundary line of the development as possible; and
- Acoustic enclosures for outdoor equipment.

11.8.2.2 Minimum Controls for Traffic Noise

Due to the lack of information at this juncture of reporting, assessment, minimum controls and mitigation will be provided by the appointed Noise Consultant during the detailed design stage and in accordance with *Technical Guideline for Land Traffic Noise Impact Assessment* [R-53].

11.9 Residual Impacts (Mitigated Scenario)

11.9.1 Rock Breaking and Excavation Air Overpressure

Rock breaking and excavation events are proposed at the A1-W1 worksite with the closest Biodiversity Study Area being Windsor, as well as at the A1-W2 worksite with closest Biodiversity Study Area being Eng Neo Avenue Forest, Site I and Site II. The approximate distance from A1-W1 worksite to the boundary of the receptor is 30m. For the of A1-W2 worksite, the approximate distance from A1-W2 worksite to the nearest boundary of the receptor is 37m for Mitigated Scenario.

Based on the approach mentioned in Section 11.2.2.1.1, for Priority 1 receptors the air over pressure for 2.9kg is 156 dB at 30m distance from A1-W2 worksite. the air over pressure for 0.6 kg is 133 dB at 104m distance at A1-W2 (Mitigated) worksite based on formula (2).

Table 11-26 Summary of Prediction and Evaluation of Airborne Noise – Rock Breaking and Excavation Impacts A1-W1 Worksite and A1-W2 Worksite

Horizontal Distance from A1-W1 Worksite, m	Ecologically sensitive Study Area	Receptor Priority	Discharge Mass (Up to)	SPL	Impact Intensity	Impact Consequence	Likelihood	Impact Significance
30	Windsor (Mitigated)	1	2.9kg	156	Medium	Medium	Certain	Moderate*
38		2		153	Medium	Low	Certain	Moderate
111		3		139	Low	Very Low	Certain	Minor
104	Eng Neo Avenue Forest, Sites I and II (Mitigated)	1	0.6kg	133	Low	Low	Certain	Moderate
397		2		116	Negligible	Imperceptible	Certain	Negligible
37		3		146	Low	Very Low	Certain	Minor
Note: * This measure reduces the impact significance, resulting in Minor – Moderate at Windsor after applying the mitigation measures refer to Section 12.8.								

From A1-W1 Worksite for Mitigated scenario, Priority 1 ecologically sensitive habitat will potentially experience medium impact intensity with medium impact consequence. Since the likelihood of rock breaking and excavation works occurring during the entire construction is regarded as **Certain**, the resulting impact significance is **Moderate.** Priority 2 ecologically sensitive habitats which include low value habitats will potentially experience medium impact intensity with low impact consequence and the resulting impact significance is **Moderate.** Priority 3 ecologically sensitive receptors which are degraded habitats, will potentially experience low impact intensity with very low impact consequence and the resulting impact significance is **Minor.**

From A1-W2 Worksite (Mitigated Scenario), Priority 1 ecologically sensitive habitat will potentially experience low impact intensity with low impact consequence. Since the likelihood of rock breaking and excavation works occurring during the entire construction is regarded as **Certain**, the resulting impact significance is **Moderate.** Priority 2 ecologically sensitive habitat will potentially experience negligible impact intensity with imperceptible impact consequence and the resulting impact significance is **Negligible.** Priority 3 ecologically sensitive habitat will potentially experience medium impact intensity with very low impact consequence and the resulting impact significance is **Minor.**

11.9.2 Construction Scenarios 1 to 2

Residual Construction Impact Assessment assumes that the mitigation measures within Section 11.8 are implemented in the construction areas. Based on the residual airborne construction noise prediction, the area of "Major" impact significance is expected to be reduced significantly during post-mitigated scenarios than base scenario. The residual construction noise impact for post-mitigated scenario is shown in Table 11-27.

Since the likelihood of the assessment was based on the work period and active noise period for machinery. The likelihood evaluation of Scenario 1- Cut and cover works and associated activities of optimised A1-W2 and A1-W1

(refer to Table 11-27) became Regular due to the work period reduce from 24 hr (Base Scenario) to 12 hr (7am-7pm) in the Mitigated Scenario of A1-W2 and A1-W1 worksites.

Table 11-27 Summary of Residual Construction Noise Impacts

Scenario	Ecologically sensitive Study Area	Receptor Priority	Maximum Noise Level Observed, dB(A)	Impact Intensity	Impact Consequence	Likelihood	Impact Significance
1 - Cut and cover works and associated activities	Eng Neo Avenue Forest	1	52	Negligible	Very Low	Regular	Minor
	Site I	1	67	High	High	Regular	Major
	Site II	1	58	High	High	Regular	Major
	Site I and Site II	2	58	Medium	Low	Regular	Moderate
		3	73	High	Low	Regular	Moderate
	Windsor	1	58	Low	Low	Regular	Moderate
		2	58	Low	Very Low	Regular	Minor
		3	70	High	Low	Regular	Moderate
2 – TBM	Eng Neo Avenue Forest	1	52	Negligible	Very Low	Certain	Minor
	Site I	1	42	Negligible	Very Low	Certain	Minor
	Site II	1	45	Low	Low	Certain	Moderate
	Site I and Site II	2	43	Negligible	Imperceptible	Certain	Negligible
		3	54	High	Low	Certain	Moderate
	Windsor *	1	No Launching/ Retrieval Worksites near Windsor, TBM pass by below ground without causing any airborne noise impact.	Negligible	Very Low	NA	NA
		2		Negligible	Very Low	NA	NA
		3		Negligible	Imperceptible	NA	NA

Note
* No TBM Launching/ Retrieval Worksites near Windsor

Eng Neo Avenue Forest, Site I and Site II

During the Cut and cover works and associated activities based on the residual airborne construction noise prediction above, Priority 1 ecologically sensitive habitat at Eng Neo Avenue Forest will potentially experience negligible impact intensity with very low impact consequence. Since the likelihood occurring during the entire construction is regarded as Regular, the resulting impact significance is **Minor**. But for Priority 1 ecologically sensitive receptors at Site I and Site II will potentially experience high impact intensity and the resulting impact significance is **Major**.

Priority 2 and Priority 3 ecologically sensitive habitat at Site I and Site II will potentially experience medium and high impact intensity respectively and the resulting impact significance is **Moderate**.

During the TBM Work, Priority 1 ecologically sensitive habitat at Eng Neo Avenue Forest and Site I will potentially experience negligible impact intensity and the resulting impact significance is **Minor**. Priority 1 ecologically sensitive receptors at Site II will potentially experience low impact intensity and the resulting impact significance is **Moderate**.

Priority 2 ecologically sensitive habitat at Site I and Site II will potentially experience negligible and the resulting impact significance is **Negligible**.

Priority 3 ecologically sensitive habitat at Site I and Site II will potentially experience high impact intensity and the resulting impact significance is **Moderate**.

Windsor

Based on the residual airborne construction noise prediction above, the highest noise level 58 dB(A) at Priority 1 ecologically sensitive receptors was observed during Cut and cover works and associated activities. TBM worksites was not assessed due to A1-W1 worksite not having such construction work.

Priority 1 ecologically sensitive habitat will potentially experience low impact intensity with low impact consequence since the likelihood occurring during the entire construction is regarded as **Regula**r, the resulting impact significance is **Moderate** for Scenario 1 Cut and cover works and associated activities.

Priority 2 ecologically sensitive habitat will potentially experience low impact intensity with very low impact consequence. since the likelihood occurring during the entire construction is regarded as **Regula**r, the resulting impact significance is **Minor** for Scenario 1 Cut and cover works and associated activities**.** Priority 3 receptors will potentially experience high impact intensity and the resulting impact significance as **Moderate**

It is to be noted that the area which is closed proximity to the northern boundary of A1-W1 worksite is golf course and assumed to be Priority 3 receptors and the impact between the southern boundary and the road is not applicable for assessment.

A summary of construction noise impact at ground level for both Base Scenario and Post Mitigated Scenario are shown in Table 11-28 and the $L_{Aeq(12\ hours)}$ and $L_{Aeq(5\ mins)}$ airborne noise contours with impact significance (1.5m high) are shown in Figure 11-6 to Figure 11-15 for Scenario 1, and Figure 11-16 to Figure 11-20 for Scenario 2 respectively.

Table 11-28 Summary of Construction Noise Impacts (Base and Post Mitigated Scenario Evaluation)

Scenario	Ecologically sensitive Study Area	Receptor Priority	Base Scenario Evaluation					Post Mitigated Evaluation				
			Maximum Noise Level Observed, dB(A)	Impact Intensity	Impact Consequence	Likelihood	Impact Significance	Maximum Noise Level Observed, dB(A)	Impact Intensity	Impact Consequence	Likelihood	Impact Significance
1 - Cut and cover works and associated activities	Eng Neo Avenue Forest	1	76	High	High	Certain	Major	52	Negligible	Very Low	Regular	Minor
	Site I	1	55	High	High	Certain	Major	67	High	High	Regular	Major
	Site II	1	49	Low	Low	Certain	Moderate	58	High	High	Regular	Major
	Site I and Site II	2	43	Negligible	Imperceptible	Certain	Negligible	58	Medium	Low	Regular	Moderate
		3	55	High	Low	Certain	Moderate	73	High	Low	Regular	Moderate
	Windsor	1	65	High	High	Certain	Major	58	Low	Low	Regular	Moderate
		2	56	Low	Low	Certain	Moderate	58	Low	Very Low	Regular	Minor
		3	68	High	Low	Certain	Moderate	70	High	Low	Regular	Moderate
2 – TBM	Eng Neo Avenue Forest	1	77	High	High	Certain	Major	52	Negligible	Very Low	Certain	Minor
	Site I	1	49	Low	Low	Certain	Moderate	42	Negligible	Very Low	Certain	Minor
	Site II	1	46	Negligible	Very Low	Certain	Minor	45	Low	Low	Certain	Moderate
	Site I and Site II	2	40	Negligible	Imperceptible	Certain	Negligible	43	Negligible	Imperceptible	Certain	Negligible
		3	52	Negligible	Imperceptible	Certain	Negligible	54	High	Low	Certain	Moderate
	Windsor *	1	NA	Negligible	Very Low	NA	NA	NA	Negligible	Very Low	NA	NA
		2		Negligible	Very Low	NA	NA		Negligible	Very Low	NA	NA
		3		Negligible	Imperceptible	NA	NA		Negligible	Imperceptible	NA	NA

Note
*No TBM Launching/ Retrieval Worksites near Windsor

Based on the residual airborne noise impact assessment above, the proposed 12m noise barrier at A1-W1 worksite will be beneficial by reducing impact significance from Major (base scenario) to Moderate (post mitigated scenario) at Windsor.

For the Priority 1 receptors at the Eng Neo Avenue Forest, impact significance reduces to Minor from base scenario-Major impact significance for both scenarios. But at Site II impact significance became Major due to the A1-W2 worksite which is closed to the boundary of Priority 1 receptors during Cut and cover works and associated activities.

In any case, the receptors which are at height immediately next to construction site are likely to have a straight line of sight despite a noise barrier, therefore the benefit of barrier is unlikely to occur for the avian and arboreal species at height. It can be expected that the fauna which are highly mobile are able to move away from construction and it may not be possible to render further mitigation of impacts for their benefit; other than shortening the timespan of noisy construction activities, source selection of low noise machines, and administrative best practice measures. The resulting impact significance for the respective Biodiversity Study Area are shown below:

Base Scenario (Priority 1 receptors)

- Eng Neo Avenue Forest: **Major**
- Site I: **Moderate** to **Major**
- Site II: **Minor** to **Moderate**
- Windsor: **Major**

Post Mitigated Scenario (Priority 1 receptors)

- Eng Neo Avenue Forest: **Minor**
- Site I: **Minor** to **Major**
- Site II: **Moderate** to **Major**
- Windsor: **Moderate**

Base Scenario (Priority 2 and 3 receptors)

- Site I and Site II: **Negligible** to **Moderate**
- Windsor: **Moderate**

Post Mitigated Scenario (Priority 2 and 3 receptors)

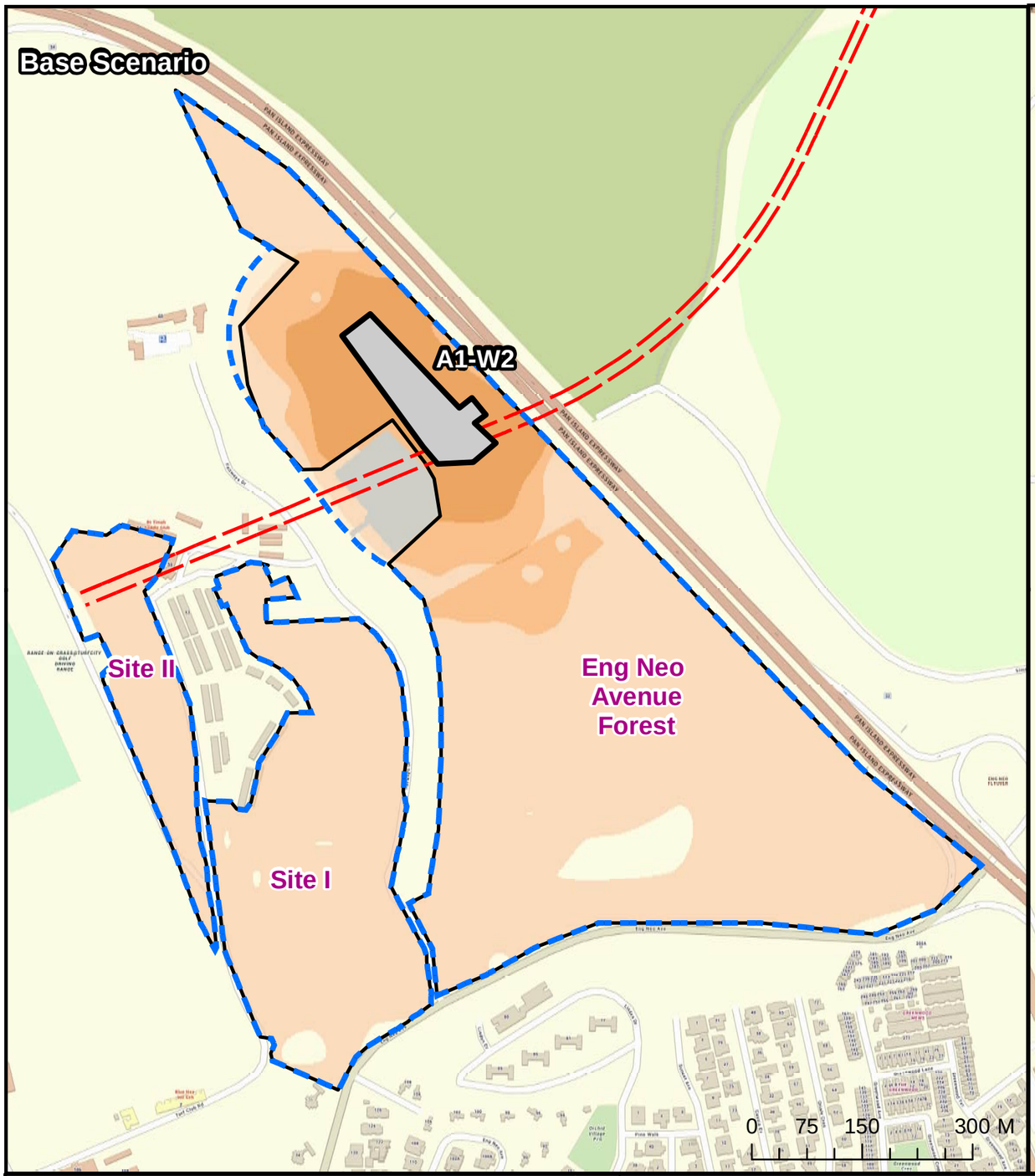
- Site I and Site II: **Negligible** to **Moderate**
- Windsor: **Minor** to **Moderate**

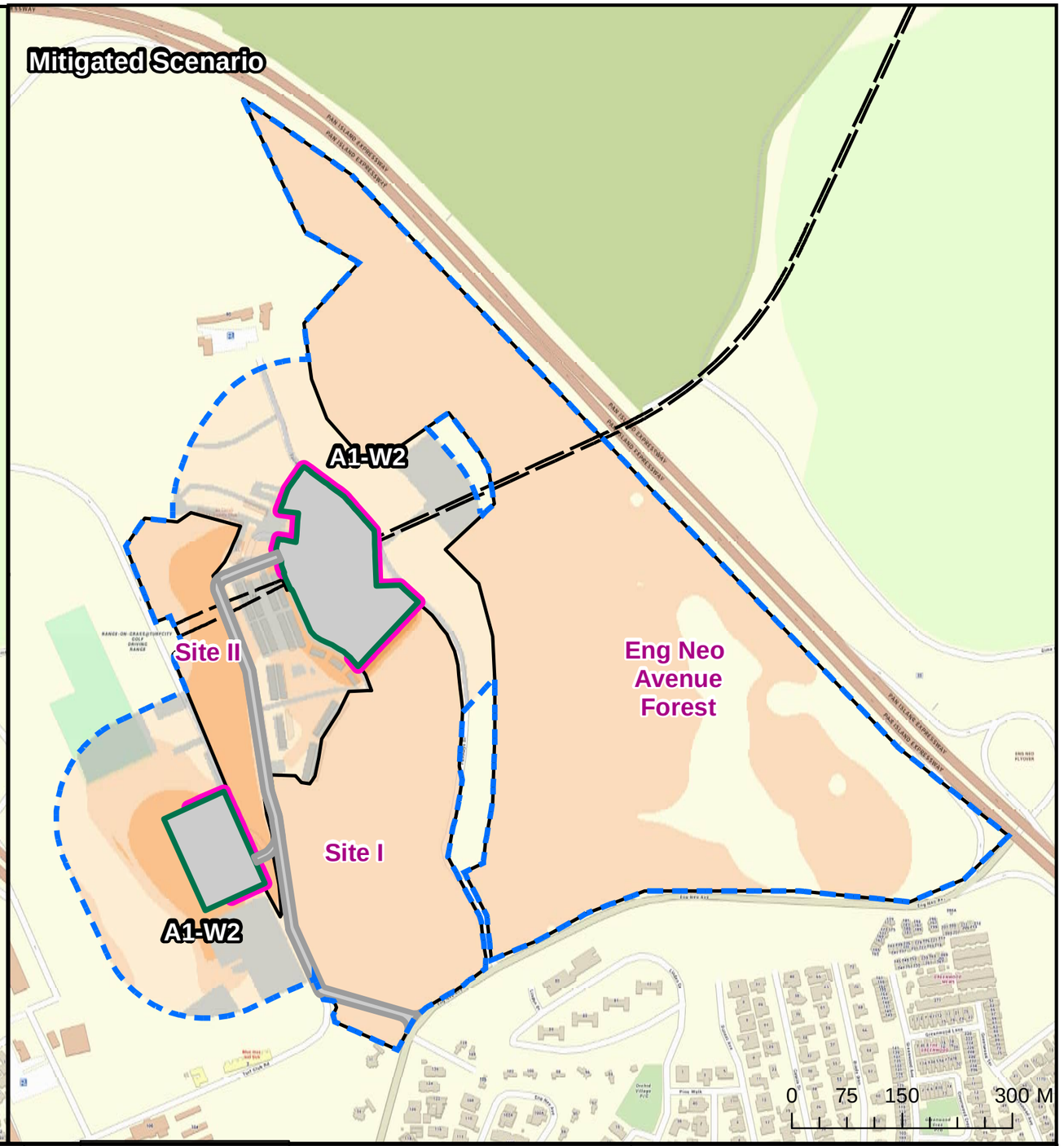
The $L_{Aeq(12\ hours)}$ and $L_{Aeq(5\ mins)}$ airborne noise contours (1.5m high) are shown in Figure 11-6 to Figure 11-15 for Scenario 1, and Figure 11-16 to Figure 11-20 for Scenario 2 respectively. The area of “Major” impact significance are expected to be reduced significantly and can be seen obviously in the figures.

It is to be noted that sound power level of utility diversion works along Island Club Road at A1-W1 worksite (see Figure 3-15) is much lower than worst-case (shown in Table 11-10), which was not modelled under this assessment. If there are any complaints regarding the noise impact arising from the Project worksites, PRO shall engage with ECO to resolve this issue.

It is to be noted that the road work construction of the A1-W2 worksite was also modelled separately under this assessment. Since its construction footprint is very close to the ecological receptors at Site I and Site II, predicted noise level is expected to be up to 22 dB(A) exceedance than criteria with major impact significance. However, non-safety critical works during road construction should only be restricted in the day, and road construction be carried out for short lengths at a time, and for a short period of time. Erecting high barriers for road construction can be more intrusive to the habitat due to short duration of actual road construction, therefore during this phase, portable noise barrier are highly recommended close to the noisy equipment/ activities and no night works after 7pm for all non-safety critical activities since the site is next to the sensitive receptors.. If there are any complaints regarding the noise impact arising from the Project worksites, PRO shall engage with ECO to resolve this issue.

Since the expected noise impact during the operational phase will be negligible (refer to section 11.7.2.1), no residual impact was evaluated for operational phase.





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Proposed Noise Barrier -12m
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- A1-W2 Temporary Access Road
- Noise Study Area
- Biodiversity Study Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

Note: Site I and II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	PZ	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
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Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
SCENARIO 1
TYPICAL CONSTRUCTION WORKS LEQ (12 HOURS) (7AM - 7PM)
A1-W2 WORKSITE AT 1.5M HEIGHT

Designed	Checked	Approved
PZ	JAG	JAG
	Drawn: PZ	Date: MAR 2022

Figure No. : 11-6 | Rev. : - | Sheet : 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap

Base Scenario

A1-W2

Site II

Eng Neo Avenue Forest

Site I

0 75 150 300 M

Mitigated Scenario

A1-W2

Site II

Eng Neo Avenue Forest

Site I

A1-W2

0 75 150 300 M

Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Proposed Noise Barrier -12m
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- A1-W2 Temporary Access Road
- Noise Study Area
- Biodiversity Study Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

Note: Site I and II: Forested area adjacent to Fairways Quarters

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Figure Title :
SCENARIO 1
TYPICAL CONSTRUCTION WORKS
LEQ (12 HOURS) (7PM - 7AM)
A1-W2 WORKSITE
AT 1.5M HEIGHT

Designed	Checked	Approved
PZ	JAG	JAG
	Drawn: PZ	Date: MAR 2022

Figure No. : 11-7 | Rev. : - | Sheet : 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap

Base Scenario

A1-W2

Site II

Site I

Eng Neo Avenue Forest

0 75 150 300 M

Mitigated Scenario

A1-W2

Site II

Site I

A1-W2

Eng Neo Avenue Forest

0 75 150 300 M

Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Proposed Noise Barrier -12m
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- A1-W2 Temporary Access Road
- Noise Study Area
- Biodiversity Study Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

Note: Site I and II: Forested area adjacent to Fairways Quarters

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LTA Endorsement :
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Consultant : AECOM

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Project Title :
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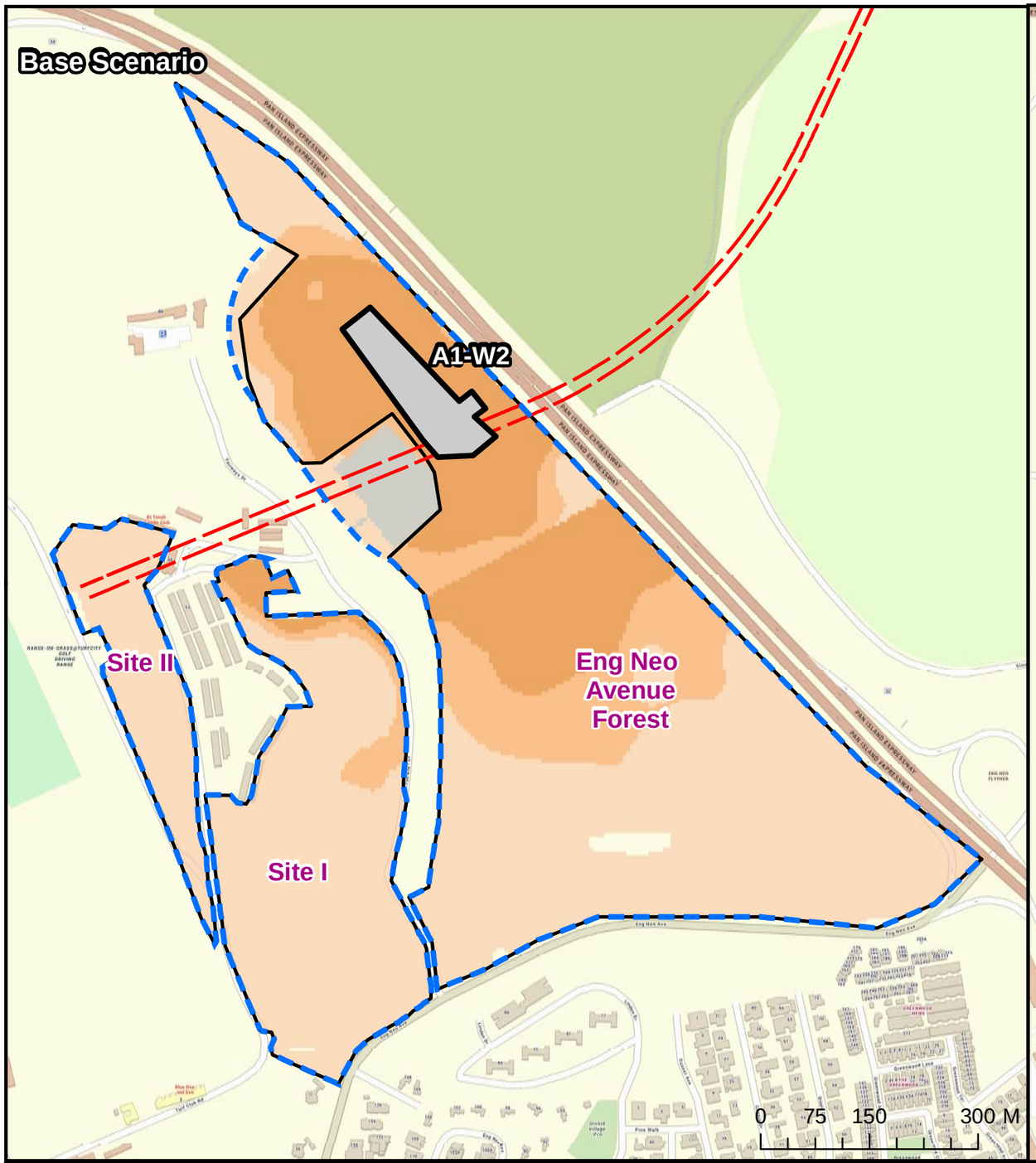
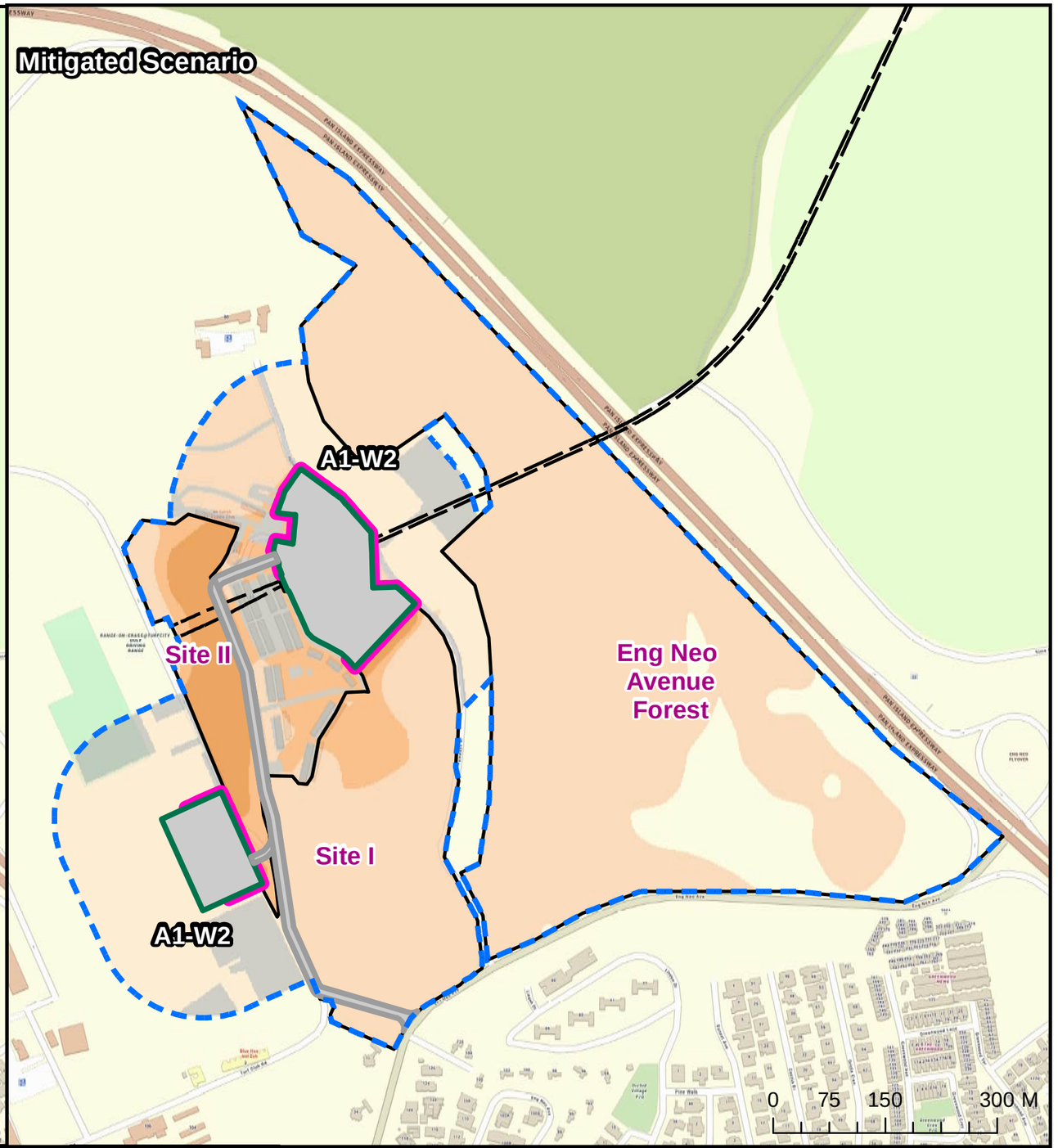
Figure Title :
SCENARIO 1 TYPICAL CONSTRUCTION WORKS LEQ (5 MINS) (7AM - 7PM) A1-W2 WORKSITE AT 1.5M HEIGHT

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
PZ	JAG	JAG	11-8	-	1 of 1
	Drawn PZ	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Proposed Noise Barrier -12m
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- A1-W2 Temporary Access Road
- Noise Study Area
- Biodiversity Study Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

Note: Site I and II: Forested area adjacent to Fairways Quarters

N

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-	MAR 2022	PZ	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
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LTA Endorsement :
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Consultant : AECOM

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Project Title :
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ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)**

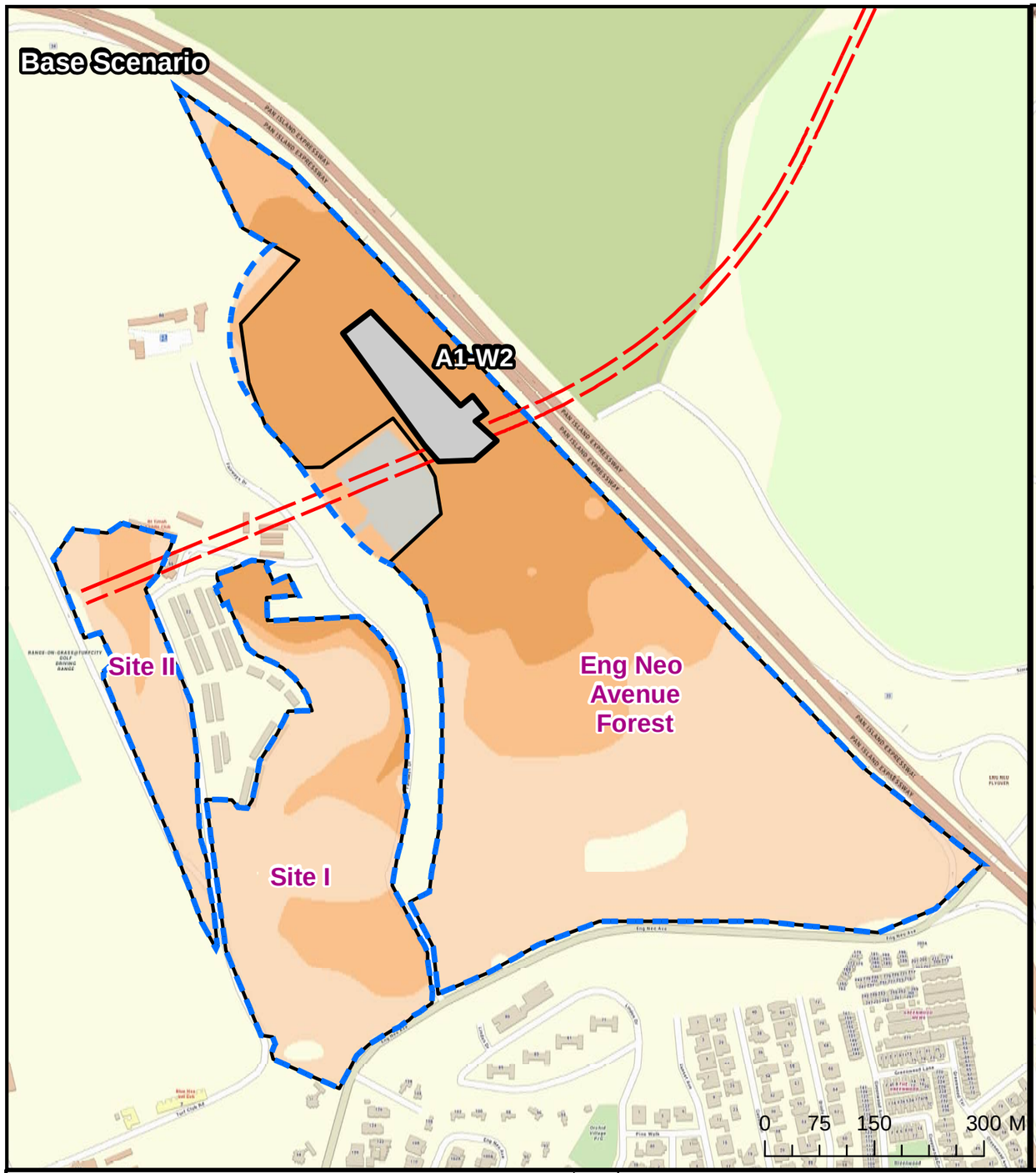
Figure Title :
**SCENARIO 1
TYPICAL CONSTRUCTION WORKS
LEQ (5 MINS) (7PM - 10PM)
A1-W2 WORKSITE
AT 1.5M HEIGHT**

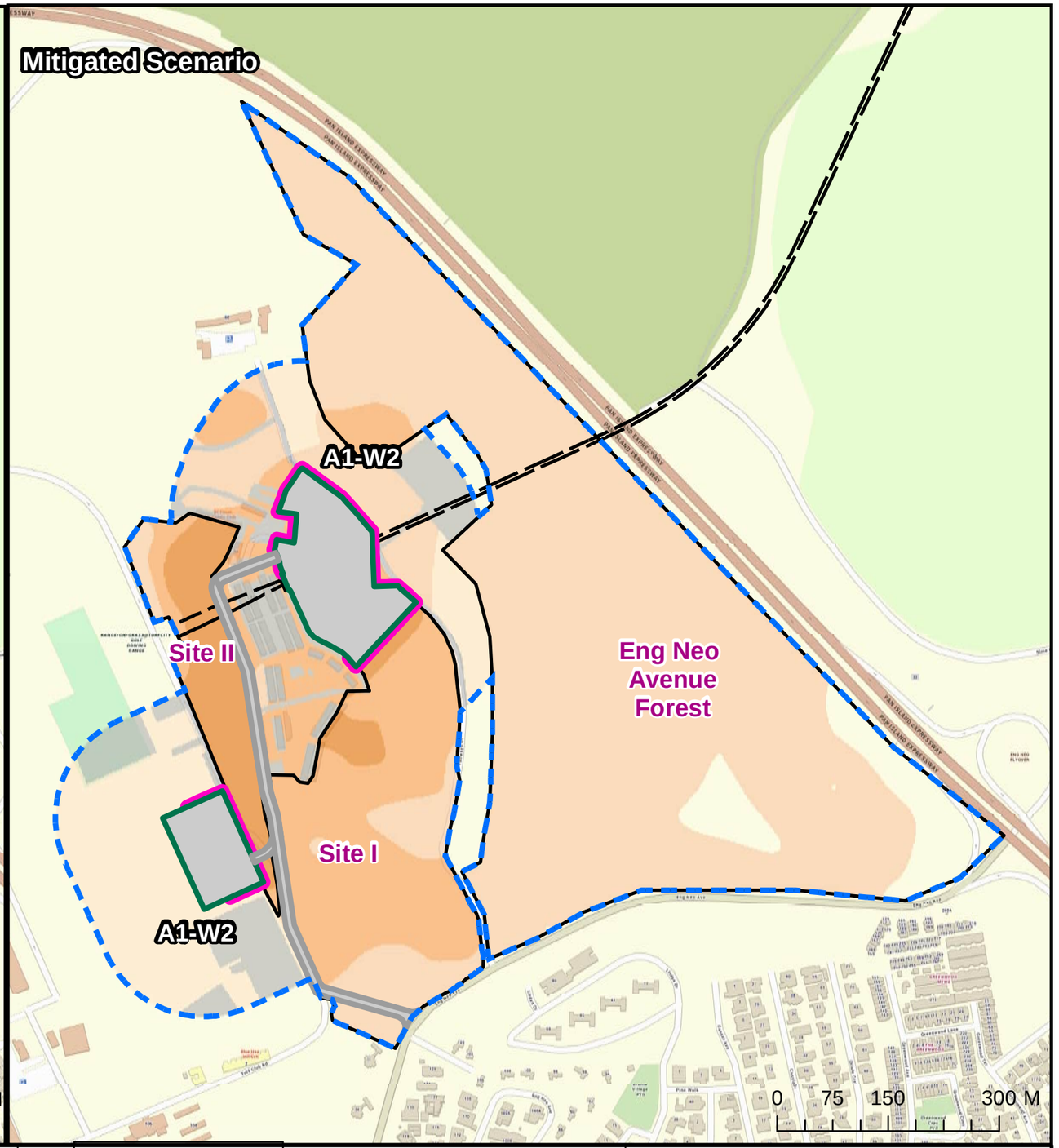
Designed	Checked	Approved
PZ	JAG	JAG
	Drawn PZ	Date MAR 2022

Figure No. :	Rev.	Sheet
11-9	-	1 of 1

CAD File Name : NA — A3

Note: Source of basemap - OneMap





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Proposed Noise Barrier -12m
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- A1-W2 Temporary Access Road
- Noise Study Area
- Biodiversity Study Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

Note: Site I and II: Forested area adjacent to Fairways Quarters

N

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Project Title :
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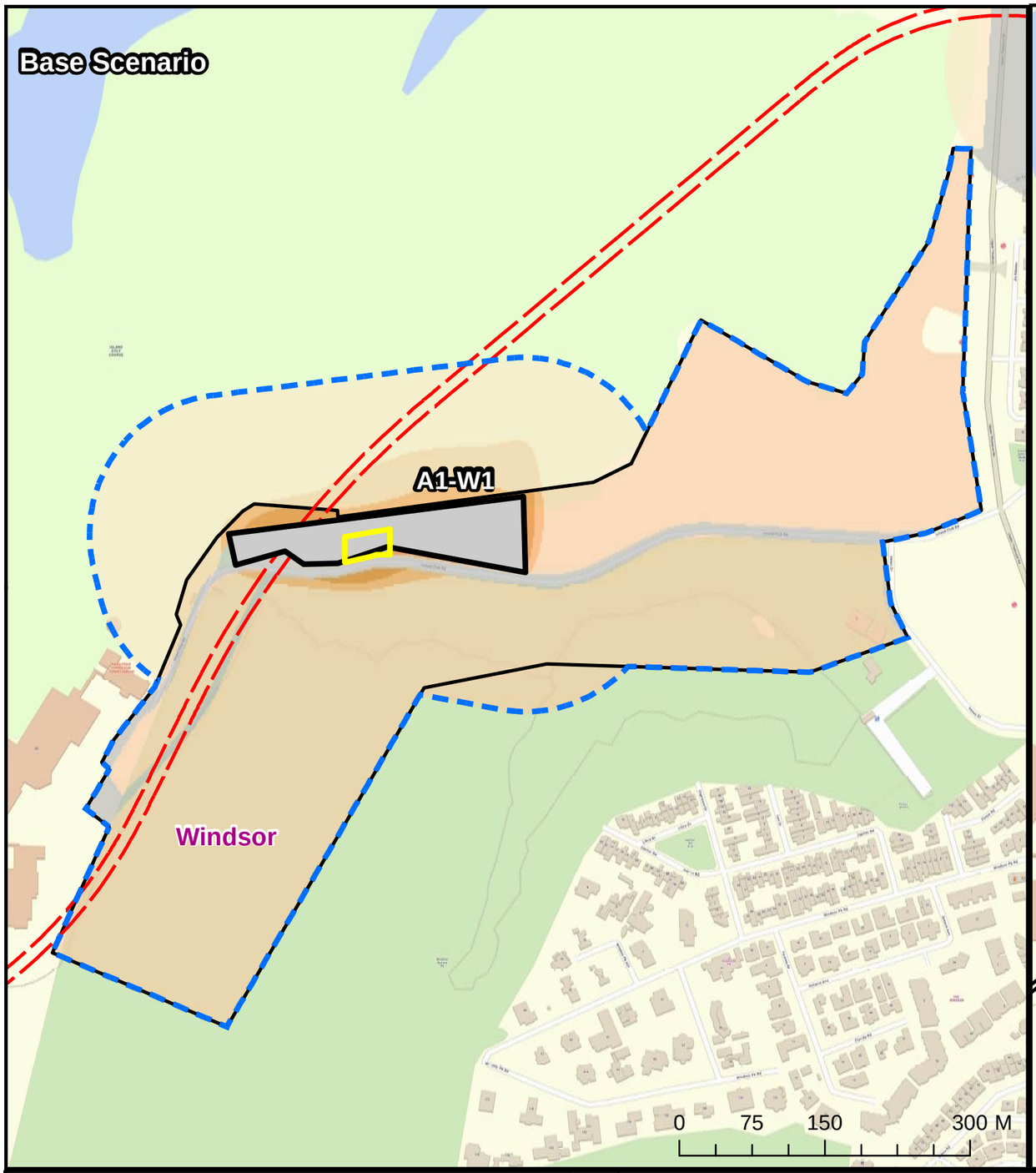
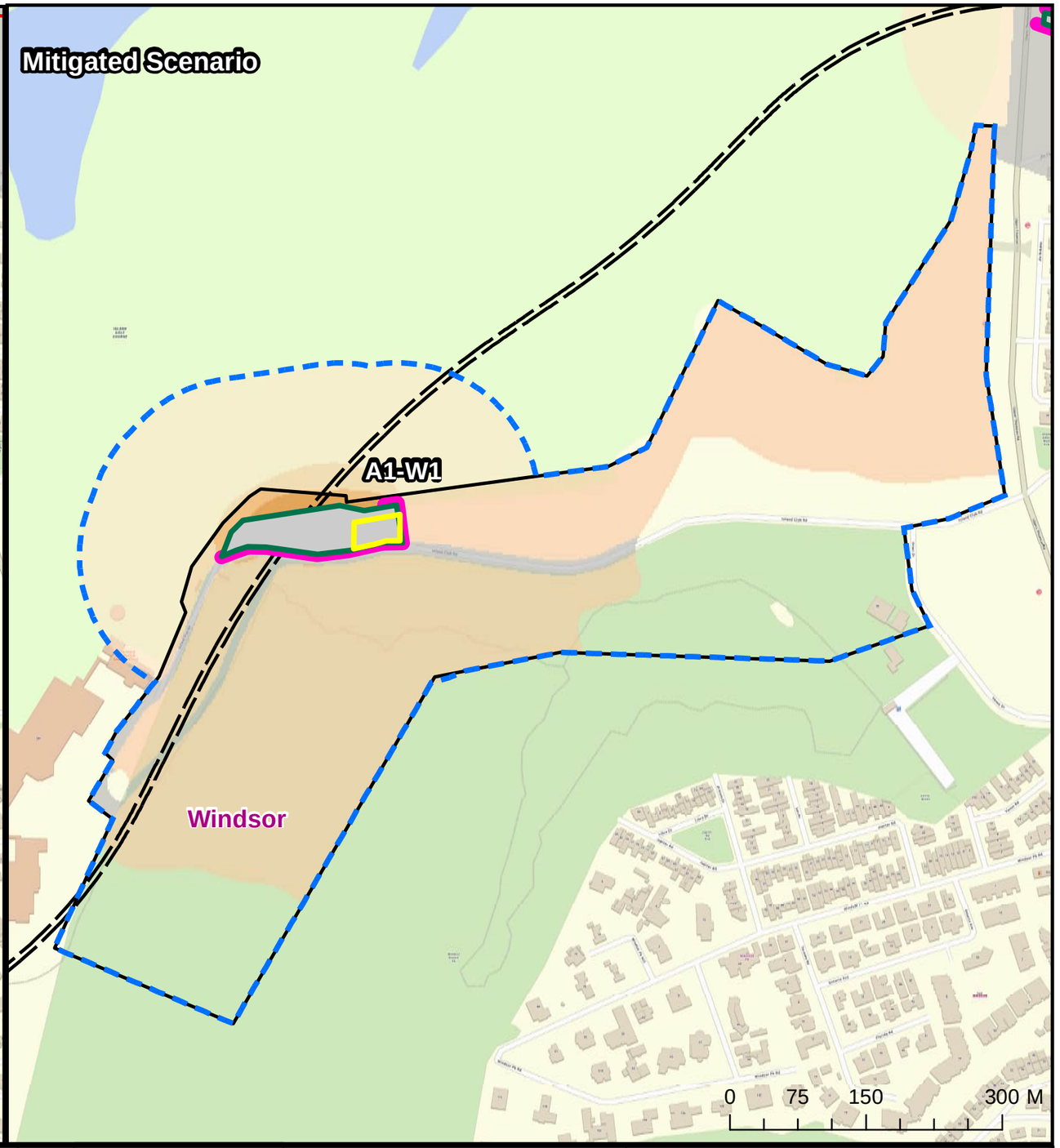
Figure Title :
SCENARIO 1 TYPICAL CONSTRUCTION WORKS LEQ (5 MINS) (10PM - 7AM) A1-W2 WORKSITE AT 1.5M HEIGHT

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
PZ	JAG	JAG	11-10	-	1 of 1
	Drawn PZ	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Proposed Noise Barrier -12m
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- Noise Study Area
- PUB Water Pipeline Project at BKSR (Shafts)
- Biodiversity Study Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
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Qualified Person Endorsement :
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LTA Endorsement :
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Consultant : AECOM

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(WINDSOR AND
ENG NEO AVENUE FOREST)

Figure Title :
SCENARIO 1
TYPICAL CONSTRUCTION WORKS
LEQ (12 HOURS) (7AM - 7PM)
A1-W1 WORKSITE
AT 1.5M HEIGHT

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
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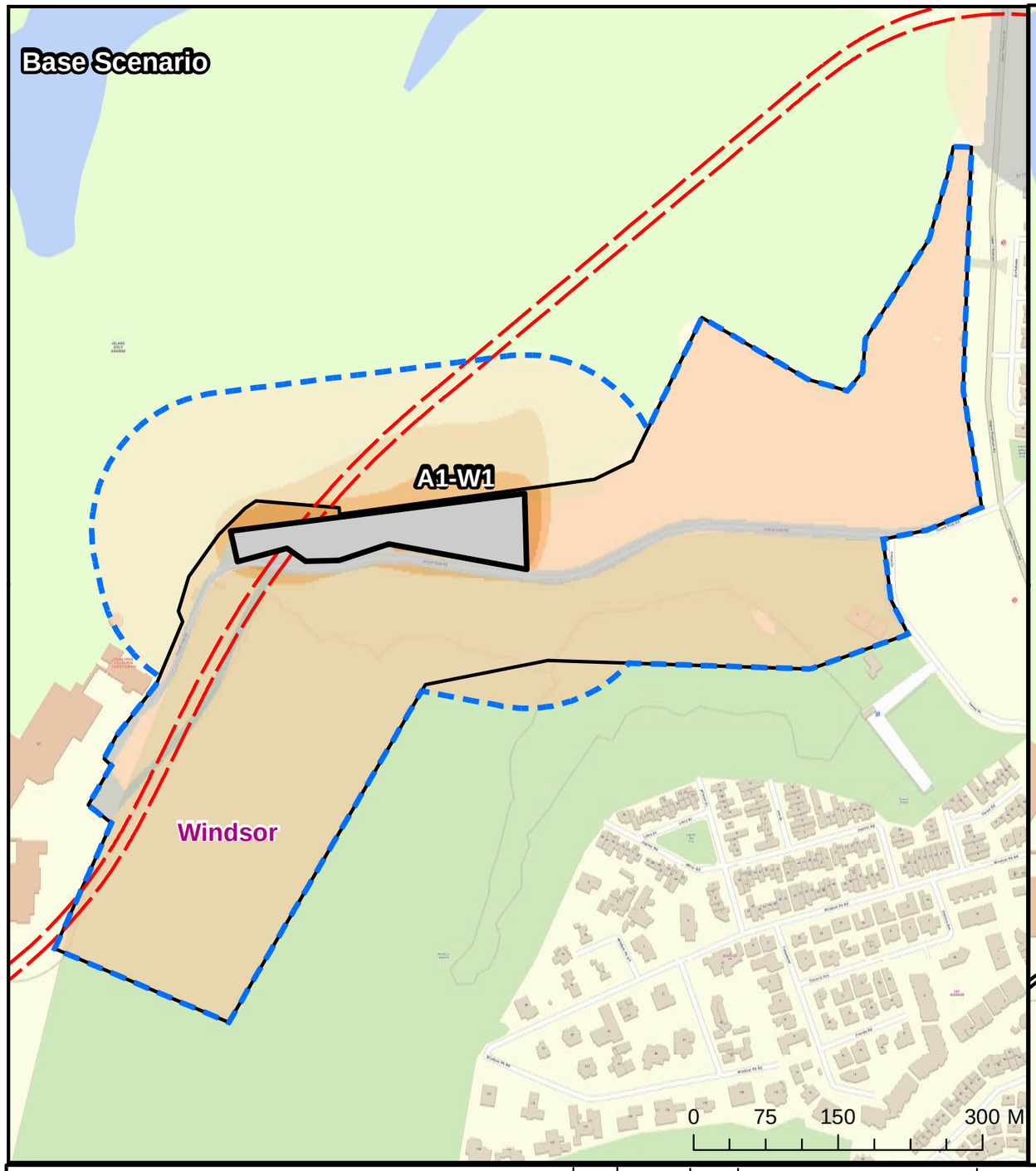
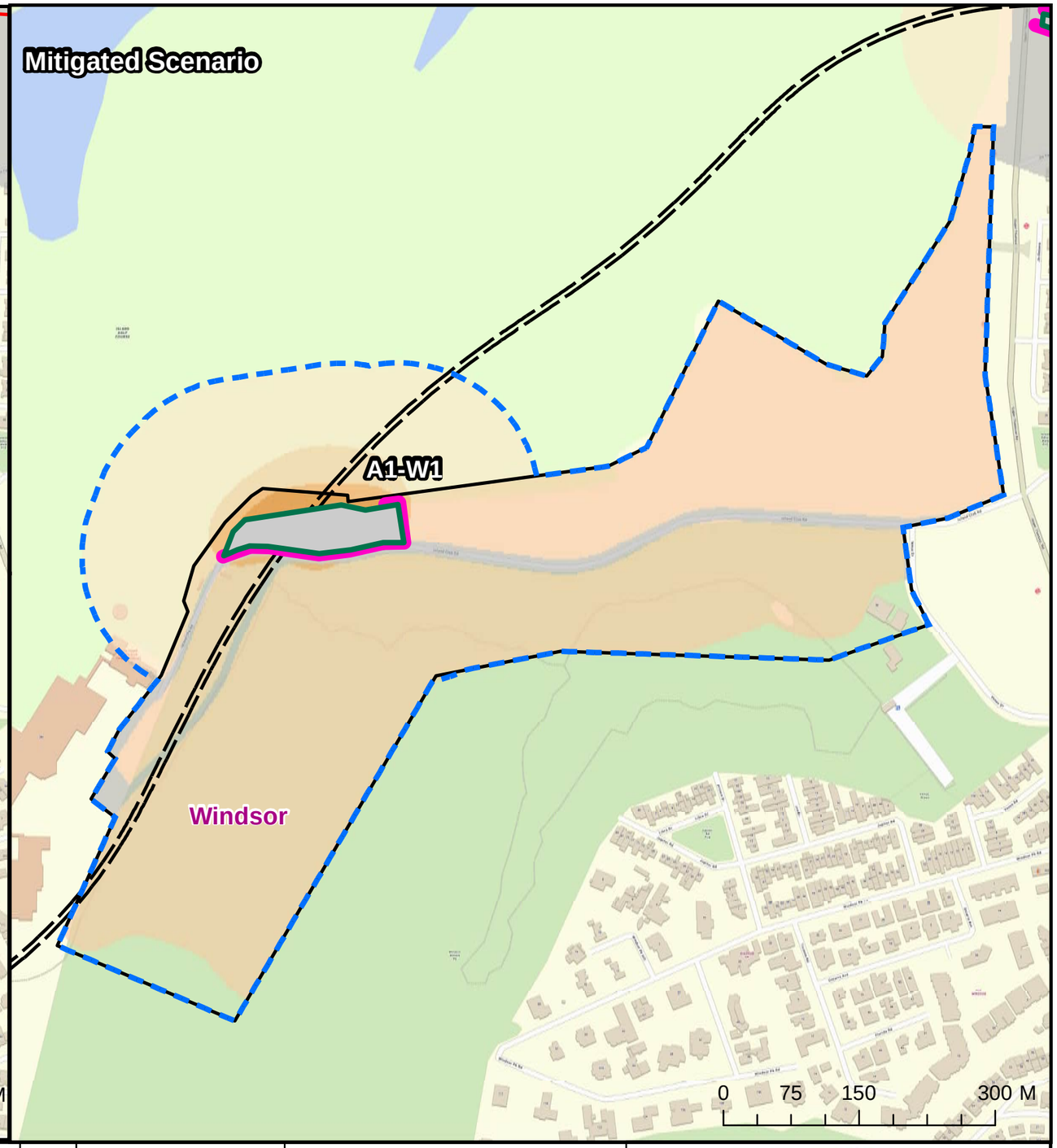
	Drawn PZ	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Proposed Noise Barrier -12m
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- Noise Study Area
- Biodiversity Study Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	PZ	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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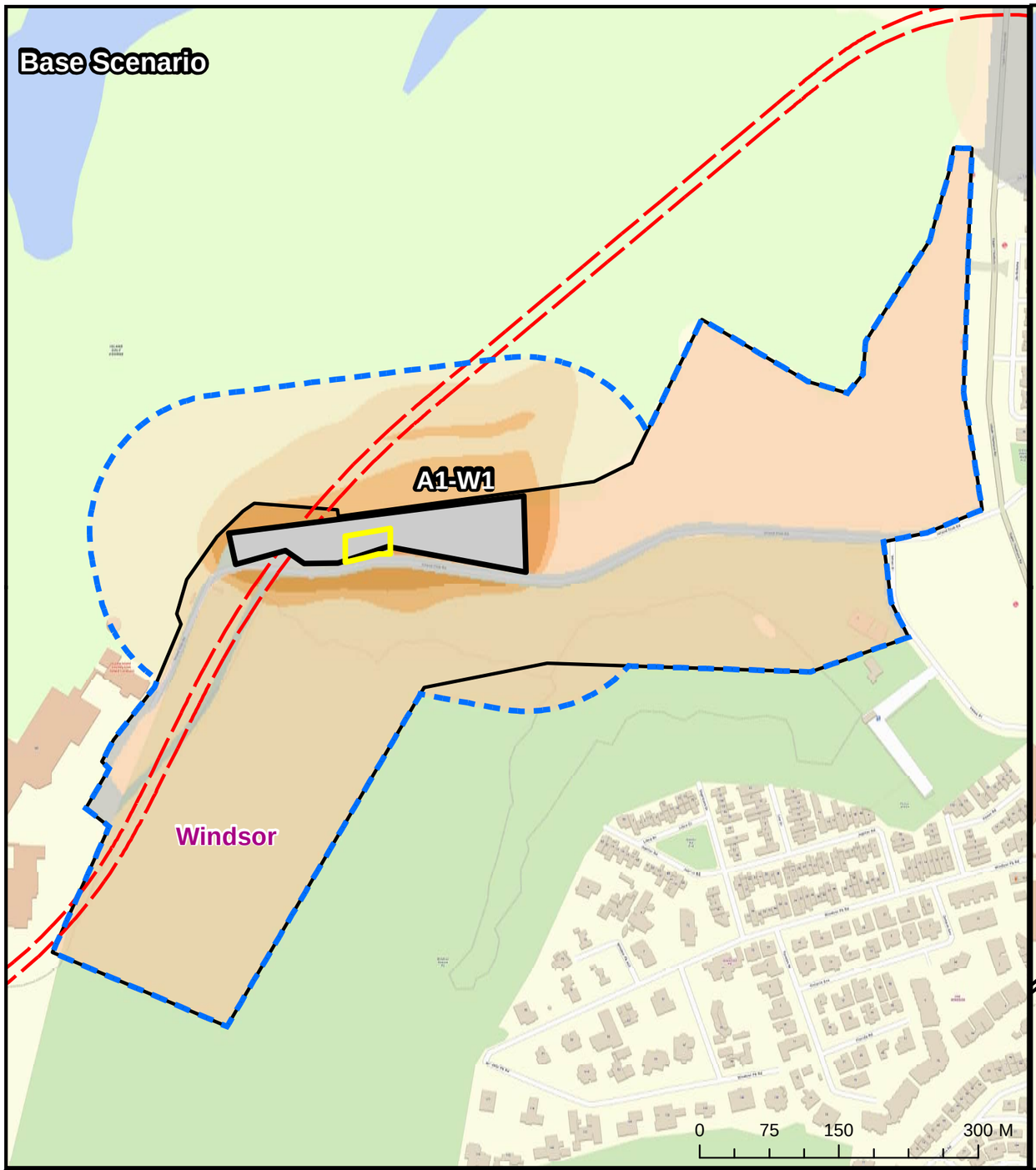
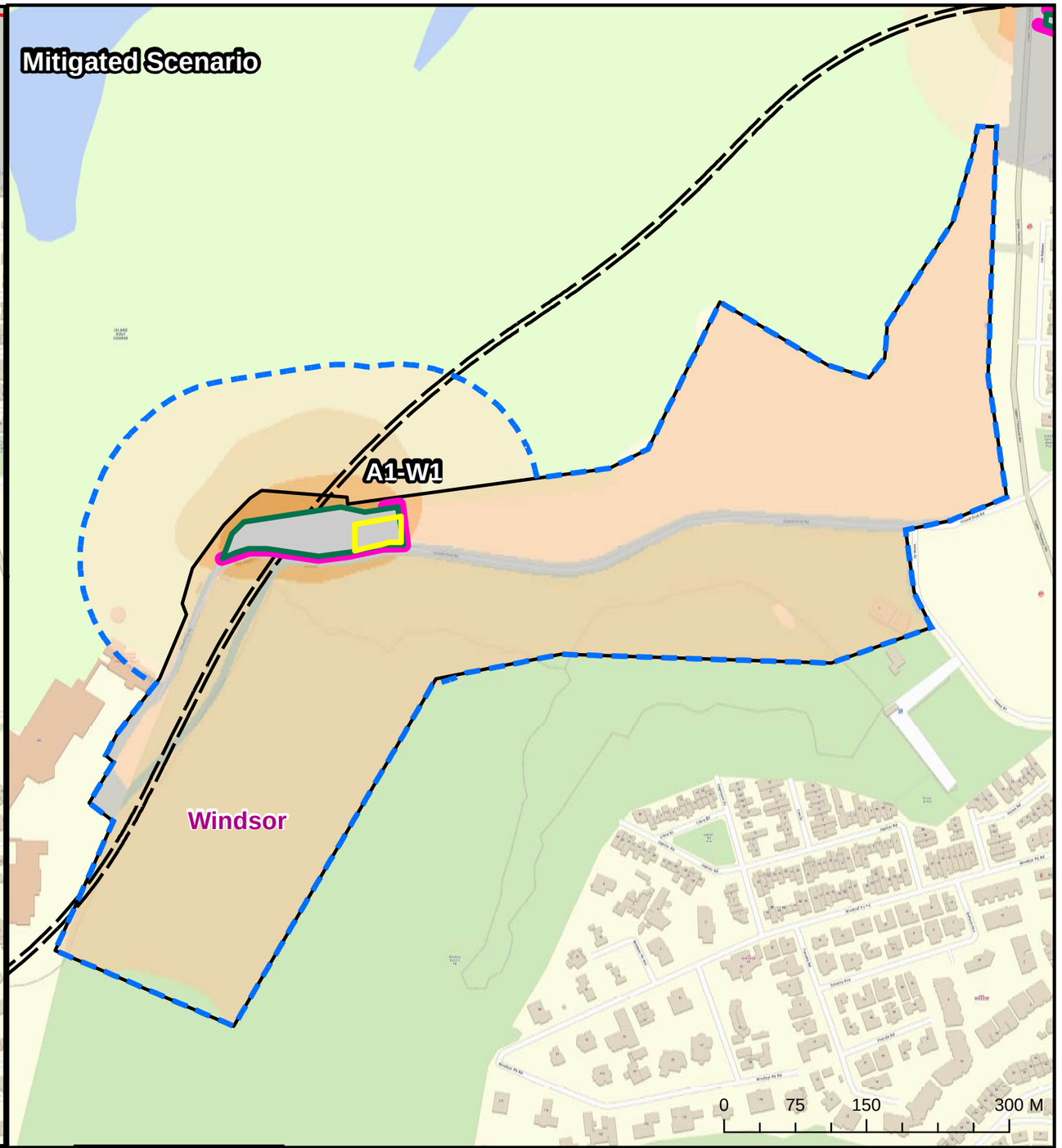
Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)

Figure Title :
SCENARIO 1
TYPICAL CONSTRUCTION WORKS
LEQ (12 HOURS) (7PM - 7AM)
A1-W1 WORKSITE
AT 1.5M HEIGHT

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
PZ	JAG	JAG	11-12	-	1 of 1
	Drawn PZ	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Proposed Noise Barrier -12m
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- Noise Study Area
- PUB Water Pipeline Project at BKSR (Shafts)
- Biodiversity Study Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	PZ	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
SCENARIO 1
TYPICAL CONSTRUCTION WORKS
LEQ (5 MINS) (7AM - 7PM)
A1-W1 WORKSITE
AT 1.5M HEIGHT

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
PZ	JAG	JAG	11-13	-	1 of 1
	Drawn PZ	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

Base Scenario

A1-W1

Windsor

0 75 150 300 M

Mitigated Scenario

A1-W1

Windsor

0 75 150 300 M

Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Proposed Noise Barrier -12m
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- Noise Study Area
- Biodiversity Study Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	PZ	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
SCENARIO 1
TYPICAL CONSTRUCTION WORKS LEQ (5 MINS) (7PM - 10PM)
A1-W1 WORKSITE
AT 1.5M HEIGHT

Designed	Checked	Approved
PZ	JAG	JAG
	Drawn: PZ	Date: MAR 2022

Figure No. : 11-14 | Rev. : - | Sheet : 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap

Base Scenario

A1-W1

Windsor

0 75 150 300 M

Mitigated Scenario

A1-W1

Windsor

0 75 150 300 M

Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Proposed Noise Barrier -12m
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- Noise Study Area
- Biodiversity Study Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	PZ	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement : NA

NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :

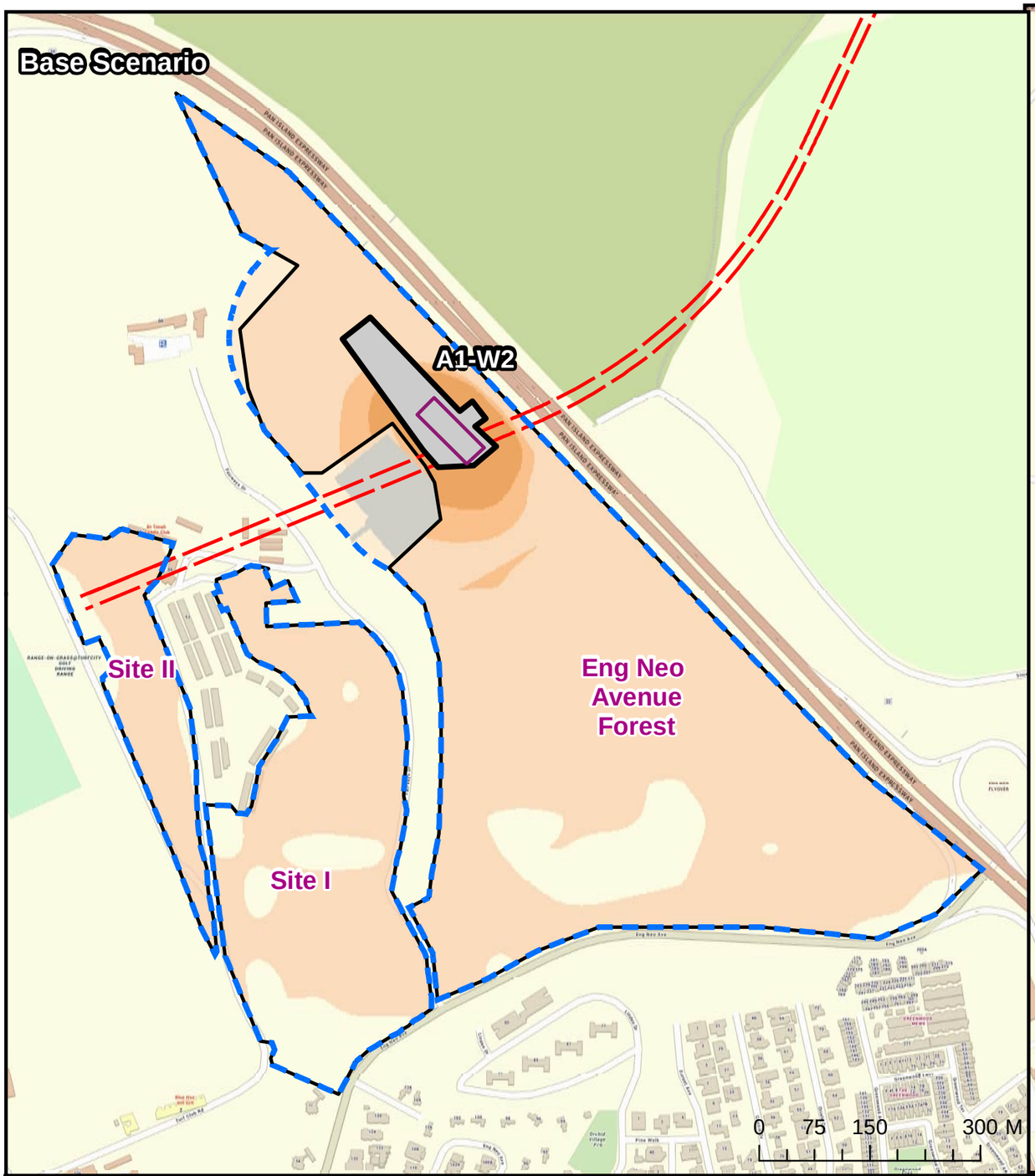
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)

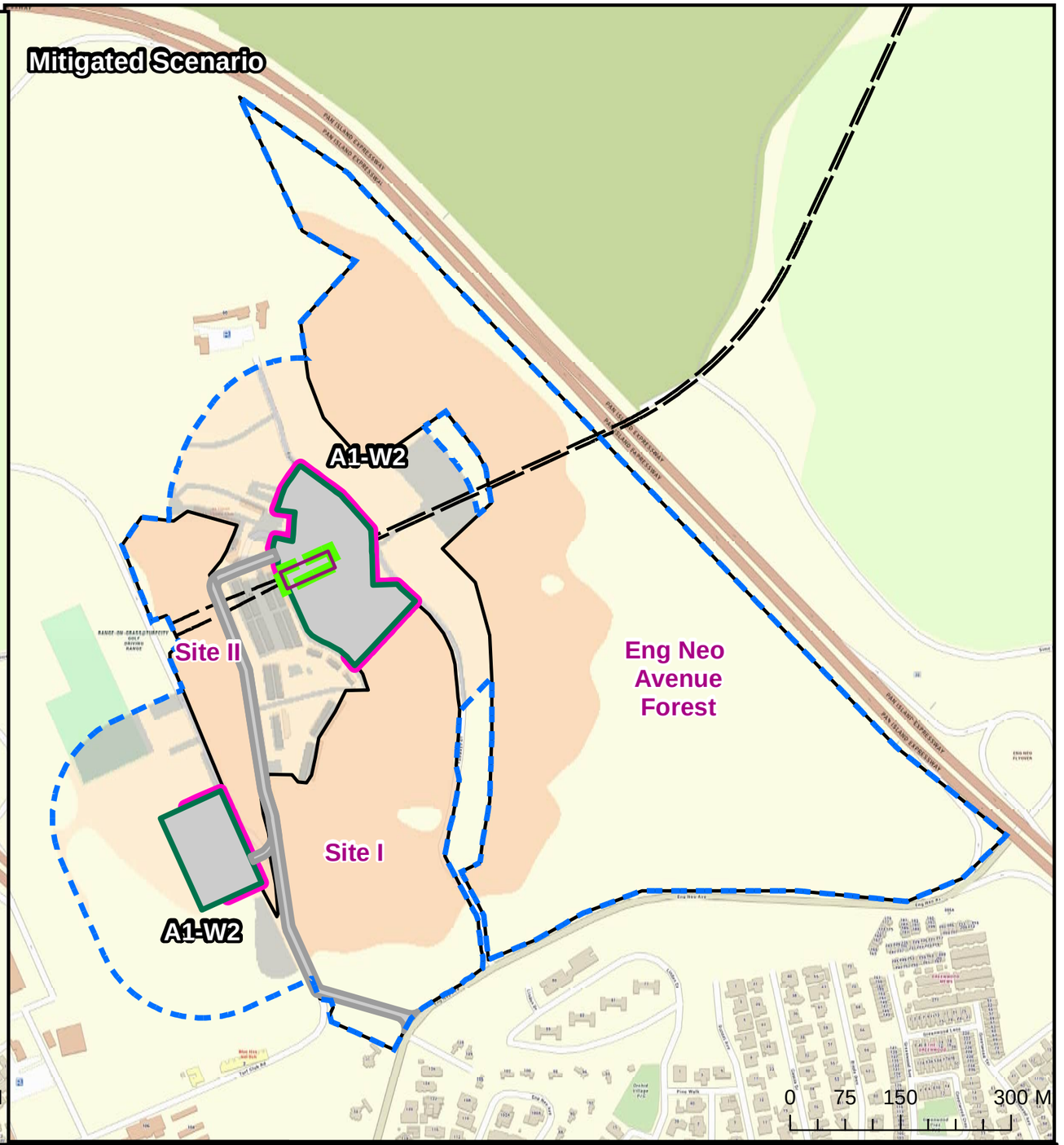
Figure Title :

SCENARIO 1
TYPICAL CONSTRUCTION WORKS
LEQ (5 MINS) (10PM - 7AM)
A1-W1 WORKSITE
AT 1.5M HEIGHT

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
PZ	JAG	JAG	11-15	-	1 of 1
	Drawn PZ	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Proposed Noise Barrier -12m
- Proposed Noise Barrier - Enclosed Noise Barrier (15m)
- TBM Worksite
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- A1-W2 Temporary Access Road
- Noise Study Area
- Biodiversity Study Area

Note: Site I and II: Forested area adjacent to Fairways Quarters

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
-	MAR 2022	PZ	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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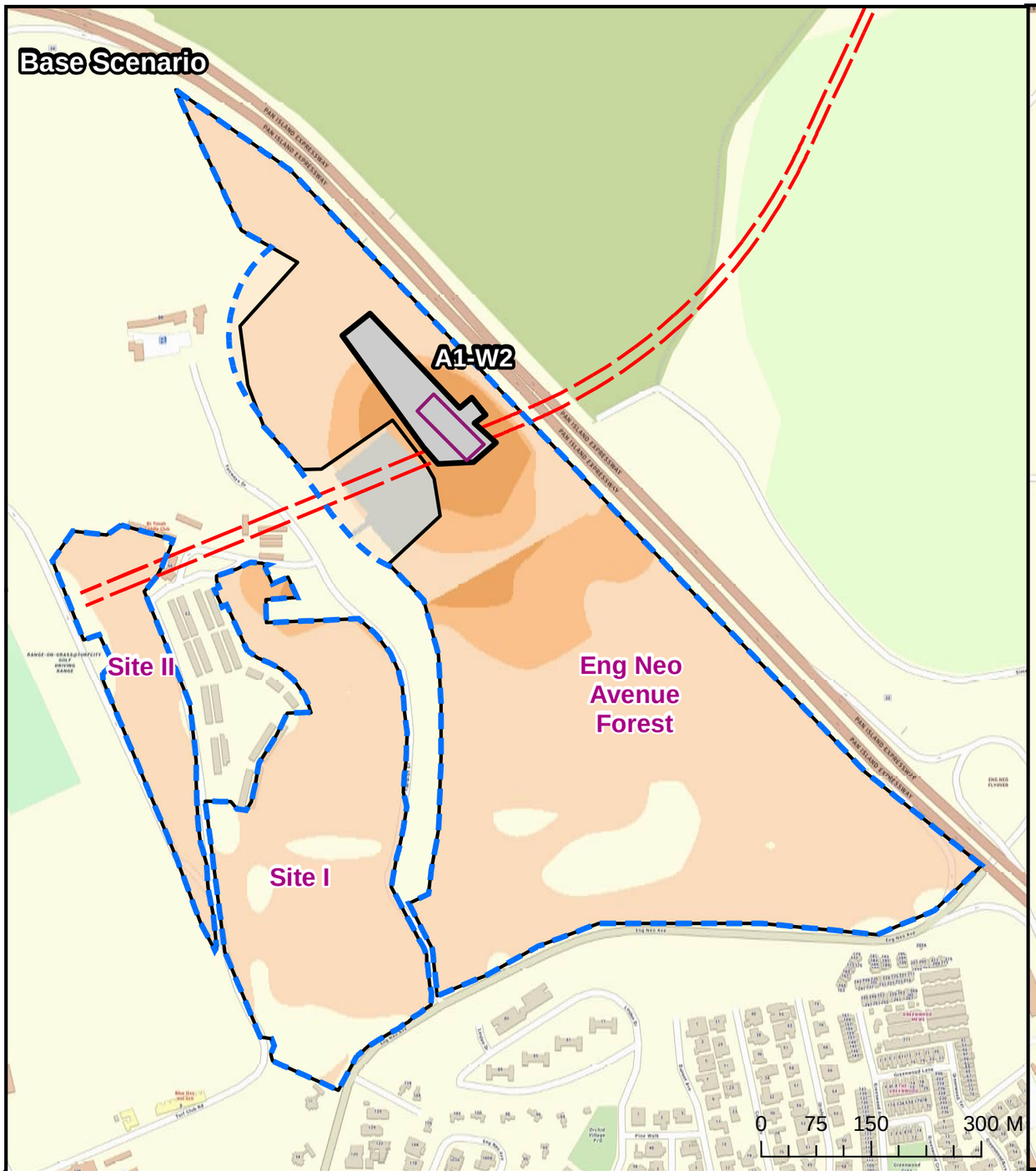
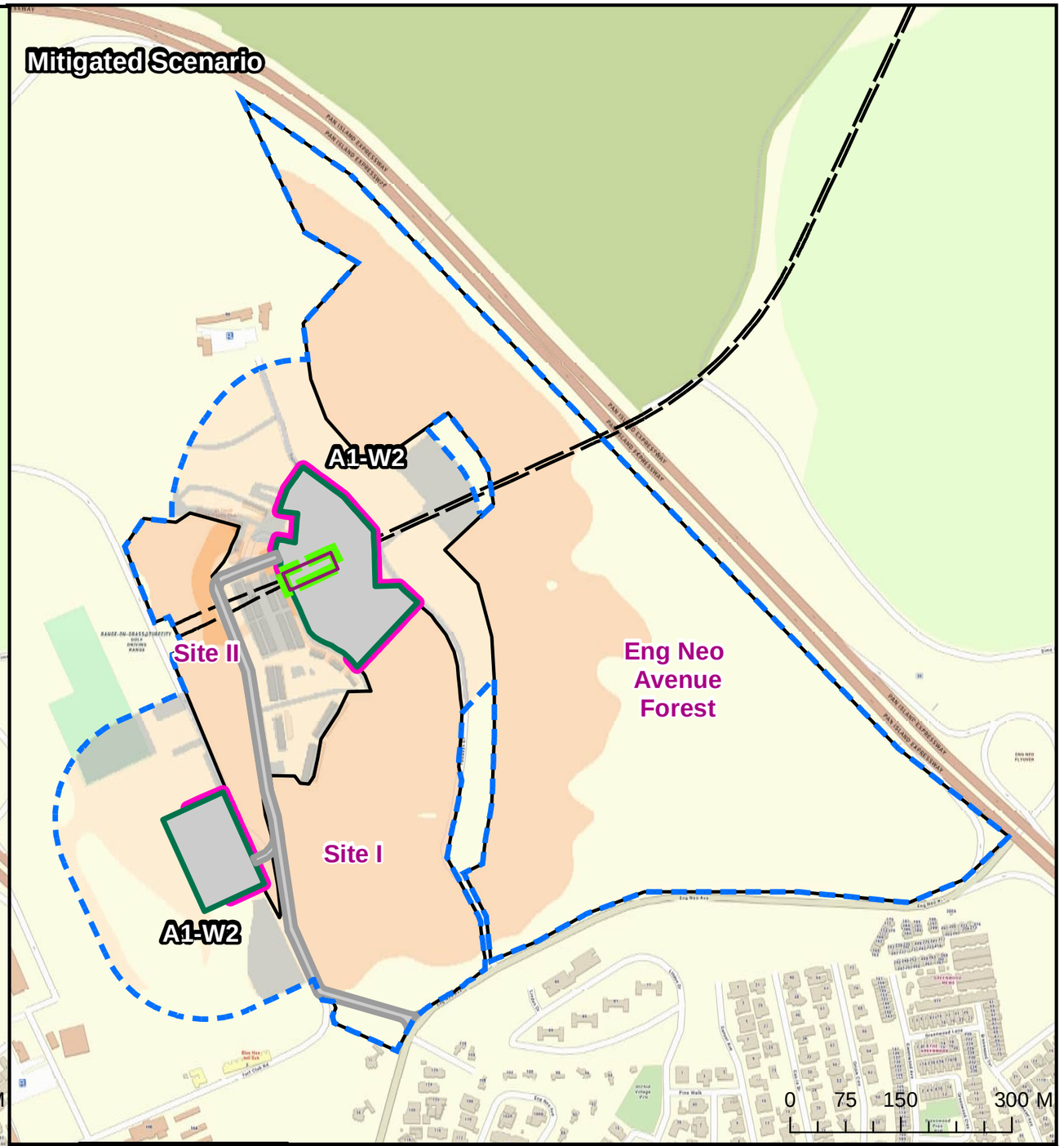
Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)

Figure Title :
SCENARIO 2
TBM LEQ (12 HOURS) (7AM - 7PM)
A1-W2 WORKSITE
AT 1.5M HEIGHT

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
PZ	JAG	JAG	11-16	-	1 of 1
	Drawn PZ	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Proposed Noise Barrier -12m
- Proposed Noise Barrier - Enclosed Noise Barrier (15m)
- TBM Worksite
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- A1-W2 Temporary Access Road
- Noise Study Area
- Biodiversity Study Area

Note: Site I and II: Forested area adjacent to Fairways Quarters

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

N

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-	MAR 2022	PZ	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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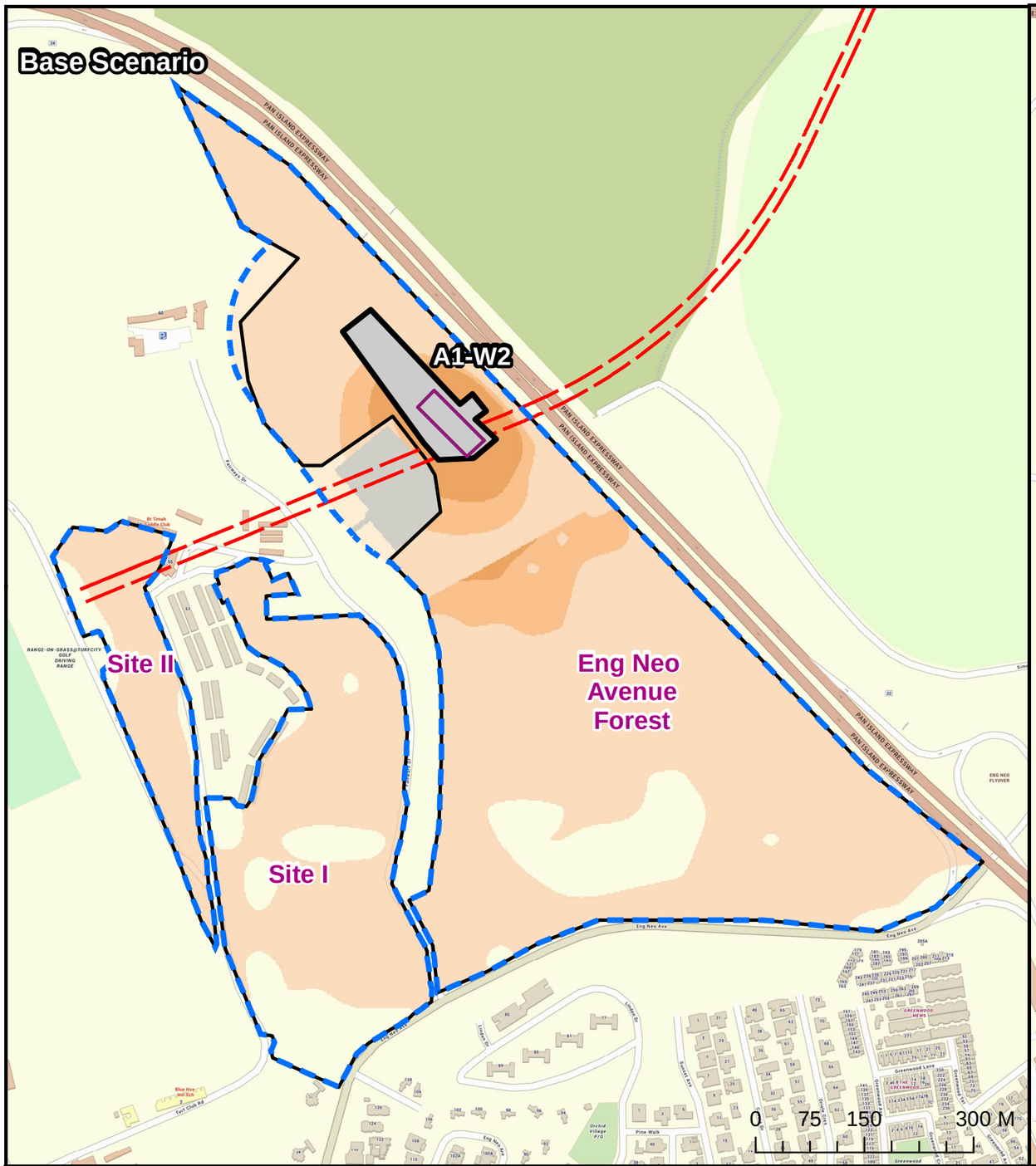
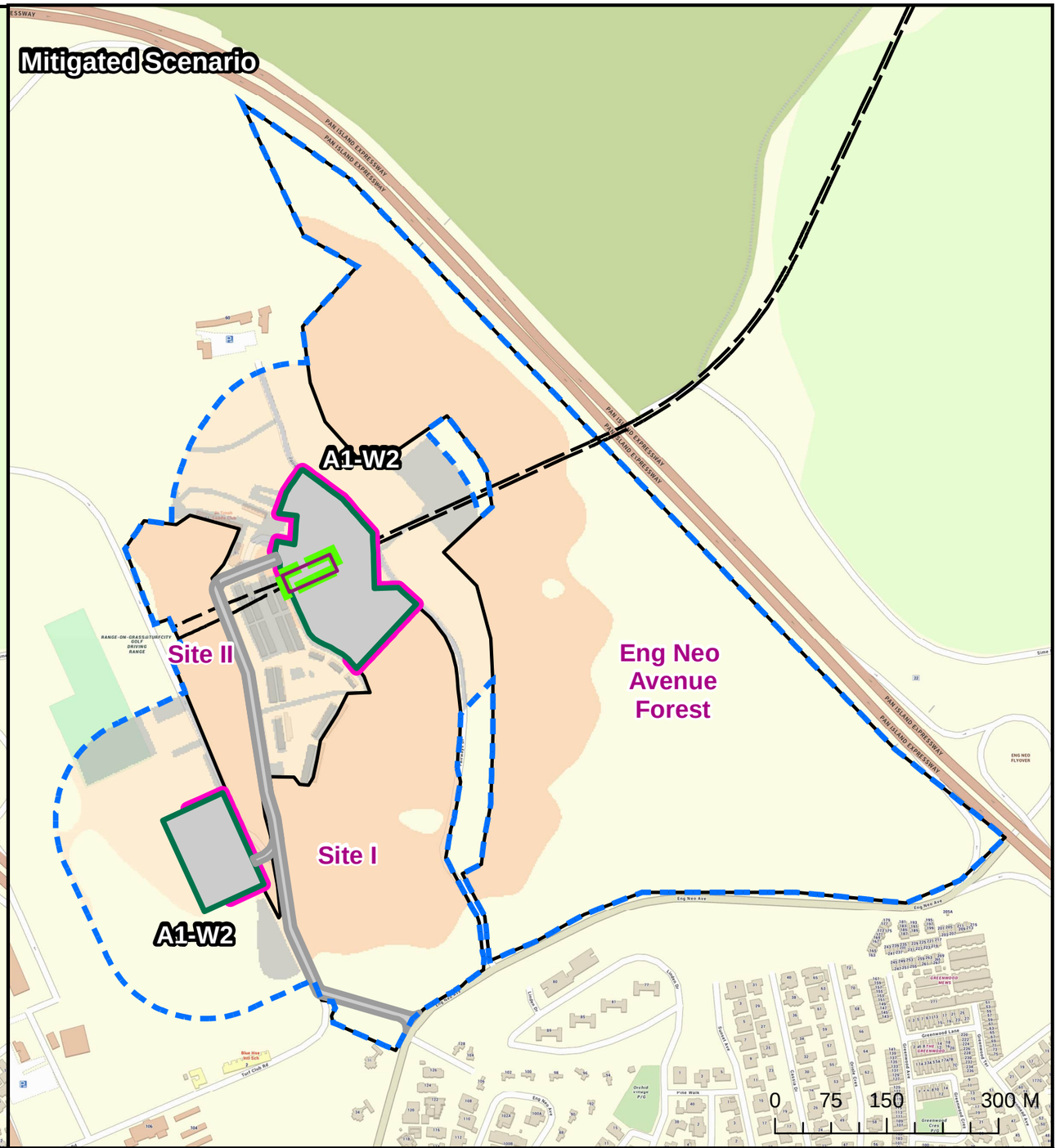
Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
SCENARIO 2
TBM LEQ (12 HOURS) (7PM - 7AM)
A1-W2 WORKSITE
AT 1.5M HEIGHT

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
PZ	JAG	JAG	11-17	-	1 of 1
	Drawn PZ	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Proposed Noise Barrier -12m
- Proposed Noise Barrier - Enclosed Noise Barrier (15m)
- TBM Worksite
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- A1-W2 Temporary Access Road
- Noise Study Area
- Biodiversity Study Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

Note: Site I and II: Forested area adjacent to Fairways Quarters

N

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-	MAR 2022	PZ	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

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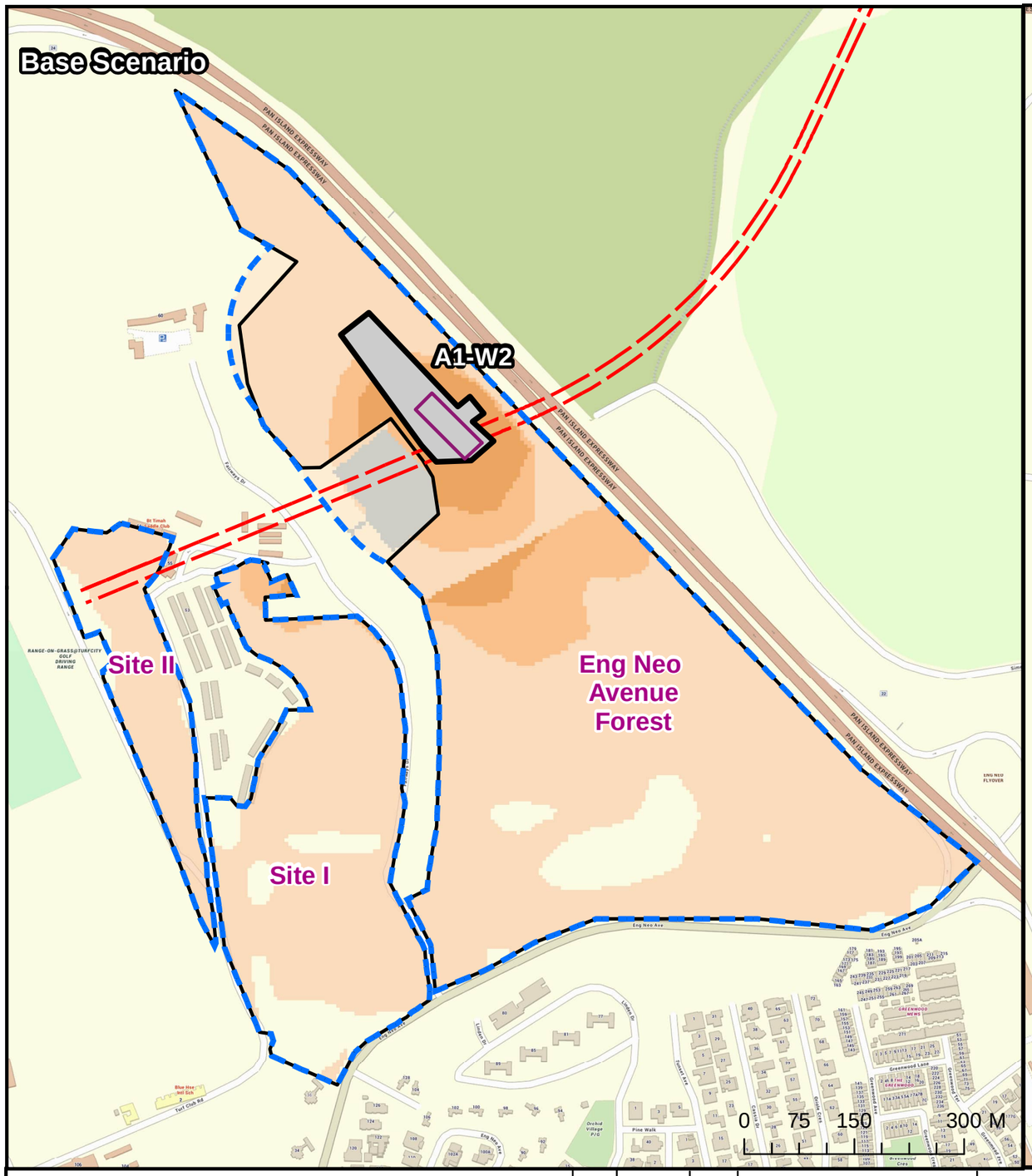
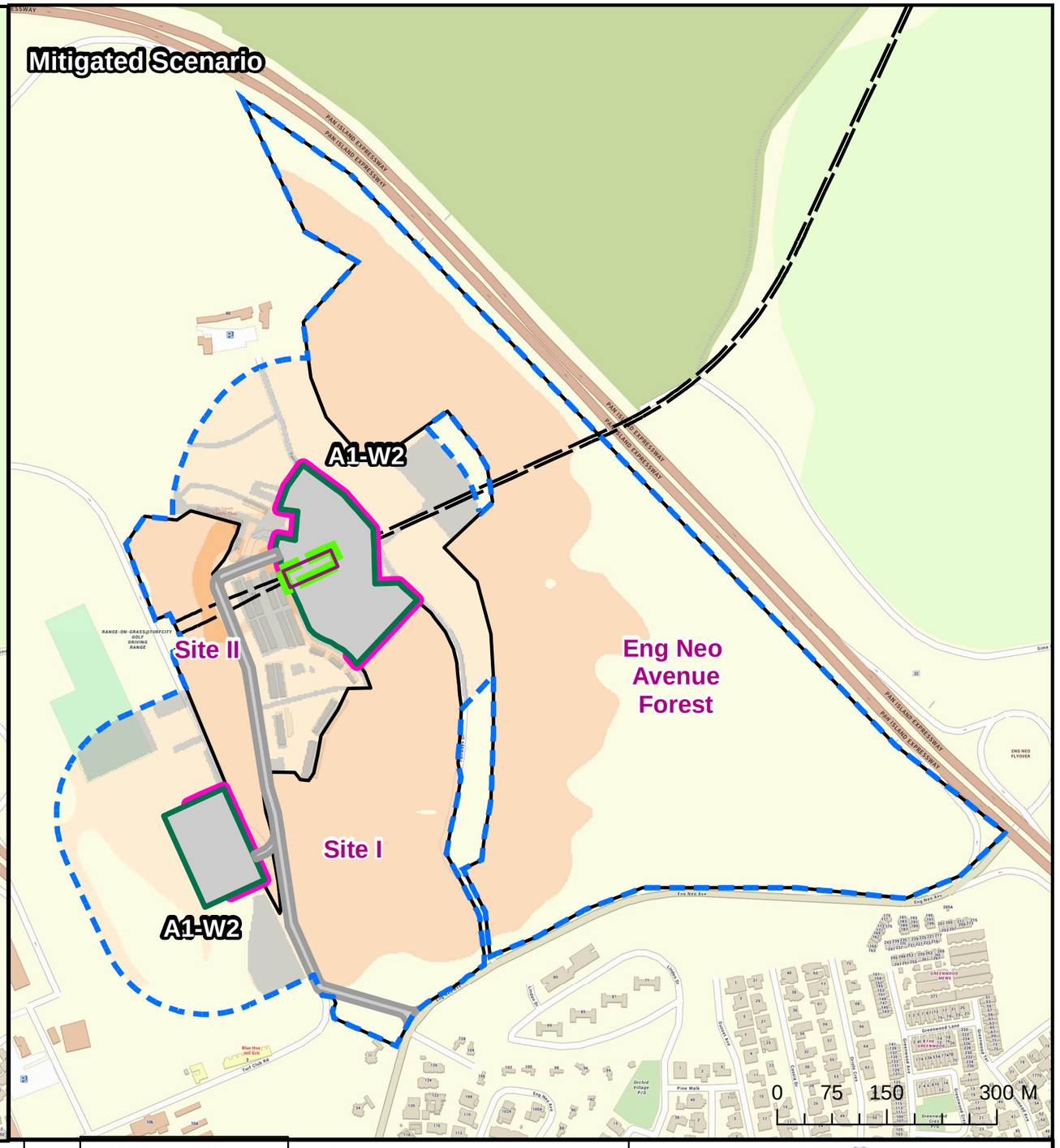
Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
SCENARIO 2
TBM LEQ (5 MINS) (7AM - 7PM)
A1-W2 WORKSITE
AT 1.5M HEIGHT

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
PZ	JAG	JAG	11-18	-	1 of 1
	Drawn PZ	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Proposed Noise Barrier -12m
- Proposed Noise Barrier - Enclosed Noise Barrier (15m)
- TBM Worksite
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- A1-W2 Temporary Access Road
- Noise Study Area
- Biodiversity Study Area

Note: Site I and II: Forested area adjacent to Fairways Quarters

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
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Qualified Person Endorsement :
NA

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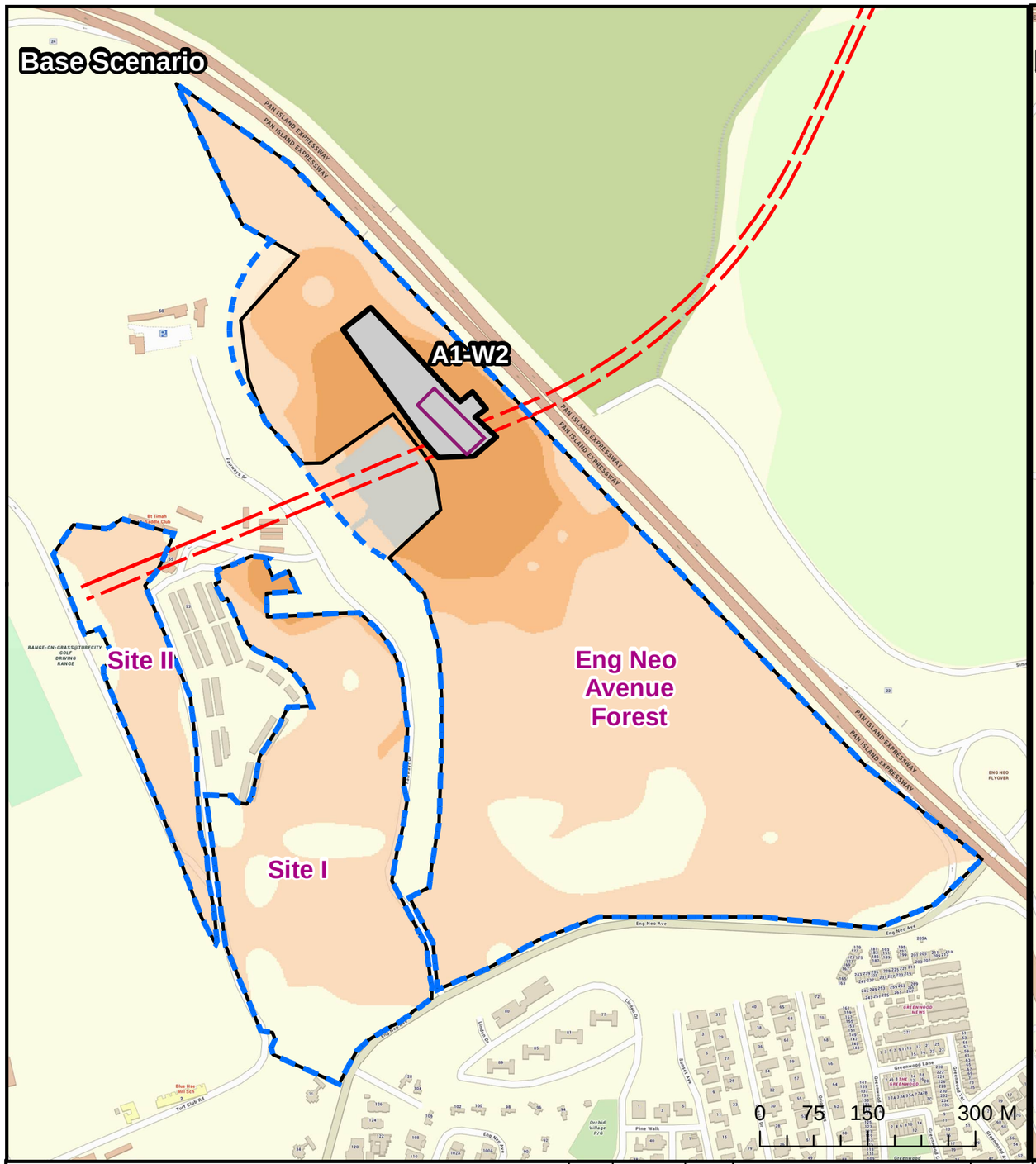
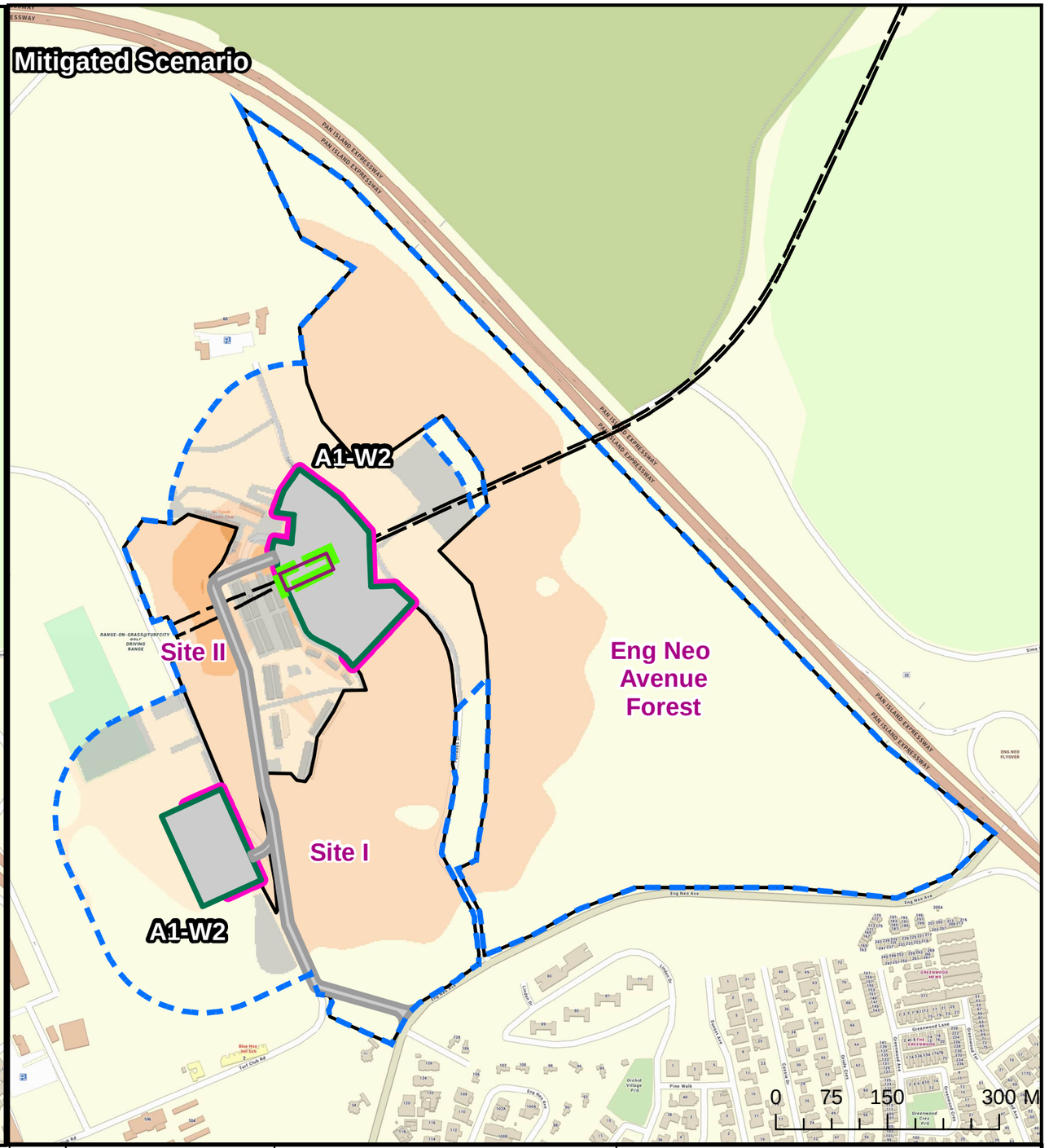
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)

Figure Title :
SCENARIO 2
TBM LEQ (5 MINS) (7PM - 10PM)
A1-W2 WORKSITE
AT 1.5M HEIGHT

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
PZ	JAG	JAG	11-19	-	1 of 1
	Drawn PZ	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Proposed Noise Barrier -12m
- Proposed Noise Barrier - Enclosed Noise Barrier (15m)
- TBM Worksite
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- A1-W2 Temporary Access Road
- Noise Study Area
- Biodiversity Study Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

Note: Site I and II: Forested area adjacent to Fairways Quarters

N

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Qualified Person Endorsement :
NA

LTA Endorsement :
NA

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(WINDSOR AND
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Figure Title :
SCENARIO 2
TBM LEQ (5 MINS) (10PM - 7AM)
A1-W2 WORKSITE
AT 1.5M HEIGHT

Designed	Checked	Approved
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Figure No. : 11-20 | Rev. : - | Sheet : 1 of 1

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Note: Source of basemap - OneMap

11.10 Cumulative Impacts from Other Major Concurrent Development

11.10.1 Construction Phase

It is known that some other construction activities are planned to occur in the vicinity of the Project as highlighted in Section 3.4.1. Hence, cumulative impacts from other relevant major concurrent developments in the vicinity of the Project shall be assessed and considered.

11.10.1.1 A1-W1 Worksite

Shaft 4 as part of PUB BKSR project is collocated at the eastern side of A1-W1. It is to be noted that the construction noise impacts generated from the various construction activities will depend on the inventory adopted for each activity of the construction programme from BKSR and A1-W1 joint construction. The main source of noise will be from the Powered Mechanical Equipment (PMEs). Overall, the noise level generated from BKSR site (120 dBA) was same as maximum generated level at A1-W1 worksite. Therefore, the noise contribution from both sites are the same, while the area of both are different. For the assessment of cumulative impacts, the information about the inventory and PMEs was included as part of all noise impacts calculation in the sections above as worst case and assessed jointly in the noise section already due to availability of the equipment and stages. Therefore, the noise contribution from both sites were the same, while the areas of both were different.

11.10.1.2 A1-W2 Worksite

The CR14 works near A1-W2 of the same contract was included as part of the noise model. It is evaluated to be contributing to the noise level of A1-W2. Therefore, the noise contribution from this concurrent activity to A1-W2 of this project is considered major impact significance. The detailed information associated with the CR14 works, such as noise contour figures, equipment inventory and PMEs, were not included in this report, however, will be provided in a separated EIS report when it can be developed with more information available.

11.10.2 Operational Phase

No cumulative impacts were considered significant during operational phase at A1-W1, CR13 retrieval shaft, A1-W2 sites. Currently there are no developments planned near CR13 however, if similar developments are planned around it in distant future, the cumulative impact may need to be assessed at that stage as well.

11.11 Summary of Key Findings

Noise impact assessment was carried for the construction phase of the proposed worksites for CR2005. The construction noise Study Area was defined as combination of Eng Neo Avenue Forest, Site I, Site II, and 150 m from A-W2 worksites, and 150m from A1-W1 construction worksite or Windsor whichever is greater. The noise impact assessment for the operational phase of the proposed worksites for CR2005 included providing noise boundary criteria for ACMV noise at the facility buildings and qualitatively assessing traffic noise to the noise sensitive receptors. However, it is to be noted that the LTA may not be designing in detail for the compliance to noise criteria at this stage, in which case the imposed criteria at boundary shall form a mandatory requirement when the worksite is designed during detailed design stage. Baseline noise monitoring was carried out at six (6) locations. Uncorrected baseline noise was used as a more stringent criteria for assessment of ecological receptors in this Study. Besides, the baseline airborne noise monitoring was supplemented with secondary baseline data obtained from the concurrent study carried out by AECOM in the vicinity, to obtain the baseline noise levels within the Study Area.

The baseline study recorded average $L_{eq(12\ hour)}$, $L_{eq(1\ hour)}$ and $L_{eq(5\ min)}$ baseline noise levels and compared against the construction criteria provided by NEA guidelines. The baseline noise levels were used to develop project-specific criteria for the construction phase.

For the assessment on construction phase, the noise levels generated from the equipment used during construction detailed in Section 11.3.1 was predicted using SoundPLAN ver 8.2. Topography plays an important role in noise propagation and was included in this assessment. A quantitative assessment at the noise sensitive receptors (within the Study Area) was carried out and compared with the stipulated Environmental Protection and Management (Control of Noise at Construction Sites) Regulations (2008). The identified noise sensitive receptors will be assessed in accordance to the impact evaluation matrix as shown in Section 6.4.2. Noise contours were provided to the extent where topography is available. Based on the impact evaluation, mitigation to reduce airborne noise impacts were recommended for the affected ecological noise sensitive receptors.

The study on construction noise impact to the noise sensitive receptors focused on two (2) different construction scenarios, including Scenario 1: Cut and cover works and associated activities; and Scenario 2: Tunnel Boring Machine (TBM) works. It must be noted at this stage that worst-case assumptions on equipment usage, period of

usage, and more conservative approach for barrier heights were proposed to predict the worst impacts to these locations of highly sensitive nature.

For the impact assessment on the modelling scenario 1 to scenario 2 of construction, base scenario results show impact significance of Moderate to Major with a highest noise level 65 dB(A) at Windsor, Major with a highest noise level 77dB(A) at Eng Neo Avenue Forest, Moderate to Major with a highest noise level 55dB(A) at Site I, and Minor to Moderate at Site II.

Following the assessment of all design optimisation options, it still requires for noise barrier with a height of 12m as the mitigation measures at A1-W1 site (as shown in Figure 11-5). At A1-W2 site, it still requires for 12m height noise barrier around the worksite and LTA standard 15m full enclosed noise barrier for TBM. The ground level and low height noise sensitive receptors benefit from the noise barrier, however, receptors at top of the trees may not benefit from noise barriers. Based on a couple of height sensitivity analysis, it was determined that an optimum height of 12 m noise barrier gives the maximum benefit to the arboreal receptors around the site and any further increase in noise barrier height does not yield any benefit to the receptors at optimised A1-W1 and A1-W2 worksites. Based on the residual airborne noise impact assessment above, the proposed 12m noise barrier at A1-W1 worksite will be beneficial by reduction impact significance from Moderate-Major (base scenario) to **Minor-Moderate** (post mitigated scenario) for main construction activities at Windsor. It is to be noted that sound power level of utility diversion works along Island Club Road at A1-W1 worksite is much lower than worst-case (shown in Table 11-10), which was not modelled for this assessment. If there are any complaints regarding the noise impact arising from the Project worksites, the PRO shall engage with ECO to resolve this issue.

For A1-W2, impact significance reduced to **Minor** from base scenario-Major impact significance for both scenarios at Eng Neo Avenue Forest. Site I still experiences **Major** impact from both base worksite and post-mitigated worksite due to its close proximity to surrounding forested area, which cannot be mitigated any further. But at Site II impact significance became **Major** due to the A1-W2 worksite which is closer to the boundary of surrounding forested areas during Cut and cover works and associated activities. However, the total areas of “Major” impact significance are expected to be reduced significantly from base to mitigated worksite and can be seen obviously in the noise figures (refer to Figure 11-6 to Figure 11-20) at optimised A1-W1 and A1-W2 worksites.

The road work construction of the A1-W2 worksite was also modelled separately under this assessment. Since its construction footprint is very close to the ecological receptors at Site I and Site II, predicted noise level is expected to be up to 22 dB(A) exceedance than criteria with **Major** impact significance. However, non-safety critical works during road construction should only be restricted in the day, and road construction be carried out for short lengths at a time, and for a short period of time. Erecting high barriers for road construction can be more intrusive to the habitat due to short duration of actual road construction, therefore during this phase, portable noise barrier are highly recommended close to the noisy equipment/ activities and no night works after 7pm for all non-safety critical activities since the site is next to the sensitive receptors. If there are any complaints regarding the noise impact arising from the Project worksites, PRO shall engage with ECO to resolve this issue.

For rock breaking and excavation works proposed at the A1-W1 and A1-W2 worksite, the approach taken was to provide a guideline to the criteria as set out in BS5228-2:2009+A1:2014. Based on assumptions made (location, depth, method) and known information (distance to nearest receptors), this assessment provides an estimate on the maximum amount of charge (charge mass, kg) that should be permitted in order to keep air overpressure within the stated criteria. Predictive methods in AS 2187.2-2006 Explosive – Storage and Use Part 2 were used to predict air overpressure based on constants recommended within the guideline. Based on the impact assessment, from A1-W1 worksite (Base Scenario) rock breaking and excavation works, Priority 1 ecologically sensitive receptors from Windsor will potentially experience medium impact intensity with medium impact consequence. Since the likelihood of rock breaking and excavation works occurring during the entire construction is regarded as Certain and the resulting impact significance is Major. From the A1-W2 worksite, the Priority 1 ecologically sensitive receptors at Eng Neo Avenue Forest, Site I and Site II will potentially experience medium impact intensity and the resulting impact significance is Major. After applying the mitigation measures within Section 11.8, the resulting impact significance from rock breaking and excavation at A1-W1 Worksites (Mitigated Scenario) ranges from **Minor** to **Moderate**, while the resulting impact significance from A1-W2 Worksites (Mitigated Scenario) ranges from **Negligible** to **Major**.

In addition to mitigation measures, EMMP for conducting further noise monitoring at adequate numbers in other proposed locations in conjunction with ground-borne vibration impact assessment have been proposed for vibration sensitive phases. Information on the additional monitoring locations will be further addressed in Section 12.

For the cumulative impact assessment for the concurrent developments, the information about the inventory and PMEs was not available except for CR14 near A1-W2 worksite and PUB Water Pipeline project at BKSR around Shaft 4 located at A1-W1 worksite. For the assessment of cumulative impact, the information about the inventory

and PMEs were included as part of the noise impact calculation as worst case and assessed jointly in the noise section. At Windsor, overall, the predicted noise level generated from BKSR site (120 dB(A)) is same as the maximum generated level at A1-W1 worksite. Therefore, the noise contribution from both sites are the same, although the areas of both sites are different. The footprints of this BKSR project does not add on significantly to the noise level at A1-W1 worksite.

For the cumulative impact assessment on the concurrent developments near A1-W2, it was included in the noise model and evaluated to be contributing to the noise level from A1-W2 especially at Site II. Therefore, the noise contribution is **Major**. Due to confidentiality of that project, the detail information about the noise figures, inventory and PMEs were not included in the section above.

No cumulative impacts were considered as significant during operational phase at A1-W2, A1-W1, CR13 retrieval shaft worksites. Currently there are no developments planned near CR13 however, if similar developments are planned around it in distant future, the cumulative impact may need to be assessed at that stage as well.

Table 11-29 Summary of Airborne Noise Impact Assessment

Sensitive Receptor	Impact Significance with Minimum Controls[2]	Residual Impact Significance with Mitigation Measures (if required)
Construction Phase		
Eng Neo Avenue Forest	Major	Minor
Site I and Site II	Negligible to Major	Negligible to Major[1]
Windsor	Moderate to Major	Minor to Moderate[1]
Operational Phase		
Eng Neo Avenue Forest	Negligible	Negligible
Site I and Site II	Negligible	Negligible
Windsor	Negligible	Negligible

Note:
1. Due to the surrounding ambient noise levels which are naturally very low, the fact that sensitive receptors are in close proximity, and that noise barriers are unlikely to impede noise that will reach habitat on elevated/undulant terrain, meaning receptors in these locations will still be impacted. Collectively, these therefore mean, that impact significance cannot be reduced further.
2. The initial impact assessment with minimum controls was considered insignificant (Negligible to Minor), no residual impact assessment was undertaken, hence the impact significance remained the same.

12. Ground-borne Vibration

12.1 Introduction

This section presents the assessment of vibration impacts arising from the construction and operational phases of the Project on ecologically sensitive receptors in the Study Area. Ground-borne vibration from construction activities (at A1-W1, A1-W2 worksites and alignment) and operational activities may be felt by or cause a disturbance, especially on the ecological receptors proximity to the Project.

Flora is not considered to be sensitive to vibration impact. Hence the impact assessment only focuses on the behaviour of fauna. Ground-borne noise is generated by the vibration of walls, ceilings and floors inside buildings. Therefore ground-borne noise only occurs indoors; and is excluded from the assessment of fauna which lives in the open.

The critical steps for conducting the ground-borne vibration impact assessment are as follows:

- Define the Study Area (Section 4.1).
- A baseline vibration study to determine the current vibration levels in the Study Area.
- Review secondary baseline vibration monitoring data.
- Establish assessment criteria for the ground-borne vibration impact assessment.
- Identify activities in Project construction and operational phases which may cause significant ground-borne vibration impact to the fauna in the Study Area.
- Identify and classify the sensitivity of the faunal receptors in the Study Area.
- Identify minimum controls to be implemented by the LTA for managing or avoiding ground-borne vibration impacts in the construction and operational phases.
- Predict ground-borne vibration levels from significant activities on the faunal receptors assuming minimum controls are in place.
- Recommend additional mitigation measures to be implemented if required.
- Determine the overall significance of the residual ground-borne vibration impacts after commitment to and implementation of the mitigation measures; and
- Define an appropriate monitoring and management plan to be observed during construction and operational phases to maintain consistency with the findings of this study.

12.2 Methodology

The sections below outline the methodology used in the ground-borne vibration impact assessment for both construction and operational phases, including the determination of the Study Area and baseline vibration.

12.2.1 Baseline Vibration Study

The baseline vibration study aims to understand the existing vibration levels at the sensitive receptors. These are used to establish the impact assessment criteria and as a reference for monitoring during the Project's construction, operational or both phases. The baseline study comprises monitoring carried out (primary data collection) and data measured previously for other Projects (secondary). The Peak Particle Velocity (PPV) vibration metric has been used throughout.

12.2.1.1 Primary Data Collection (Baseline Monitoring)

The Project conducted baseline vibration monitoring at four (4) locations within the Study Area. These were considered representative of the baseline vibration levels of the impacted biodiversity areas. V07 and V07A are located within Eng Neo Avenue Forest, while V08 is located within Windsor Nature Park.

In 2020, a Svantek 977 with an SV80 single-axis accelerometer was used to measure the baseline vibration monitoring levels at V08 and V07. In 2022, baseline vibration monitoring is repeated at V07, and additional monitoring is carried out at V07A using Svan 258PRO with a tri-axis accelerometer of the same sensitivity. Although in 2022, there is vibration data for the x and y-axis, only the baseline vibration data for the z-axis is used in the assessment.

Table 12-1 and Figure 12-1 show the baseline vibration monitoring locations.

The vibration monitoring locations were initially selected at the Inception stage [R-2], based on the following considerations:

- Identification of the vibration sensitive receptors (VSR) nearest the construction worksite/ Project footprint comprises the fauna of high conservation value.
- VSRs outside the Study Area (100 m from the construction worksite/ Project footprint areas) were not included in the initial assessment.
- VSRs were not used within areas of ongoing construction works for other Projects.
- The closest VSR to the construction worksite areas were selected; and
- Monitoring was conducted at the ground level to capture the baseline vibration based on the existing geological profile experienced by the VSRs.

Additional baseline monitoring at location V07A was suggested due to changes in the worksite at A1-W2 during the Preliminary stage.

Baseline ground-borne vibration levels were monitored over 24 hours at 1-minute intervals in 2020. The duration for monitoring at V07 and V07A has been extended to 7 days in 2022.

Appendix P presents the results of baseline vibration monitoring levels.

12.2.1.2 Secondary Data Collection (Review of Background Data)

Secondary data collection of previously measured data was conducted via desktop research or review of the client's resources and those available in the public domain (O-13 and R-1).

CR2005 reviewed baseline vibration monitoring data from a few separate studies by LTA [R-1, O-13] and Environmental Impact Assessment Report for Proposed Water Pipelines from Bukit Kallang to Upper Thomson Road [R-59].

Since the Project uses baseline data from different sources, processing differs. Where available, the Project reviewed and processed the raw data to minimise inconsistencies between data sets. The baseline vibration data are represented by the 99th percentile of the measured PPV values, of which the highest outliers in the data set are removed for this assessment. Further details of the baseline review are provided in Section 12.5.

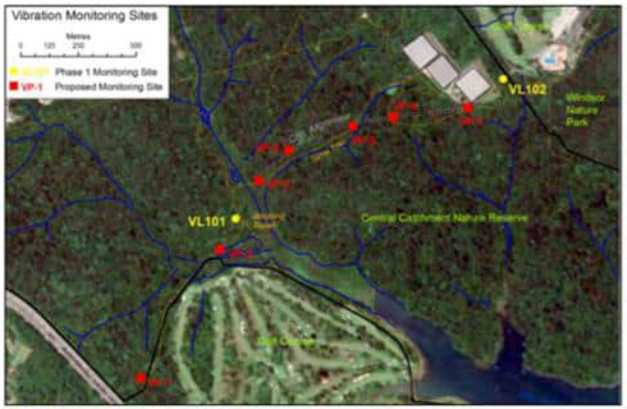
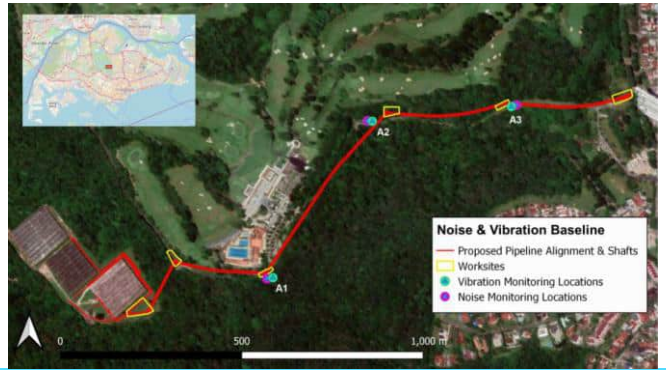
Table 12-1 Primary Baseline Ground-borne Vibration Monitoring Locations

Monitoring Location	Nearest Construction Worksite Area / Project Footprint	Sensitivity of Receptor	Justification	Photo of Monitoring Location
Within Eng Neo Avenue Forest –V07 (2020)	A1-W2 Worksite (Eng Neo Avenue Forest)	Priority 1	Representative baseline vibration monitoring location within Eng Neo Avenue Forest. The baseline ground-borne vibration level represents the area for A1-W2 construction worksite/ Project footprint since it is sited within the Eng Neo Avenue Forest.	
Within Eng Neo Avenue Forest – V07 (2022)	A1-W2 Worksite (Eng Neo Avenue Forest)	Priority 1	Representative baseline vibration monitoring location within Eng Neo Avenue Forest. The baseline ground-borne vibration level represents the area for A1-W2 construction worksite/ Project footprint since it is sited within the Eng Neo Avenue Forest.	

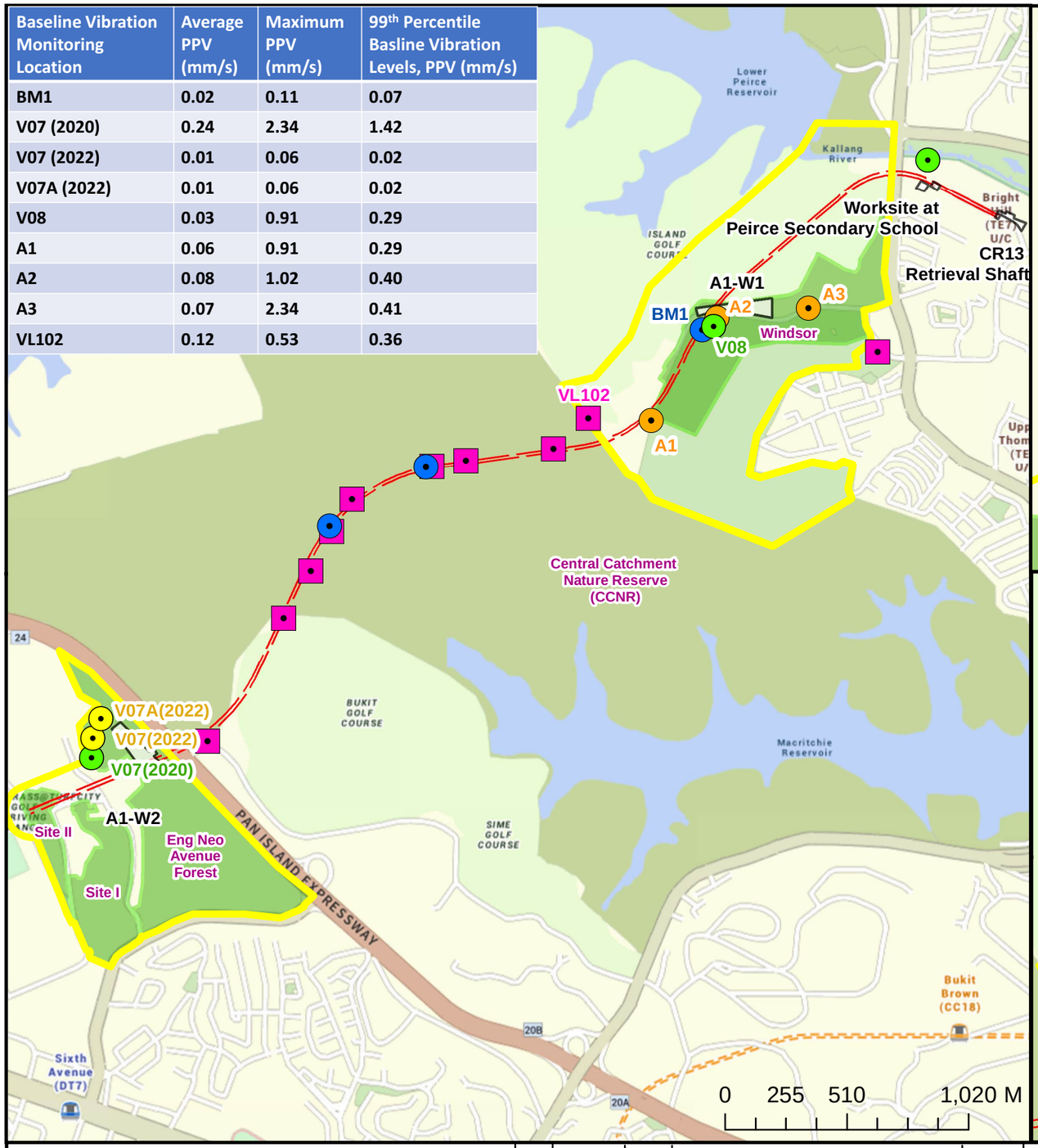
Monitoring Location	Nearest Construction Worksite Area / Project Footprint	Sensitivity of Receptor	Justification	Photo of Monitoring Location
Within Eng Neo Avenue Forest – V07A	A1-W2 Worksite (Deeper into Eng Neo Avenue Forest)	Priority 1	Representative baseline vibration monitoring location within Eng Neo Avenue Forest. The baseline ground-borne vibration level represents the area for A1-W2 construction worksite/ Project footprint since it is sited within the Eng Neo Avenue Forest.	
Windsor – V08	A1-W1 Worksite (Windsor)	Priority 1	Representative baseline vibration monitoring location within Windsor Nature Park. The monitoring setup was restricted to the paths and the allowed access areas as per the BIOME permit. The baseline ground-borne vibration level is very low as it is representative of the interior of the park.	

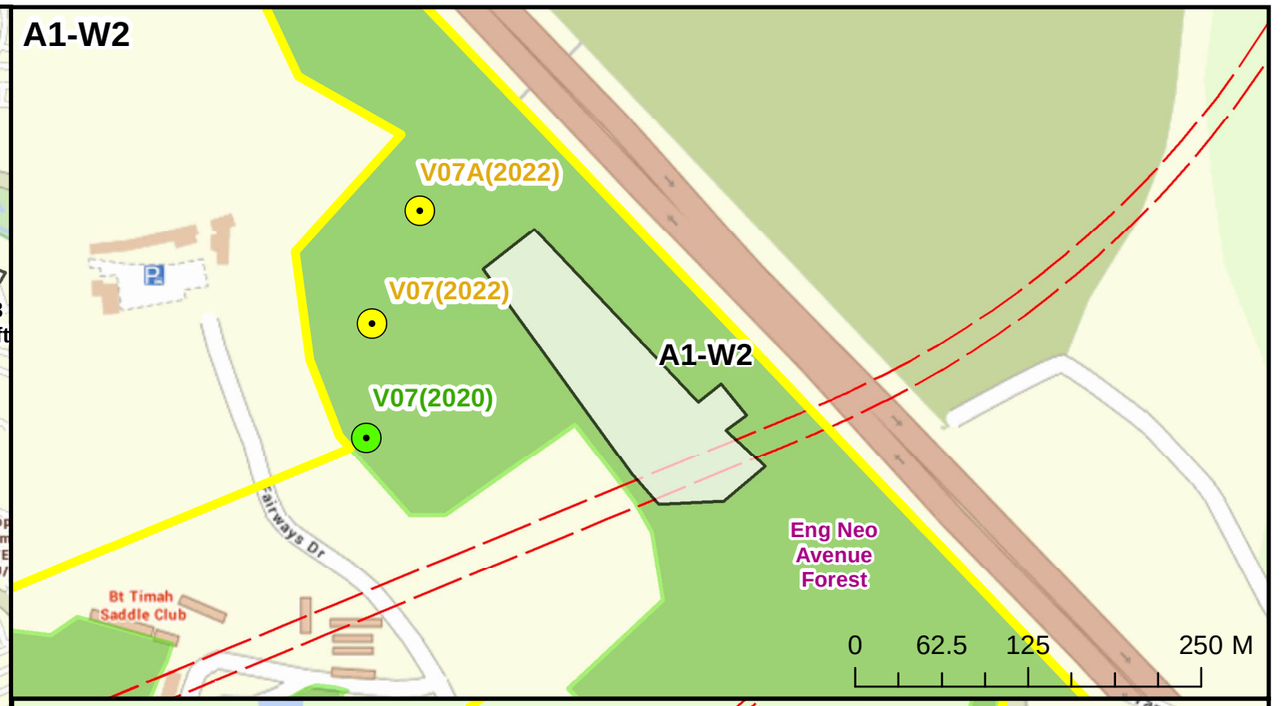
Table 12-2 Secondary Baseline Ground–borne Vibration Data

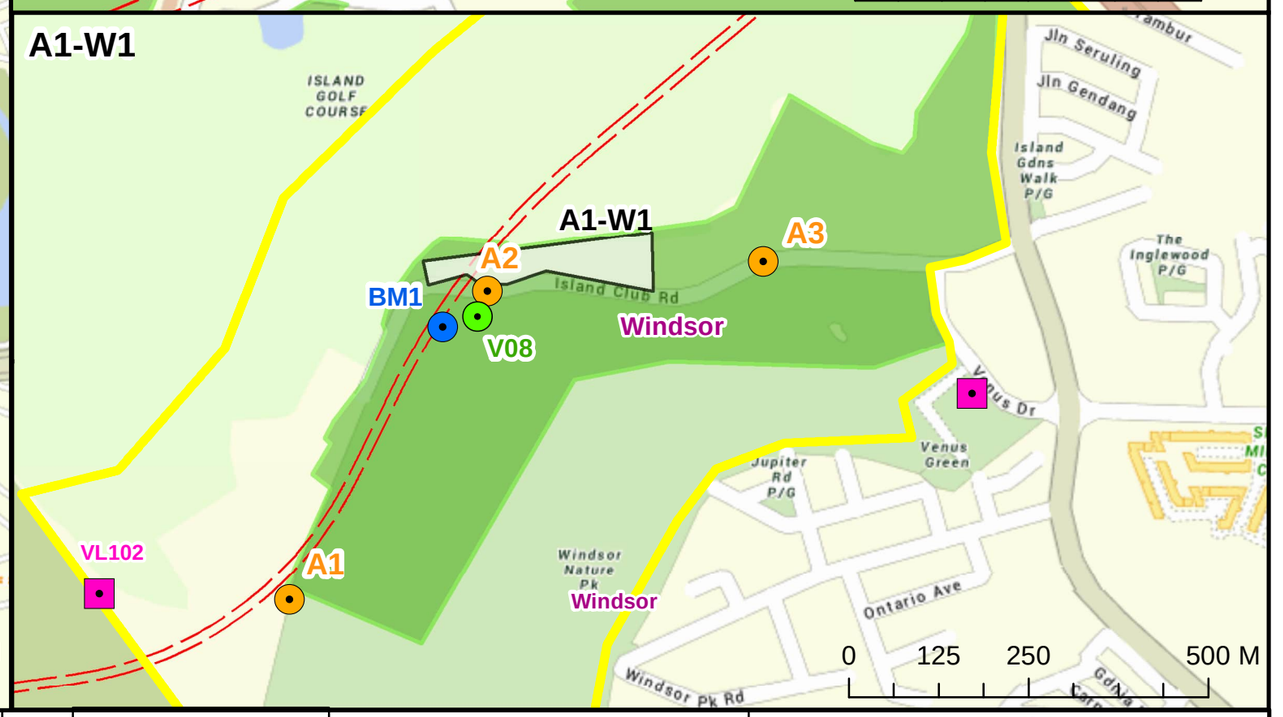
Baseline Vibration Monitoring Location		Source of Information
Eng Neo Avenue Forest Biodiversity Study Area		Ground-borne Noise and Vibration Study Powerpoint dated 5 March 2021 (a separate study by LTA) [O-13]
Windsor – BM1	 	Ground-borne Noise and Vibration Study Powerpoint dated 5 March 2021 (a separate study by LTA) [O-13]

Baseline Vibration Monitoring Location		Source of Information
Inside CCNR - VL102 (grass verge along PUB service road)	 Figure 3: Vibration monitoring sites VP-1 through VP-7, VL101 and VL102 within CCNR.	CR1001 CCNR EIA Report Volume 3, Annex 3.0
Windsor - A1 Windsor - A2 Windsor - A3		Environmental Impact Assessment Report for Proposed Water Pipelines from Bukit Kallang to Upper Thomson Road.

Baseline Vibration Monitoring Location	Average PPV (mm/s)	Maximum PPV (mm/s)	99th Percentile Basline Vibration Levels, PPV (mm/s)
BM1	0.02	0.11	0.07
V07 (2020)	0.24	2.34	1.42
V07 (2022)	0.01	0.06	0.02
V07A (2022)	0.01	0.06	0.02
V08	0.03	0.91	0.29
A1	0.06	0.91	0.29
A2	0.08	1.02	0.40
A3	0.07	2.34	0.41
VL102	0.12	0.53	0.36







Legend

- Baseline Vibration Monitoring Locations
- CR2008 Vibration Monitoring Location
- Bukit Kallang Pipeline Proposed Vibration Monitoring Location
- Vibration Monitoring - CCNR EIA [R-1]
- 20220317_Vibration_100m
- Base Scenario Construction Worksite Footprint
- Proposed CRL Alignment
- Biodiversity Study Area

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
BASELINE GROUND-BORNE VIBRATION MONITORING LOCATIONS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 1	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

12.2.1.2.1 *Baseline at Eng Neo Avenue Forest*

The 99th percentile vibration level at V07 in 2020 is 1.42 mm/s as the data show high vibration levels during the day and night. Since it was impossible to confirm the sources of localised activities causing this constantly high vibration, the baseline data was removed from this study.

The 99th percentile vibration level at V07 and V08 in 2022 is 0.02 mm/s as the points are far from vibration sources. V07 is 65 m from Fairways Drive, and V07A is 137 m from Pan Island Expressway. Although horses and small loaders are known to transit at these points, no significant vibration levels have been recorded during the one-week monitoring period. The measured data were analysed to determine vibration intensity thresholds for the impact intensity evaluation.

12.2.1.2.2 *Baseline at Windsor*

Six (6) baseline vibration measurements within the Windsor Nature Park were available at various distances from the nearby Island Club Road (Section 12.2.1.2). The vibration sources identified in this area include roads frequented by heavy vehicular traffic, human footfalls, a sewerage pump station, and SICC activities. Based on the vibration over the day and night periods, the dominant vibration source in this area seems to be the traffic on Island Club Road. The main factors influencing the levels and impacts of road traffic-induced vibration include:

- Source – depends on the vehicle mass, road surface condition, traffic flow and vehicle speed.
- Transmission path – includes receptor distance, soil/ ground absorption, spatial topography; and
- Receiver – species of vibration sensitive fauna, location and habits (home, feeding, foraging and breeding.)

No account has been made for the other vibration sources such as human footfall, other animals in Windsor Nature Park, the sewerage pumping station, and seismic background noise due to these sources' limited baseline vibration monitoring data at the time of this study.

Whilst the Windsor Nature Park 's underlying geology is consistent according to the borehole logs [R-70] [R-71], the baseline vibration levels measured at each location are influenced by local ground conditions that affect the propagation of vibration between the road and the measurement positions. A regression analysis of the measured data was undertaken to determine vibration intensity thresholds for the impact intensity evaluation.

12.2.2 Assessment Criteria

The study assesses the vibration impacts on the structural integrity of the burrows belonging to the fossorial species and the behaviour of the ecologically sensitive receptors in the biodiversity area.

Currently, there are no applicable Singapore or international standards or guidelines that assess the impacts of ground-borne vibration from the construction and operation of the railway on faunal/ ecological receptors. Based on the literature review, the impacts on the behaviour of ecological species and burrow collapse depend on the vibration level and the frequency of vibration.

Some species (burrowing rodents, ground spiders and termites.) use low amplitude and low-frequency vibration as a communication mechanism for fossorial fauna (animals adapted to living underground, often by digging burrows and tunnels). It is assumed that while their typical sensitive frequencies are within the range of frequencies anticipated to be produced by construction activities, the amplitudes of their vibration communications are typically below the baseline vibrations determined during the study. Therefore, fossorial fauna occupying the site can potentially accommodate construction induced vibration through frequency discrimination or otherwise due to the transient nature of construction vibration. This field of study is data deficient in the international arena and, in particular, the local context of Singapore to explore any deducible impact analysis. Therefore, this assessment has not considered the frequency range of construction vibration.

Vibration magnitude can impact a living being in two ways: 1) structural damage to its home/ abode (in the context of fauna, burrows for fossorial mammals), and 2) behavioural impact, which includes but is not limited to feeding and mating. While some information on the impact on fauna from vibration levels in other contexts is available, there is limited or no data available to correlate vibration levels to behavioural impact on fauna. Therefore, a criterion has been developed based on the step change of the Human Comfort Criteria.

Note that once structural damage occurs, it can potentially lead to fauna mortality. Hence the likelihood aspect of the assessment was removed, and the impact was assessed using intensity. However, behavioural impacts may be temporary or permanent; therefore, the likelihood/duration of impact was important in this case.

Note that there is minimal literature on how vibration may impact fauna. Therefore, this area requires several studies before reliable criteria can be established. A criterion has been developed based on the Human Comfort Criteria step change in the absence of reliable criteria.

12.2.2.1 Structural Integrity Criteria for Burrows

The literature review on the impact of vibration on fauna found insufficient data to provide reliable criteria. The available data are presented in Table 12-3 and include well-established criteria for buildings from the FTA [R-55] and information on the collapse of rat burrows [W-87].

The study assesses the vibration impacts on the structural integrity of the burrows belonging to the fossorial species and the behaviour of the ecologically sensitive receptors in the biodiversity area. The predicted construction vibration levels were screened to identify levels equal to or greater than PPV, 5.00 mm/s (equivalent to 50 % of the recorded vibration threshold). Based on these data, the vibration threshold for partial burrow collapse in a desert environment is PPV, 10.00 mm/s [W-87]. Rock breaking and excavation; high amplitude vibratory compacting could generate vibrations greater than PPV, 5.00 mm/s at the biodiversity study areas. The burrows may be susceptible to vibration damage and collapse, thus entombing the fossorial species. To avoid an overly onerous assessment that may be impractical for the Singapore context, the Project considered taking the 80% value of the vibration threshold as the assessment criteria – PPV, 8.00 mm/s for burrows.

For the A1-W2 worksite, the vibration threshold for rock breaking and excavation is 8 mm/s for fauna assessment;

Table 12-3 Vibration Thresholds for Structural Damage

Structure of Concern	PPV (mm/s)
Reinforced-concrete, steel or timber (no plaster) [R-55]	13
Engineered concrete and masonry (no plaster) [R-55]	8
Non-engineered timber and masonry buildings [R-55]	5
Buildings are extremely susceptible to vibration damage [R-55]	3
Partial Burrow collapse for Kangaroo Rat in Desert conditions [W-87].	10

12.2.2.2 Behavioural Criteria for Fauna

Vibration affects fauna in several ways (refer to Section 12.4.1). For a detailed assessment, vibration frequency and amplitude must be studied extensively before reliable impact criteria can be adopted across various projects.

Fauna of conservation species such as Sunda pangolin (*Manis javanica*) and lesser mousedeer (*Tragulus kanchil*) have been observed to inhabit both Eng Neo Avenue Forest (Table 7-15) and Windsor (Table 12-26), with a baseline vibration levels of PPV, 0.02 mm/s and PPV, 0.07 mm/s, respectively (Section 12.5.2). However, further vibration monitoring and ecological surveys would be required to determine the extent of habitation and the corresponding vibration levels across both areas.

Researchers studying the behaviour of laboratory mouse rats (a highly adaptable species) found transient responses in their creatures, including abrupt freezing of motion, contorted postures, and a wide range of responses

[W-91]. The vibrations that cause these responses are from 70 - 100 Hz at PPV, 1.1 - 2.0 mm/s, lasting between 2 and 10 seconds. Animals did not exhibit any behavioural response or impact when exposed to PPV, 0.1 mm/s at 70 - 100 Hz. Note that Windsor's baseline vibration (PPV, 0.07 mm/s) is lower than this.

While the mouse rats used in this study seem to adapt to human movements and presence, the wild fauna is considered shyer and may not be used to fluctuations in vibration caused by human intervention. The human

intervention activities for this Project are rock breaking and excavation, rotary bore piling, bulldozing, vibratory compacting, and tunnel boring.

Guidance on human response to vibration in buildings is available from BS 5228-2:2009+A1:2014, BS 6472-1:2008 and BS 6472-2:2008. This guidance advises that humans respond differently according to individual sensitivities and the vibration time (day or night).

Whilst human response and faunal behaviour are not directly comparable, a grading of impact intensity (Negligible, Low, Medium and High) for fauna has been derived. This grading system is based on the step change of human response and comfort level from BS 5228-2_2009+A1_2014; and the 99th percentile of baseline vibration for the Study Area (refer to Table 12 4). The difference between impact intensity values was also used to derive each vibration threshold curve for the assessment. The following explains how the impact intensity criteria are developed:

Step 1: Calculate step increment between each thresholds of the Human Comfort Criteria (see column 3 of Table 12-4).

Step 2: Apply calculated step increment to baseline of 0.07 mm/s to obtain the absolute values for impact intensity (see column 4 of Table 12-4).

Step 3: Calculate the difference (delta) between each absolute values (see column 5 of Table 12-4).

Step 4: PPV values below ambient are not assessed. Hence, the first threshold (T1) would start from ambient (see row 2 of Table 12-5).

Step 5: Add the first delta value to ambient to obtain T1 (see row 3 of Table 12-5).

Step 6: Add the second delta value to T1 to obtain T2 (see row 4 of Table 12-5).

Step 7: Repeat for T3 and T4. The last threshold should be > T4 (see rows 5 to 7 of Table 12-5). This is the criteria for Windsor.

Step 8: To calculate the criteria for Eng Neo Avenue Forest, repeat Step 2 but with a baseline of 0.02 mm/s (see column 6 of Table 12-4).

Step 9: Calculate the difference (delta) between the first three absolute values (see column 7 of Table 12-4).

Step 10: Add the first delta value to ambient to obtain T1 (see row 3 of Table 12-5), add the second delta value to T1 to obtain T2 (see row 4 of Table 12-5).

Step 11: For Eng Neo Avenue Forest, T3 will have a range from T2 to Windsor's forth absolute value (2.49), (see row 5 of Table 12-5).

Step 12: For Eng Neo Avenue Forest, T4 will have a range from T3 to Windsor's fifth absolute value (4.99) (see row 6 of Table 12-5).

Table 12-4 presents the step change in vibration intensity thresholds for Windsor and Eng Neo Avenue Forest.

Table 12-4 Step Change in Vibration Intensity Thresholds

Based on Human Comfort Criteria BS5228-2: 2009+A1:2014			Criteria for Fauna			
Impact Intensity (Human Comfort Criteria)	Human Response Absolute Level PPV (mm/s)	Relative Change from Previous Intensity Level	Absolute Values Impact Intensity for Windsor	Difference between Impact Intensity Values for Windsor	Absolute Values Impact Intensity for Eng Neo Avenue Forest	Difference between Impact Intensity Values for Eng Neo Avenue Forest
Just perceptible in most sensitive situations	0.14	-	0.07	-	0.02	-

Based on Human Comfort Criteria BS5228-2: 2009+A1:2014			Criteria for Fauna			
Impact Intensity (Human Comfort Criteria)	Human Response Absolute Level PPV (mm/s)	Relative Change from Previous Intensity Level	Absolute Values Impact Intensity for Windsor	Difference between Impact Intensity Values for Windsor	Absolute Values Impact Intensity for Eng Neo Avenue Forest	Difference between Impact Intensity Values for Eng Neo Avenue Forest
Just perceptible in residential	0.3	0.3 / 0.14 = 2.14	0.15	0.08	0.10	0.08
Complaints in residential	1.0	1.0 / 0.3 = 3.33	0.49	0.35	0.45	0.35
Intolerable	10	10.0 / 1.0 = 10	2.49 and 4.99	1.96 2.49	2.49 and 4.99	No difference required, use the same Absolute Values from Windsor

Table 12-5 shows the difference between impact intensity values used to generate the threshold range.

Table 12-5 Thresholds for Vibration Impact Assessment

Threshold	Range for Windsor	Range for Eng Neo Avenue Forest
-	< Ambient	< Ambient (0.02)
T1	Ambient + 0.08	Ambient (0.02) + 0.08 = 0.10
T2	T1 + 0.35	T1 + 0.35 = 0.45
T3	T2 + 1.96	T2 (0.45) to 2.49
T4	T3 + 2.49	T3 (2.49) to 4.99
> T4	> T3 + 2.49	> T3 (2.49) to 4.99

In addition to using these derived criteria to complete the evaluation, the study considers the known behaviour of the animals, the intensity of behavioural changes, and the extent of impacts on the home range. A matrix for impact intensity was formulated with two components, vibration thresholds and impacted area (based on the home range of the Sunda pangolin).

The baseline vibration values differ between the Biodiversity Study Area (Eng Neo Avenue Forest vs Windsor) and spatially within Windsor as human and horse activity (vibration sources) are limited to certain areas such as boardwalks.

Examination of the baseline vibration in Windsor suggests that the road is the dominant vibration source, with vibration levels of PPV, 0.1 - 0.4 mm/s at 8 - 30 m from the road (Section 12.5.2). Vibration levels decay over distance, further away from the road at 50 m; the measured vibration is PPV, 0.07 mm/s.

While birds tend to move away more easily and find other sources of habitation, fossorial animals may find it harder to do so and may/ may not adapt to the conditions. With the paucity of information coupled with the myriad behaviours of fauna, vibration impacts are hard to predict. Therefore, as a conservative approach, species deep in

the forest has different behaviour compared to those living near the road. Species may habituate to the road vibration levels for their activities, while species living deep in the forest are more sensitive to vibration levels. This consideration is a conservative approach that may not represent fauna adaptation capability. The study has erred on caution due to the paucity of information.

There are limitations concerning established reliable criteria for assessing vibration impact on fauna. 99th percentile of baseline vibration data was used to develop a criterion for Eng Neo Avenue Forest; used as an input to a

regression equation to calculate the impact intensity criteria for Windsor. The baseline study comprises monitoring carried out (primary data collection) and data measured previously for other Projects (secondary).

Since the vibration level from the road attenuates over distance, a conservative assessment suggests that the intensity criteria should not be fixed at a constant level but kept as a range in terms of ambient level and area affected. This consideration is relevant because fauna generally located within the Study Area are subject to these ongoing vibration levels and hence are habituated to these levels and are not disturbed by the human activities in the area. The sections below detail how this approach was materialised into intensity criteria and likelihood for predicting and evaluating impacts.

12.2.2.3 Determining Impact Intensity

For the construction phase, the assessment in this report predicts the ground-borne vibration impacts during identified stages of the construction phase. AECOM referred to *BS 5228-2:2009+A1:2014, BS 6472-1:2008, BS 6472-2:2008* and *the FTA Transit Noise and Vibration Impact Assessment Manual (2018*) for guidance in predicting vibration levels of the construction activities for this Project.

Where available, local data have also been used to increase the accuracy of the predictions to account for local ground conditions, including rock breaking and excavation and TBM activities.

To determine the impact on structural damage, if the predicted vibration level is higher than PPV, 5.00 mm/s, such as rock breaking and excavation, these may result in severe impacts such as fauna mortality in some cases. Therefore, if rock breaking and excavation must be carried out during construction, its intensity can be controlled based on the chemical dosage. Impacts from this phase shall be assessed in this study, emphasising the intensity of impact with an objective for it to be kept as low as reasonably practicable below a threshold value of PPV, 8.00 mm/s (see Section 12.2.3.1.4.1).

For other construction activities (such as piling and TBM) and the operational phase, the vibration levels are likely lower than PPV, 5.00 mm/s.

For behavioural impact assessment, the fauna is mobile within the Biodiversity Study Area and neighbouring areas, which are wooded and provide appropriate habitat. The Biodiversity Study Area that faunal species use for their feeding, resting and breeding is their home range. It is anticipated that a **High** impact intensity over a small fraction of the home range could be considered a **Low** impact intensity as the fauna are mobile. Also, a **Low** impact intensity over a large fraction of the home range could be considered low. Hence these two parameters are not independent, and an impact intensity matrix has been derived for this study.

Table 12-6 Impact Intensity Assessment for Construction and Operational Vibration

Area Affected (ha)	Impact Intensity				
6 < area	Negligible	Low	Medium	High	High
4.8 < area ≤ 6	Negligible	Low	Medium	Medium	High
2.4 < area ≤ 4.8	Negligible	Low	Low	Medium	High
1.2 < area ≤ 2.4	Negligible	Neglible	Low	Medium	Medium
0 < area ≤ 1.2	Negligible	Negligible	Low	Medium	Medium
Ambient Level	**Ambient to T1**	**T1 to T2**	**T2 to T3**	**T3 to T4**	**> T4**

The baseline and vibration levels from the construction activities were predicted using coding in ArcGIS. Based on the matrix, the Impact Intensity is identified. This would be used to identify the Impact Consequence and, subsequently, Impact Significance. This study, therefore, proposes the impact assessment criteria in Table 12-6 above. This impact assessment criterion assesses vibration impacts caused by construction and operation phases.

To determine and quantify impact amplitude for the operational phase, a separate study by LTA provided inputs on predicted vibration levels from the operation of the trains.

12.2.3 Prediction and Evaluation of Impact Assessment

The assumptions, predictions and evaluation of impact assessment methodology for the construction and operational phases are presented in this section. Based on the geographical profile study conducted (refer to

Section 4.7), the local geological profile along the Project alignment is mainly dominated by Bukit Timah Granite (Rengam Facies).

12.2.3.1 Construction Phase

12.2.3.1.1 *Identification of Potential Sources of Impacts*

In a typical underground railway construction phase, as described in Section 3.2, there are several potential sources of ground-borne vibration impacts such as rock breaking and excavation, rotary bore piling, tunnel boring and bulldozer. Simultaneous equipment operation could increase vibration levels substantially, but predicting any cumulative increase is impossible without a detailed construction programme. FTA Transit Noise and Vibration Impact Assessment Manual (2018) [R-55] states that potential effects from construction vibration for each piece of equipment shall be assessed individually.

Both underground and above-ground construction works are expected at A1-W2 and A1-W1 worksites, whereas only underpinning works are expected for the worksite at Peirce Secondary School. The work associated with the CR13 TBM retrieval shaft worksite is covered under this Contract. In contrast, the station worksite and associated impacts have been previously covered under a separate contract (Cross Island Line Phase 1 or CRL1). The station is already underway construction during the writing of this report.

12.2.3.1.2 *Identification of Sensitive Receptors*

Ecologically sensitive receptors at Eng Neo Avenue Forest and Windsor may be impacted by the construction and operation of the Project. Sensitive receptors are identified based on the Study Area (i.e. the Biodiversity Study Area around the construction worksites during the construction phase; the Biodiversity Study Area around the rail alignment during the operational phase). Based on the experience of similar projects and studies on the impact on humans, it is anticipated that effects from construction and operation generated vibration will not generally occur outside the vibration Study Area as the vibration levels by this distance typically tend to dissipate to insignificant levels. If an impact is significant within the entire Study Area, such as rock breaking and excavation, the Study Area was increased to assess and envelope a more expansive area until the impact dissipates to near ambient conditions. Vibration sensitive receptors are sub-categorised into three categories: Priority 1, Priority 2 and Priority 3 (from the most sensitive to the least) based on the known impact of vibration and species sensitivity in the available literature. Urban areas such as houses and existing roads are not assessed.

12.2.3.1.3 *Understanding of Baseline Conditions*

Primary and secondary data were used to establish the baseline conditions of vibration levels from existing natural and anthropogenic (human) sources. Where adequate baseline monitored data were available, the regression method was used to determine the vibration levels at different distances from the source.

12.2.3.1.4 *Minimum controls*

During the development of this report, working meetings with LTA and LTA's appointed technical advisor were held to provide inputs into the design and therefore try to optimise the design with the least environmental impact. Therefore, these recommendations have been incorporated into the design and considered basic minimum control.

12.2.3.1.4.1 Rock Breaking and Excavation at Windsor

The prediction in the EIS is highly conservative and provides a high-level impact assessment of the vibration impacts on ecologically sensitive receptors. A study [W-89] states that variations in geological profile (as excavation is sequentially carried out) can change the vibration attenuation significantly; the vibration on the ground surface is much smaller than below the ground surface; the vibration wave attenuation of rock is much lower than that in soil.

As mentioned in Section 12.2.2.1, the vibration threshold used for assessing structural integrity is PPV, 8.00 mm/s.

Several researchers have investigated how ground vibration can be predicted and have proposed various formulae based on field observations from several sites. CR2005 has predicted vibration levels for rock breaking and excavation following the guidance of BS 647-2-2008 and, secondly, with an empirical equation (from LTA Contract T207).

Using the guidance of BS 6472-2-2008, the Project predicts the vibration levels emitted for the various MIC and slant distance combinations for the construction vibration impact assessment. The empirical relationship between predicted vibration level, PPV (mm/s), MIC (kg) and distance, x (m), is expressed in the equation below:

Equation 1

$$PPV = 1291\left(\frac{x}{\sqrt{MIC}}\right)^{-1.5}$$

Based on Equation 1 above, the PPV, 8.00 mm/s, occurs at 50.5 m from the source at MIC of 2.9 kg and 30 m from the source at MIC of 1.7 kg, as seen in Table 12-7.

Table 12-7 Predicted Values Using BS 6472-2-2008 Equation

Depth / m	Horizontal Distance / m	Slant Distance / m	Maximum Instantaneous Charge					
			1.2 kg	1.3 kg	1.5 kg	1.7 kg	2 kg	2.9 kg
			Peak Particle Velocity, mm/s					
25	10	27	11	11	13	14	16	21
	19	31	8	9	10	11	12	16
	20	32	8	9	10	11	12	16
	30	39	6	6	7	8	9	12
	40	47	5	5	5	6	7	9
	45	51	4	4	5	5	6	8
	50	56	4	4	4	5	5	7
	100	103	1	2	2	2	2	3
	200	202	1	1	1	1	1	1
	300	301	0	0	0	0	0	1

The predicted vibration levels of rock breaking and excavation are presented in Section 12.7.1.3.1 for the A1-W1 worksite. Appendix T presents the detailed calculation.

For added comparison, an equation from T207 has been used to predict vibration levels for the same activities. The formula is:

Equation 2

$$PPV = K(D/\sqrt{MIC})^{-n}$$

D is the distance (m), MIC is the charge (kg), K is the site-specific constant (1200), and n is the site-specific constant (1.6). The prediction assumes that the site constants apply to the A1-W1 worksite.

Based on Equation 2 above, the PPV, 8.00 mm/s, occurs at 30 m from the source at MIC of 2.9 kg, as seen in Table 12-8.

Table 12-8 Predicted Values Using T207 Equation

Depth / m	Horizontal Distance / m	Slant Distance / m	Maximum Instantaneous Charge					
			1.2 kg	1.3 kg	1.5 kg	1.7 kg	2 kg	2.9 kg
			Peak Particle Velocity, mm/s					
25	10	27	7	8	9	9	11	14
	19	31	6	6	7	7	8	11
	20	32	5	6	6	7	8	11
	30	39	4	4	5	5	6	8
	40	47	3	3	3	4	4	6
	45	51	3	3	3	3	4	5
	50	56	2	2	3	3	3	5
	100	103	1	1	1	1	1	2
	200	202	0	0	0	0	0	1
	300	301	0	0	0	0	0	0

Between the two prediction methods, the equation from T207 gives higher estimates for the same MIC and distance combinations. The vibration level calculated at *MIC* = 2.9 *kg* was PPV, 8.00 mm/s at 30 m which coincides with the boundary of the A1-W1 worksite. Thus, the *MIC* = 2.9 *kg* was used for further assessments. Given the potential for fauna mortality at its first instance of likelihood, the assessment for this type of activity was delinked from likelihood or duration (considering it definitive as a worst-case) and focused on the intensity of impact.

The activities detailed for rotary bore piling and bulldozing were predicted to be much lower than 8 mm/s PPV, therefore, assessed for behavioural impacts on the fauna. Activities such as tunnel boring, vibratory compactor, rock breaking, and excavation with predicted vibration levels of more than PPV, 5.00 mm/s were assessed for structural collapse.

12.2.3.1.4.2 Rock Breaking and Excavation at Eng Neo Avenue Forest I

In the base scenario where the worksite is within Eng Neo Avenue forest, rock breaking and excavation assessments were conducted similar to Windsor. Assessments were determined using a depth of 25 m and MIC *2.9 kg* for the T207 approach and MIC *1.7 kg* for the BS 6472-2-2008 Equation approach.

The vibration impact assessment from rock breaking and excavation works at A1-W2 compares the predicted vibration levels against the vibration threshold of PPV, 8.00 mm/s. Apart from the ecological receptors affected by the high vibration levels, nature's ecological structures, such as burrows for fossorial species, may be susceptible to vibration damage and collapse, thus entombing the fossorial species. Since the impacts could impact mortality rates of the fossorial species, an assessment using a vibration threshold is most conservative for this Project. The vibration threshold for partial burrow collapse in a desert environment is PPV, 10.00 mm/s [W-87]. Hence, it should be noted that the vibration threshold causes site-specific burrow collapses. To avoid an overly onerous assessment that may be impractical for the Singapore context, CR2005 suggests taking the 80% value of the upper vibration threshold as the assessment criteria. Thus, a vibration threshold of PPV, 8.00 mm/s, is recommended for the assessment.

One source of rock breaking and excavation was assessed for the launch shaft for the mitigated scenario.

Table 12-9 Predicted Values Using BS 6472-2-2008 Equation for Launch Shaft

Depth / m	Horizontal Distance / m	Slant Distance / m	Maximum Instantaneous Charge		
			0.2 kg	0.3 kg	0.4 kg
			Peak Particle Velocity, mm/s		
18	10	27	2.7	3.7	4.6
	20	32	2.1	2.8	3.5
	30	35	1.8	2.5	3.1

Table 12-10 Predicted Values Using T207 Equation for Launch Shaft

Depth / m	Horizontal Distance / m	Slant Distance / m	Maximum Instantaneous Charge, kg		
			0.5 kg	0.6 kg	0.7 kg
			Peak Particle Velocity, mm/s		
18	10	27	3.5	4.1	4.6
	20	32	2.6	3.1	3.5
	30	35	2.3	2.7	3.0

12.2.3.1.4.3 Rotary Bored Piling

The activities detailed in this section were predicted to be much lower than PPV, 3.00 mm/s. Therefore, they assessed for behavioural impacts on the fauna only.

This study assumed that the rotary bore piling method drills small diameter holes, which are then grouted by cement grout after placement of steel reinforcement bars (refer to Section 3.2.2.2.2), to analyse rotary bore piling, ground-improvement works and underpinning works. Therefore, the vibration impacts from the rotary bore piling method are assessed for A1-W2, A1-W1, Peirce Secondary School and CR13 Retrieval Shaft worksites (base and mitigated scenarios). The rotary method is a relatively common and low vibration piling method used in Singapore. However, when writing this report, there is no formula to predict the vibration levels from the rotary bore piling.

AECOM predicts the vibration levels using regression analysis of the historical data set (see Appendix T). For a conservative assessment, CR2005 considers the 95th percentile in the historical data pool to form a regression analysis of historical data to predict the PPV levels at the distance of this Project's ground-borne vibration ecologically sensitive receptors.

The empirical relationship between predicted vibration level, PPV and distance is plotted in the figure below and has the equation: $\boldsymbol{PPV = 102.31x^{-2.073}}$

$$y = 102.31x^{-2.073}$$

Where y is the predicted PPV level and x is the distance between source and receptor.

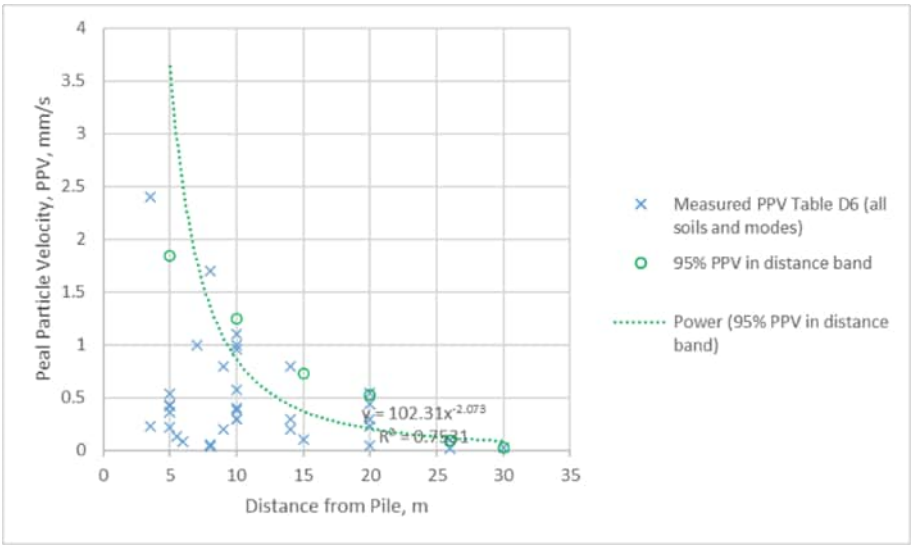


Figure 12-2 Vibration Prediction Curve for Rotary Bore Piling

The regression line calculation to predict vibration levels for rotary bore piling is detailed in Appendix T.

12.2.3.1.4.4 Tunnel Boring

This study assessed the vibration impacts of tunnel boring in Eng Neo Avenue Forest and Windsor (base and mitigated scenarios). The vertical alignment in the Biodiversity Study Area remains the same for the base, and mitigated scenarios are controlled by the level below the rock head [O-11]. The ground-borne vibration levels caused by tunnel boring were predicted using the method stated in BS5228-2:2009+A1:2004. The geological profile is typically not homogamous; however, to simplify the process for the assessment, it is assumed to be. The predicted results are potentially conservative since the formula is applicable for soil types.

$$v\_res \leq \frac{180}{r^{1.3}}$$

Where:

v_res is the resultant ppv, in millimetres per second (mm/s)

$10 \leq r \leq 100$ m

r is the slope distance from the tunnel crown, in metres (m)

This study also predicts the vibration level from tunnel boring using the Esvelt equation used in the CRL1 EIS Report [R-1]. Esvelt formula assumes Bukit Timah Granite (G2 – G3 rock type) to have a substrate hardness factor, B of 0.95 . It is estimated that these rock types are primarily encountered at the tunnel boring level under Windsor and Eng Neo Avenue Forest. Based on CRL 1 EIS Report [R-1] Esvelt equation with parameters was calibrated to empirical data based on granodiorite substrate (UK). The resulting prediction curve was independently verified using datasets from two other tunnelling sites (Sydney and Hong Kong). The Esvelt equation is a particular class of WISS equation used in the British Standard. The scalar parameter is determined as a TBM Diameter function, Material Density, and 3D Distance from TBM. It is the only available equation that parameterises the TBM cutter head diameter.

The BS5228-2:2009+A1:2004 and Esvelt equation is also used in the assessment for the transition tunnel, which comprises Bukit Timah Granite (G2 and G3 rock type). The transition tunnel is assumed to be done by drilling two (2) individual tunnels one after the other. Since tunnel boring occurs near heritage buildings, the vibration levels should not exceed the threshold of PPV, 3.00 mm/s, according to DIN 4150 [R-73]. The appointed Contractor should ensure compliance throughout the construction duration.

The equation used is:

$$PPV = \frac{10BDia}{r^n}$$

Where:

Dia is the TBM cutting wheel diameter (Single bored tunnel: 12.2m, Transition tunnel: 10m)

r is the slope distance from track level to receptor (m)

n is a site-specific constant (1.35) determined by calibration*

The prediction assumes that $n = 1.35$ applies to CR2005.

*In CRL1 EIS Report [R-1], it is reported that the Esvelt prediction model is based on measurements taken during the construction of the Epping to Chatswood Rail Line in Sydney, Australia and validated on the Kowloon, Southern Link construction in Hong Kong.

12.2.3.1.4.5 Bulldozing

The activities detailed in this section were predicted to be much lower than PPV, 3.00 mm/s; therefore, they only assessed for behavioural impacts on the fauna.

Bulldozing was also assessed for the base scenario at Eng Neo Avenue Forest and both base and mitigated scenarios for Windsor.

The vibration level from the bulldozer is predicted using the formula from the FTA [R-55]. The bulldozer is generally mobile as it tends to move around the worksite. However, the bulldozer is assumed to be stationary for the construction vibration impact assessment. The equation is used to predict the vibration attenuation over distance.

$$PPV_{equip} = PPV_{ref} \times (\frac{7.62}{D})^{1.5}$$

Where:

PPV_{equip} is the peak particle velocity of the equipment adjusted for distance, mm/s

PPV_{ref} is the source reference vibration level at 7.62 m, mm/s

D is the distance from the equipment to the receiver, m

Note that the equation is based on point sources with normal propagation conditions.

The vibration source levels from typical large and small bulldozers are provided in Table 12-11. It presents the average source level in terms of velocity. The approximate rms vibration velocity level was calculated from the PPV limits using a crest factor of 4, representing a $PPV - rms$ difference of 12 dB. Note that although the table gives one level for each piece of equipment, there is considerable variation in reported ground vibration levels from construction activities. The EIS assessed the vibration impacts from a typical large bulldozer in Section 12.7.1.2.1.3.

Table 12-11 Vibration Source Level for Construction Equipment from FTA [R-55]

Equipment	PPV at 25 ft (7.62 m), mm/s
Large Bulldozer	2.26
Small Bulldozer	0.08

12.2.3.1.4.6 Vibratory Compactor

The vibration level from the vibratory compactor is predicted using the formula from BS5228-2:2009+A1:2004. The vibratory compactor is used to construct a temporary road near the A1-W2 worksite. For the construction vibration impact assessment, the vibratory compactor is assumed to be stationary. The equation is used to predict the vibration attenuation over distance.

$$\boldsymbol{PPV_{equip} = K\sqrt{n}\left(\frac{A}{x+L}\right)^{1.5}}$$

Where:

$\boldsymbol{PPV_{equip}}$ is the peak particle velocity of the equipment, mm/s

$\boldsymbol{K}$ is the scale factor, where 75.0 is used

$\boldsymbol{n}$ is the number of vibrating drums (assuming 1 for this assessment)

$\boldsymbol{A}$ is the amplitude of the vibrating drum, mm, where 2.05 mm is used for High vibration and 0.87 mm is used for Low vibration based on the Sakai 10 tonne compactor

$\boldsymbol{x}$ is the distance from the vibrating drum

$\boldsymbol{L}$ is the width of the vibrating drum

The EIS assessed the vibration impacts from a typical vibratory compactor. Note that the elevation near the temporary road access differs slightly. However, landfilling was not included in this assessment.

12.2.3.1.5 *Classification of Overall Consequence*

A consequence category is derived based on receptor sensitivity and impact intensity, as shown in Section 6.4.2.1. The ground-borne vibration impact assessment uses a matrix method to determine the overall consequence in Table 12-12.

Table 12-12 Impact Consequence Matrix (For Ground-borne Vibration)

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

12.2.3.1.6 *Establishing Impact Significance*

The approximate number of days within a construction timeline is calculated from the start date to the end date. Refer to Table 12-13 for the likelihood evaluation for construction activities for the construction vibration impact assessment.

In general, the likelihood of ground-borne vibration impacts due to rock breaking and excavation, piling and tunnel boring occur during the construction phase.

In the operational vibrational impact assessment, the trains operate daily between 5.30 am and around midnight. Train-induced vibration occurs during the operation unless there is an unplanned or catastrophic event that results in the service's cessation. The duration of the ground-borne vibration impacts experienced by the receptor is only whilst the train is passing. Hence it is overly onerous to assume that the impact is continuous. According to LTA [O-16], based on the train's length, speed and frequency, the likelihood of occurrence for a single passage passing by a receptor is **Possible** since the operational vibration is present 23% of the time within 24 hours.

LTA [O-18] also studied the combined vibration results of simultaneous trains passing in both directions as an upper limit. It assumed that simultaneously passing trains occurred at all points along the alignment but only in specific locations. Therefore, the combined vibration levels give an overestimate of impact. A recent study by LTA showed that the maximum levels were similar between one single pass by and a simultaneous pass-by. Therefore, the report scoped out the vibration impact for two simultaneous trains passing each other.

In this work, the predicted vibration from the train on the nearest track is therefore taken as a representative vibration level for the operational impact assessment.

Table 12-13 Likelihood Evaluation for Construction Activities for Ground-borne Vibration Impact Assessment

Activity	Frequency of Exposure	Likelihood of Occurrence
Rock Breaking and Excavation	Work period = 1 Active vibration period for Machinery = 1 1 x 1 = 1	**Certain**
Rotary Piling	Work period = 0.5 Active vibration period for Machinery = 0.5 0.5 x 0.5 = 0.25	**Possible**
Bulldozer	Work period = 0.5 Active vibration period for Machinery = 0.5 0.5 x 0.5 = 0.25	**Possible**
Vibratory compactor	Work period = 0.5 Active vibration period for Machinery = 0.14 0.5 x 0.14 = 0.07	**Less Likely**
Tunnel Boring Machine (TBM)	Work period = 1 Active vibration period for Machinery = 0.72 0.72 x 1 = 0.72	**Certain**
Operational	MRT operational period per 24 h = 0.8 Bidirectional passing within 24 h = 0.23 0.8 x 0.23 = 0.20	**Possible**

*Bulldozers may be used during groundworks; the actual duration is challenging to predict; this conservative assumption is for the operation to be not higher than 15% of the construction period.

12.2.3.1.7 *Mitigation Measures and Adaptive Monitoring Programme Recommendation*

Vibration mitigation measures are recommended for the affected ecologically sensitive receptors based on the impact evaluation outcome. The vibration mitigation measures are based on the principles:

- elimination/avoidance;
- minimisation (substitution);
- minimisation (engineering controls); minimisation (administrative controls);
- remedy/repair/restore; and
- compensation/offset.

In addition, an environmental monitoring program is proposed to validate the findings of the EIS report. Works shall be controlled or re-evaluated if the monitored levels are significantly different from the predicted ones.

12.2.3.1.8 *Establishing Residual Impact Significance*

With the mitigation measures included in the assessment, a residual impact significance using the same significance matrix was re-evaluated. This residual impact should be reduced to insignificant levels or as low as reasonably practicable using cost-benefit analysis. An iterative process of suggesting mitigating measures and re-assessing was used where required.

12.2.3.2 Operational Phase

Independent noise and vibration consultants have carried out operational phase impact predictions under a separate study by LTA [O-13]. The findings available at the time of writing of this report are summarised here.

Based on the information from LTA, the general prediction model is described below:

- Source of vibration.
- Propagation path of vibration; and
- Receptor response.

The vibration source was determined from vibration measured on the track slab of an existing operational underground railway alignment. A tunnel on the MRT Circle Line was used.

A two dimensional (plane strain) finite element model (FEM) was used to estimate the change in the vibration transfer functions from source to receptor due to the different soil characteristics between the measured site and the CR2005 alignment, plus changes in tunnel depth and receptor distance.

In the separate study, LTA used GIS to calculate the expected vibration levels (in decibels, VdB) at the surface level for different tunnel depths along the alignment, based on:

- The horizontal and vertical alignment details from drawings reference PCRLSWD-PP9400, dated 29 January 2021, provided by LTA from a separate study. It should be noted that LTA has calculated vibration levels based on a maximum tunnel depth of 50 m in another separate study for this report.
- Referring to Section 4.7, the geological information for the Project describes the two main formations along the alignment:
    - Bukit Timah Granite Formation, partly with Kallang Formation on the top layer; and
    - Jurong Formation, partly with Kallang Formation on the top layer.
- Single bore tunnels.
- Non-ballasted track.
- Standard baseplates pads[9].
- Other train characteristics include:
    - Number of cars: 8
    - Total train mass (tare condition): 40 ton

[9] Baseplate pads are installed under the baseplate to reduce vibrations caused by wheel and track irregularities.

- Unsprung mass: 4.4 ton

As part of the LTA's separate study, validation measurements were conducted to compare the results of the modelling with the measured data:

- Trackside and surface measurements for two locations and the Circle Line - PSA Club (Telok Blangah) on Jurong Formation and Singapore Polo Club (Caldecott) on Bukit Timah Granite Formation.
- Surface measurement at one location along Circle Line - University Road Park.

Based on the predicted vibration levels from LTA, AECOM carried out an environmental impact assessment on the ecological receptors identified at Windsor and Eng Neo Avenue Forest (i.e. Biodiversity Study Areas) according to the impact evaluation matrix stated in Section 6.4.2. The assessment results are presented and discussed in Section 12.7.2.

12.3 Potential Sources of Ground-borne Vibration Impacts

12.3.1 Construction Phase

Table 12-14 lists the potential sources of ground-borne vibration impacts during the construction phase.

Table 12-14 Potential Sources of Ground-borne Vibration Impacts during Construction Phase

Construction Activity	Associated Impacts
Compacting of concrete using the vibrator equipment Piling works for the foundations of the facility building Rotary piling works for ground improvements and underpinning works. Tunnel boring using the TBM Rock breaking and excavation Vibratory sheet piling for temporary works Heavy construction vehicles such as bulldozers and vibratory compactors Other Construction Equipment Stationary equipment with diesel engines	Structural Damage Ecological Foraging Behaviour

Based on the review and the evaluation of the proposed construction methods for CRL2, the critical sources of construction induced vibration are rock breaking and excavation, piling and tunnel boring works. The associated ground-borne vibration impacts from these activities works may cause disturbance to the ecological foraging behaviour to the receptors near the construction area.

12.3.1.1 Rock Breaking and Excavation

Rock breaking and excavation works are potentially carried out at the A1-W1 worksite and the transition tunnel. When using combustible means to break up rocks, much of the energy is used to break up the rock and displace it from its original position. However, some excess energy is always converted into the vibration that travels away from the combustion through the ground. The vibration attenuates with increasing distance away from the combustion. The rock breaking design controls the ground-borne vibration level, the distance to the combustion, rock breaking weight, and the intervening geology.

Rock breaking and excavation induced vibration is impulsive, and each event's duration depends on the magnitude of the combustion. The variables of this activity include the number of delay intervals and rock breaking quantities, the method of rock breaking, the separation distance between the rock breaking and the receptor site, and the geological profile between the rock breaking and the combustion site. It is typically measured in terms of unfiltered time histories of three-component particle velocities from which the peak values can be identified. Typically soft ground conditions (clay, sand, alluvial) transmit less ground-borne vibration than hard ground (granite, rocks). Building damage associated with rock breaking and excavation is predominantly due to the air overpressure exciting the building elements of receptor buildings rather than ground-borne vibration.

12.3.1.2 Piling Works

Piling works are carried out at construction at A1-W2 (base scenario only), A1-W1, CR13 retrieval shaft and Peirce Secondary School worksites. The construction ground-borne vibration impact assessment assumed the impact

bore pilling method for this study. This pilling method generated the highest vibration levels and represented the worst-case scenario for the Project site.

12.3.1.3 Tunnel Boring

Tunnel boring occurs along the entire alignment of CRL2. Both ground-borne noise (or structure radiated noise) and ground-borne vibration potentially occur on the ground surface and in buildings above the tunnel. The typical activities during the tunnelling process that generates vibration include tunnel boring machines, excavators, tunnel segmental lining placement and hydraulic drilling.

12.3.1.4 Other Construction Equipment

Typical construction equipment that emits vibration is vibratory compactors and bulldozers for this Project.

A vibratory compactor is a compactor used to densify soil, asphalt or other materials by applying combined static and dynamic forces via a drum to increase the load-bearing capacity of the surface. Vibrations are generated by one or more eccentric weights rotating on a shaft centred at the drum.

A bulldozer consists of a heavy, broad steel blade mounted on the front of a tractor. It is used for shallow digging and ditching, short-range transportation of material; spreading soil dumped from trucks; final trim grading; removing trees, stumps, and boulders, and cleaning and levelling around loading equipment. A bulldozer alone can do many types of excavation, which is helpful with other machinery.

12.3.1.5 Heavy Construction Vehicles

Vibration can be generated from heavy construction vehicles travelling on the road with an uneven surface profile. The interaction between the wheels and the road surface causes waves to propagate in the soil and nearby sensitive receptors. Road induced vibration impacts are usually minimal unless there are frequent potholes in the road and the vehicles are heavy/ fast. Generally, the vibration from construction vehicles is less than from activities such as piling works.

12.3.1.6 Diesel Engines

Continuous vibration at low intensities can be emitted from diesel engines, e.g. from impact bored piling winches mounted on the skids, crawler mounted base machines and attendant plants. Diesel engines produce vibration at frequencies about 50 Hz, and those vibrations about this frequency (and higher) are attenuated more aggressively by material absorption. Such vibrations are unlikely to remain significant outside the worksite boundary.

12.3.2 Operational Phase

During the operational phase, the vibration sources are potentially the trains travelling on the CRL2 alignment and road traffic on roads within the Study Area (Table 12-15).

Table 12-15 Potential Sources of Ground-borne Vibration Impacts during Operational Phase

Operation Activity	Potential Impacted Parameter	Associated Impacts
CRL2 Alignment Road Traffic	Ground-borne vibration Structure-borne vibration	Annoyance Ecological Foraging Behaviour

Train induced vibration is caused by the roughness of the wheels and rails. The vibration is also dependent on the train suspension and tracks supporting system, as these may have resonances that result in increased vibration.

Road traffic vibration is mainly due to heavy vehicles passing at speed with an uneven surface profile. Interaction between wheels and road surface causes a dynamic excitation that propagates waves in the soil and nearby sensitive receptors. Based on the land use of the Project site, the presence of heavy vehicles at speed is rare. Given that the construction of roads in Singapore usually has an even surface profile, it is unlikely that the road traffic causes high ground-borne vibration levels in the Study Area. Thus it does not impact nearby sensitive receptor buildings and ecological receptors significantly. In addition, the existing road is unlikely to have an increase in traffic during the operation. Thus, it is also unlikely to cause high ground-borne vibration levels in the Study Area. Hence, it will not significantly impact nearby sensitive receptor buildings and ecological receptors.

12.4 Identification of Ground-borne Vibration Sensitive Receptors

Ecologically sensitive/ faunal receptors within the Study Area may be impacted by the construction and operation of the Project. It is anticipated that effects from construction and operation generated vibration does not occur

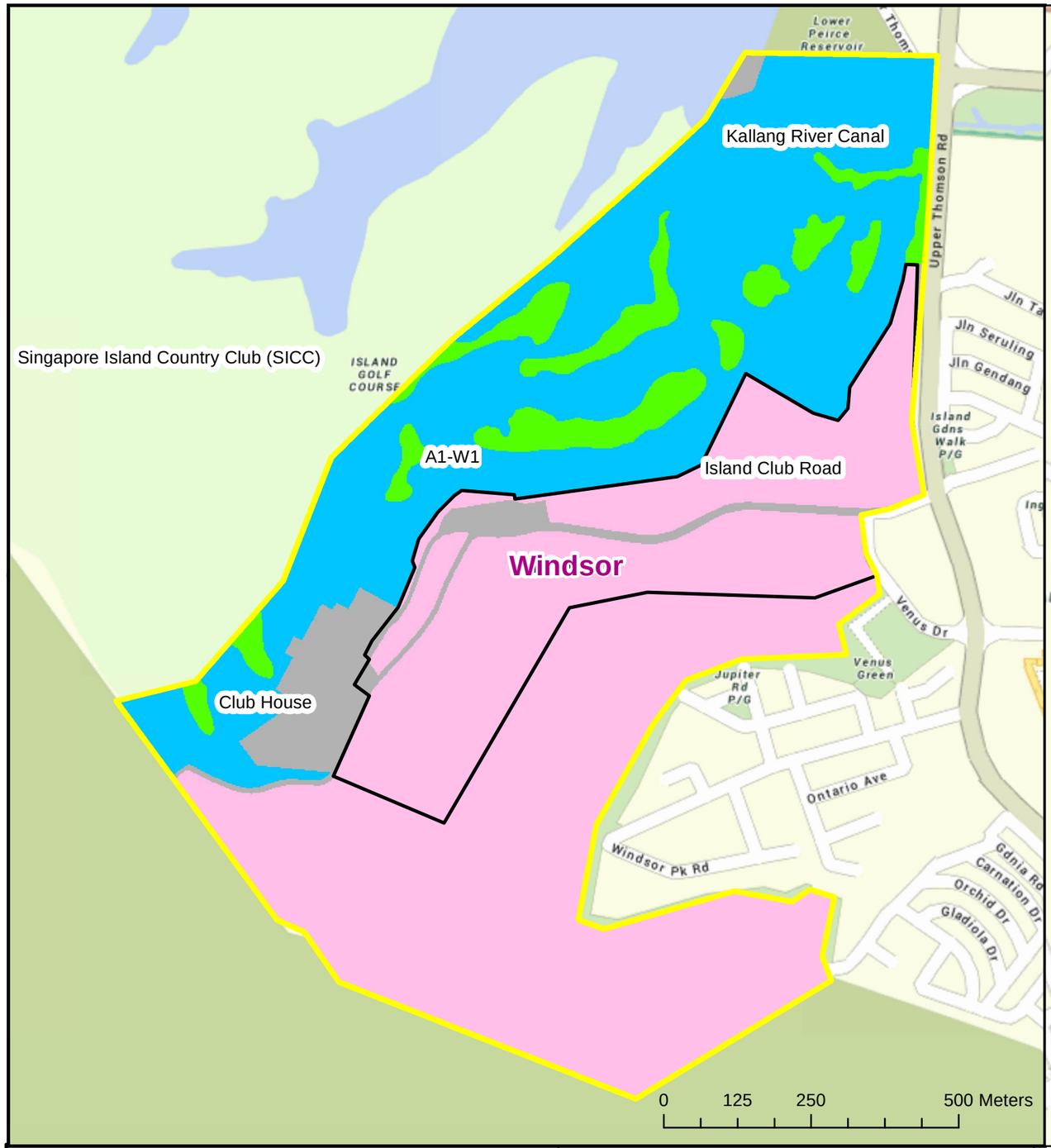
outside the vibration Study Area based on the experience of similar projects on the impact on humans. If an impact is significant within the study area, this area is typically increased to assess and envelope a wider area.

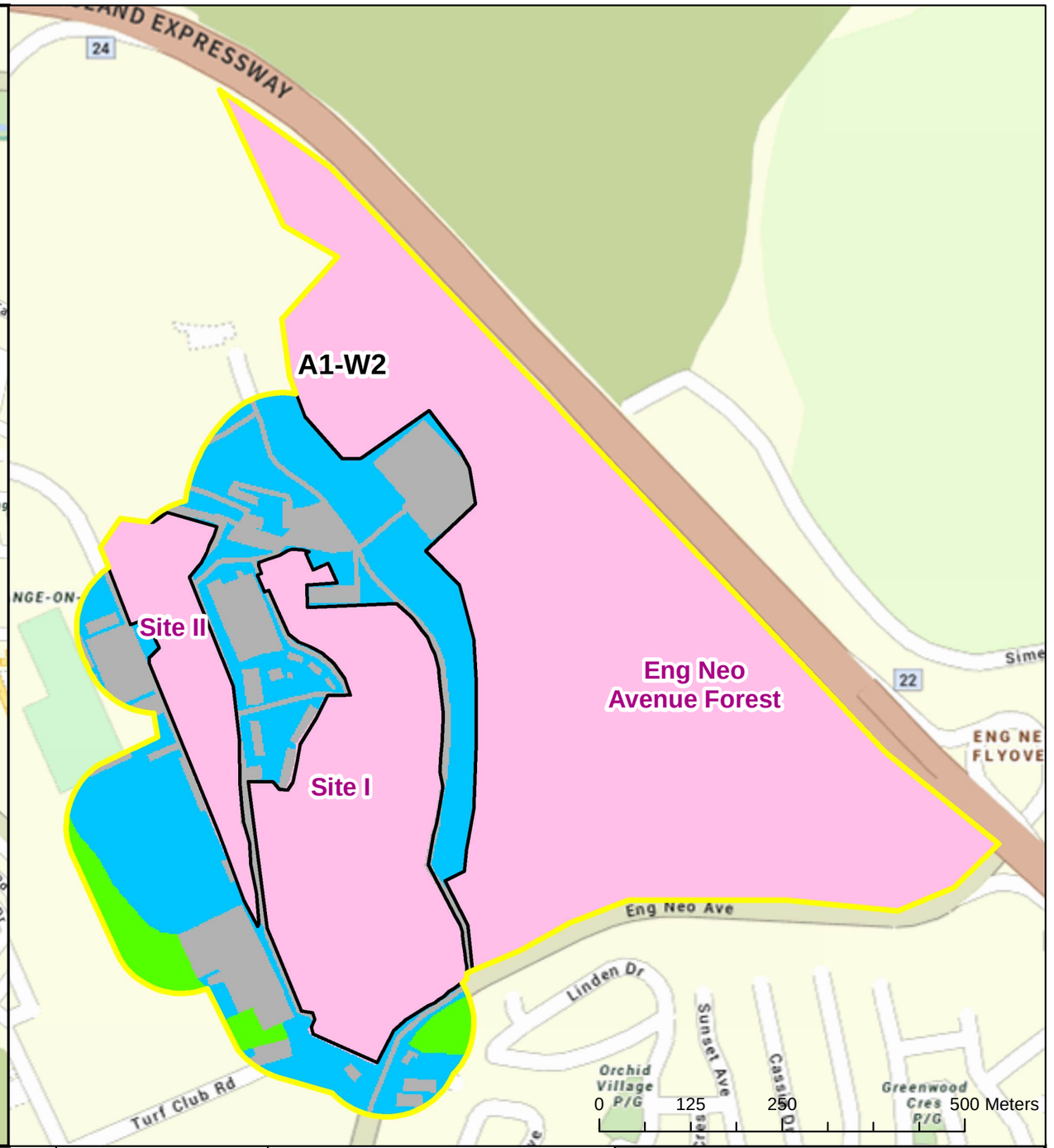
In addition, since there are urban patches of land nearby which may not be suitable to support the presence of fauna, this study assesses these regions as “Not Assessable”. As per NG Engagement held on 23rd March 2022, it was mutually agreed that a habitat sensitivity map is used for this Project to decide the probability of finding species in the area and for this assessment. Thus, in the sections that follow, the map below defines the sensitivity of the area used by sensitive fauna.

12.4.1 Habitat Receptor Sensitivity to Ground-borne Vibration

A desktop review of available studies was conducted to categorise the various ecological receptors in the Study Area. The species are first evaluated for their sensitivity towards ground-borne vibration and further classified into Priority 1, Priority 2 and Priority 3 based on their Conservation Significance.

The habitats are classified into Priority 1 (secondary forests), Priority 2 (forest fragment within SICC Golf Course) and Priority 3 (Golf Course). All urban areas such as houses and existing roads are not assessed as they are not a natural stronghold for fauna. See Figure 12-3.





Legend

- Study Area
- Biodiversity Study Area
- Not Assessable
- Priority 1
- Priority 2
- Priority 3

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
We Keep Your World Moving

Project Title :
**CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)**

Drawing Title :
**SENSITIVITY MAPS
FOR WINDSOR AND
ENG NEO AVENUE FOREST**

Designed	Checked	Approved	Drawing No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 3	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

12.4.2 Fauna Receptor – Species Sensitivity to Ground-borne Vibration

The ecologically sensitive receptors within the Biodiversity Study Area are prioritised in the order below:

1. The actual presence or likely presence from records and the faunistic field assessment (Section 7.2.3 and 7.2.5);
2. The conservation significance or importance; and
3. The ecological receptor's likely sensitivity to vibration impacts.

The ecologically sensitive receptors are listed in Appendix O, and the sensitive sites are discussed below.

12.4.2.1 Eng Neo Avenue Forest

The field assessment identified 575 species of probable occurrence at Eng Neo Avenue Forest. The field assessment documented 233 species, dominated by birds (72 species) and butterflies (64 species). From these, 15 species of conservation significance were also recorded. Three species (one odonate, one reptile and one bird) were not listed as probable species. The following table shows the primary receptors' importance within Eng Neo Avenue Forest. In the northern area of the woods, several faunal species of conservation significance and forest-dependent species have been recorded (Section 7.5.1), including Sunda colugo (Galeopterus variegatus) and Sunda pangolin (Manis javanica). Little is known regarding the home range of these identified species except for the Sunda pangolin (*Manis javanica*), which has a range of 6.3 ha [W-84]. This species is the focus of the assessment for Eng Neo Avenue Forest.

Table 12-16 Receptor Importance at Eng Neo Avenue Forest

Faunal Group	Species	Common Name	Local Status	Global Status	Vibration Sensitivity
Butterfly	*Telicota colon stinga*	Common Palm Dart	Nationally Extinct (Rediscovered)	Not Assessed	Priority 1
Butterfly	*Pachliopta aristolochiae asteris*	Common Rose	Vulnerable	Not Assessed	Priority 1
Butterfly	*Troides helena cerberus*	Common Birdwing	Vulnerable	Not assessed; CITES protected (Appendix II)	Priority 1
Bird	*Nisaetus cirrhatus*	Changeable Hawk-Eagle	Endangered	Least Concern	Priority 1
Bird	*Treron curvirostra*	Thick-billed Green Pigeon	Endangered	Least Concern	Priority 1
Bird	*Cacomantis sepulcralis*	Rusty-breasted Cuckoo	Vulnerable	Least Concern	Priority 2
Bird	*Gallus gallus*	Red Junglefowl	Endangered	Least Concern	Priority 1
Bird	*Loriculus galgulus*	Blue-crowned Hanging-parrot	Endangered	Least Concern	Priority 2
Bird	*Psittacula longicauda*	Long-tailed Parakeet	Not Assessed	Vulnerable	Priority 2
Bird	*Pycnonotus zeylanicus*	Straw-headed Bulbul	Endangered	Endangered	Priority 2
Bird	*Rallina fasciata*	Red-legged Crake	Vulnerable	Least Concern	Priority 1
Mammal	*Manis javanica*	Sunda Pangolin	Critically Endangered	Critically Endangered	Priority 1
Mammal	*Macaca fascicularis*	Long-tailed Macaque	Least Concern	Vulnerable	Priority 1
Mammal	*Galeopterus variegatus*	Sunda colugo	Near Threatened	Least Concern	Priority 1
Mammal	*Tylonycteris sp.*	Bamboo bat	Vulnerable	Least Concern	Priority 1

12.4.2.2 Site I and Site II

The field assessment documented 165 species, dominated by birds (59 species) and butterflies (26 species). From these, 13 species of conservation significance were also recorded. Table 12-15 shows the primary receptors' importance of Sites I and II.

Table 12-17 Importance of Receptor at Sites I and II

Faunal Group	Species	Common Name	Local Status	Global Status	Vibration Sensitivity
Butterfly	*Borbo cinnara*	Formosan swift	Endangered	Not Assessed	Priority 1
Butterfly	*Arhopala amphimuta amphimuta*	NA	Nationally Extinct (Rediscovered)	Not Assessed	Priority 1
Butterfly	*Troides helena cerberus*	Common birdwing	Vulnerable	Not Assessed; CITES protected (Appendix II)	Priority 1
Bird	*Accipiter trivirgatus*	Crested goshawk	Critically Endangered	Least Concern	Priority 1
Bird	*Gallus gallus*	Red junglefowl	Endangered	Least Concern	Priority 2
Bird	*Loriculus galgulus*	Blue-crowned hanging-parrot	Endangered	Least Concern	Priority 2
Bird	*Psittacula longicauda*	Long-tailed parakeet	Not Assessed	Vulnerable	Priority 2
Bird	*Pycnonotus zeylanicus*	Straw-headed bulbul	Endangered	Critically Endangered	Priority 1
Bird	*Rallina fasciata*	Red-legged crake	Vulnerable	Least Concern	Priority 1
Bird	*Strix seloputo*	Spotted wood owl	Critically Endangered	Least Concern	Priority 2
Mammal	*Macaca fascicularis*	Long-tailed macaque	Least Concern	Vulnerable	Priority 2
Mammal	*Manis javanica*	Sunda pangolin	Critically Endangered	Critically Endangered	Priority 1
Mammal	*Galeopterus variegatus*	Sunda colugo	Near Threatened	Least Concern	Priority 1
Bat	*Tylonycteris* sp.	Bamboo bat	Vulnerable	Least Concern	Priority 1

Given the site's proximity to Eng Neo Avenue Forest, rare species that could be expected at Eng Neo Avenue Forest also have a chance of being found here. Species of conservation significance appear to be distributed across the Study Area, including the globally threatened straw-headed bulbul (*Pycnonotus zeylanicus*) and Sunda pangolin (*Manis javanica*) with six independent detections (Figure 7-69).

12.4.2.3 Windsor

The field assessment documented 229 species, dominated by birds (60 species) and butterflies (51 species). From these, 26 species of conservation significance were recorded, including one butterfly species that were not listed as probable. The following table shows the primary receptors and their importance for Windsor.

In the northern area of the park, several faunal species of conservation significance and forest-dependent species were also recorded (Section 7.5.3): Sunda slow loris (*Nycticebus coucang*), Horsfield's flying squirrel (Iomys horsfieldii), Sunda colugo (*Galeopterus variegatus*), lesser mousedeer (*Tragulus kanchil*), golden-eared rough-sided frog (*Pulchrana baramica*) and blue Malayan coral snake (*Calliophis bivirgatus*). Little is known about the home range of these species except for the lesser mousedeer (*Tragulus kanchil*), which has a home range of 4 ha [W-83]. This species is the focus of the assessment for Windsor.

Table 12-18 Receptor Importance at Windsor

Faunal Group	Species	Common Name	Local Status	Global Status	Vibration Sensitivity
Butterfly	*Borbo cinnara*	Formosan Swift	Endangered	Not Assessed	Priority 1
Butterfly	*Catopyrops ancyra*	Ancyra Blue	Vulnerable	Not Assessed	Priority 1
Butterfly	*Jamides alecto ageladas*	Metallic Caerulean	Nationally Extinct (Rediscovered)	Not Assessed	Priority 1
Butterfly	*Petrelaea dana*	Dingy Line Blue	Not Assessed	Not Assessed	Priority 1
Butterfly	*Pratapa deva relata*	White Royal	Critically Endangered	Not Assessed	Priority 1
Butterfly	*Troides helena cerberus*	Common Birdwing	Vulnerable	Not Assessed; CITES protected (Appendix II)	Priority 1
Butterfly	*Eurema brigitta senna*	No Brand Grass Yellow	Nationally Extinct (Rediscovered)	Not Assessed	Priority 1
Amphibian	*Nyctixalus pictus*	Cinnamon Bush Frog	Vulnerable	Near Threatened	Priority 1
Reptile	*Draco melanopogon*	Black-bearded Flying Dragon	Vulnerable	Not Assessed	Priority 2
Reptile	*Gonyosoma oxycephalum*	Red-tailed Racer	Endangered	Least Concern	Priority 1
Reptile	*Calliophis bivirgatus*	Blue Malayan Coral Snake	Vulnerable	Least Concern	Priority 1
Reptile	*Cnemaspis peninsularis*	Peninsular Rock Gecko	Vulnerable	Not Assessed	Priority 2
Reptile	*Tropidolaemus wagleri*	Wagler's Pit Viper	Endangered	Least Concern	Priority 1
Bird	*Accipiter trivirgatus*	Crested Goshawk	Critically Endangered	Least Concern	Priority 2
Bird	*Haliaeetus ichthyaetus*	Grey-headed Fish Eagle	Critically Endangered	Near Threatened	Priority 2
Bird	*Nisaetus cirrhatus*	Changeable Hawk-Eagle	Endangered	Least Concern	Priority 2
Bird	*Treron curvirostra*	Thick-billed Green Pigeon	Endangered	Least Concern	Priority 1
Bird	*Cacomantis sepulcralis*	Rusty-breasted Cuckoo	Vulnerable	Least Concern	Priority 2
Bird	*Surniculus lugubris*	Square-tailed Drongo-Cuckoo	Critically Endangered	Least Concern	Priority 2
Bird	*Copsychus malabaricus*	White-rumped Shama	Critically Endangered	Least Concern	Priority 1
Bird	*Copsychus saularis*	Oriental Magpie-Robin	Endangered	Least Concern	Priority 1
Bird	*Gallus gallus*	Red Junglefowl	Endangered	Least Concern	Priority 1
Bird	*Loriculus galgulus*	Blue-crowned Hanging-parrot	Endangered	Least Concern	Priority 2
Bird	*Psittacula longicauda*	Long-tailed Parakeet	Not Assessed	Vulnerable	Priority 2
Bird	*Psittinus cyanurus*	Blue-rumped Parrot	Critically Endangered	Near Threatened	Priority 2
Bird	*Pycnonotus brunneus*	Asian Red-eyed Bulbul	Endangered	Least Concern	Priority 2
Bird	*Rallina fasciata*	Red-legged Crake	Vulnerable	Least Concern	Priority 1
Bird	*Ketupa ketupu*	Buffy Fish Owl	Critically Endangered	Least Concern	Priority 2
Bird	*Stachyris erythroptera*	Chestnut-winged Babbler	Endangered	Least Concern	Priority 2
Mammal	*Presbytis femoralis*	Raffles' Banded Langur	Critically Endangered	Endangered	Priority 1
Mammal	*Nycticebus coucang*	Sunda Slow Loris	Endangered	Endangered	Priority 2

Faunal Group	Species	Common Name	Local Status	Global Status	Vibration Sensitivity
Mammal	*Manis javanica*	Sunda Pangolin	Critically Endangered	Critically Endangered	Priority 1
Mammal	*Iomys horsfieldii*	Horsfield's Flying Squirrel	Endangered	Least Concern	Priority 2
Mammal	*Tragulus kanchil*	Lesser Mousedeer	Endangered	Least Concern	Priority 1

This section presents the literature review of the sensitivity of fauna to ground-borne vibration. In the study of anthropomorphism of fauna species, existing research does not provide sufficient documentation for treating fauna as human behaviours and responses [W-86].

In an ecological context, vibrational signalling, vibration reception and behaviour (prey catching, courtship, territorial behaviour) are guided by substrate vibrations. These have been best studied in vertebrates and arthropods.

Figure 12-4 Examples of Fauna (Toads, Rats) That Utilise Vibration for Signalling And Behaviour [W-40]

This section presents the literature review of the sensitivity of fauna to ground-borne vibration. In the study of anthropomorphism of fauna species, existing research does not provide sufficient documentation for treating fauna as human behaviours and responses [W-86].

In an ecological context, vibrational signalling, vibration reception and behaviour (prey catching, courtship, territorial behaviour) are guided by substrate vibrations. These have been best studied in vertebrates and arthropods.

When studying the effects of vibration on ecology, it can be challenging to separate vibration effects from other sensory disturbing effects (for example, noise, visual and olfactory cues).

The vibration sources and character from the works are as follows:

- Rock breaking and excavation work are aimed to reduce the size of rocks for tunnel boring and excavation. The vibration produced is instantaneous.
- Rotary bored piling is used in the construction, and the vibration caused by rotary bore piling is episodic[10] at the start and completion of a piling process. When the pile is driven into the ground, the vibration is continuous.
- A bulldozer is used for groundwork. Typically, the vibration produced is transitory as it moves over rough terrain.
- A tunnel boring machine is used to construct the underground railway tunnel. For tunnel boring, the critical frequency of the activity is generally below 100 Hz. The vibration caused by tunnel boring is predominantly subsurface except during the launch and retrieval of the tunnel boring machine. Hence, when the tunnel boring

[10] Rotary bore piling will be conducted for one pile (an episode) with no breaks/stops in between until the next pile (another episode) begins.

first commences or is retrieved, the initial effect is likely to cause some species in nearby proximity to be alarmed and move away briefly.

Based on observations from other site surveys at Mandai, instantaneous vibration is more likely to cause the Sunda pangolin to curl into a ball and remain stationary. The lesser mousedeer is likely to dash from cover to cover. However, it is unlikely to dash across the road due to the mousedeer's timid nature. Fossorial snakes and reptiles are also unlikely to dash across the road. The wild boar, a highly adaptable urban species, is potentially the only species that might exhibit flee response and end up on the road.

Continuous vibration tends to be more tolerable for terrestrial animals, including bats, snakes and migratory bird species. It can be reasonably assumed that the low ground-borne vibration levels are potentially more tolerable by terrestrial fauna. It is anticipated that several species (e.g. Sunda pangolin and lesser mousedeer) which would move further away during the rotary bore piling period will return to the vicinity of the worksite once habituated to the vibration.

Sunda pangolin

(Source:*https://www.wrs.com.sg/en/protecting-wildlife/conservation/our-work/understanding-local-sunda-pangolins.html*)

Lesser mousedeer

(Source:*https://www.nparks.gov.sg/florafaunaweb/fauna/2/1/21#gallery-1*)

Figure 12-5 Examples of Vibration Sensitive Species

The vibratory sensors of ecological receptors are highly complex in nature and frequency-dependent. Some fossorial species (e.g. snakes, rats, spiders and shrews) use low amplitude/ low-frequency vibration as a communication mechanism. Vibration detection by fossorial snakes was explored in Cerastes, which showed the species responded to natural and artificial ground-borne vibration stimuli, and these snakes were hunting using vibration detection [W-86].

Studies have shown that fossorial species such as talas tuco-tuco (*Ctenomys talarum*) [P-111], spadefoot (*Spea hammondii*) [P-110] have a home range more minor than that of the lesser mousedeer [P-103, P-104 and P-105]. It is also mentioned that fossorial species are predicted to have smaller home ranges than their nonfossorial relatives [P-106]. While their typical sensitive frequencies are within the range of frequencies anticipated to be produced by construction activities, the amplitudes of their vibration communications are typically below the ambient transient vibrations determined during the study (refer to Section 12.7.1). Therefore, fossorial fauna occupying the site shall be required to accommodate construction-induced vibration through frequency discrimination or communicate otherwise due to the transient nature of construction vibration.

The Singapore Blue Tarantula, *Omothymus violaceopes,* typically stay hidden in their burrows as spiderlings but come out late at night to hunt if their prey doesn't walk right in front of their burrow [W-88]. This species act much more like a fossorial tarantula at this size than an arboreal tarantula.

The most considerable vibration impact on fossorial fauna is assumed to be burrow collapse, the levels for which may occur from rock breaking and excavation (refer to Section 12.7). The outcome of the impact significance provides a conservative impact assessment result for all the ecologically sensitive receptors.

The scientific literature on ground-borne vibration impacts on ecology is inconclusive concerning their perceptibility of vibration from a subsurface source. Since most affected terrestrial species (e.g. Red-legged crake, Red junglefowl and sunda pangolin) live on the ground surface, the effects on home range and activities are negligible.

Some affected species in the vicinity could partially be habituated to the vibration levels over time, provided that the vibration levels remain relatively consistent during the tunnel boring duration.

Species that prefer burrow habitats include the golden mouse, dusky-footed wood rat, brush mouse and pinion mouse. This preference could be due to predators such as foxes, racoons, skunks, and coyotes leaving their habitats as they experience ground-borne vibration from the road surface [W-40W-43]. Burrowing and ground-dwelling mammals are highly sensitive to vibration [P-85]. Therefore, this study considers this behaviour to represent small mammals that move on land, which are assumed to experience high sensitivity to ground-borne vibration for this assessment.

Invertebrates such as bees often build hives on the trunks of trees and, in hollows, may be sensitive to vibrations. Bees can hear airborne sounds (Krichner et al., 1991) and are auditory sensitive. They also use vibration to communicate within the hive.

Adult odonates[11] are not ground-dwelling and, therefore, not vibration sensitive. Most aquatic invertebrates are less impacted by low-frequency noises, characteristic of anthropogenic sources. However, odonate nymphs (macropredators) have prey (e.g. tadpoles and fishes) that are sensitive to low-vibration sounds (Nedwell et al., 2003; Castaneda et al., 2020); thus, they are treated as vibration sensitive receptors.

Lepidopteran larvae (caterpillars) respond to low-frequency vibrations to avoid insect predators and parasites (Taylor, 2009). Some adult butterflies are known to use airborne sounds to avoid predators (Fournier, 2011). Night-flying butterflies and moths are also highly dependent on hearing to avoid bat predation (Yack & Fullard, 2000). As such, lepidopterans are highly vibration sensitive species

All fully aquatic species are negatively impacted by low-frequency vibrations (Nedwell et al., 2003; Castaneda et al., 2020). As such, all aquatic species are considered high vibration sensitive species.

Tadpoles are treated with other aquatic species and are regarded as vibration sensitive. Ground-dwelling frog species are vibration sensitive.

Snakes, in general, are deaf as they do not have an ear [P-76]. Therefore, it is usually vibration energy that impacts the behaviour of these creatures, and they are startled by vibration.

Sunda colugo *(Galeopterus variegatus)* is a nocturnal mammal and spends most of its life in trees and moves by gliding from tree to tree. There is insufficient research or literature on the impacts of vibration on these animals. A study was conducted by radio-tracking 32 lemuroid ringtail possum (*Hemibelideus lemuroides*), and their movements were monitored by a 7 m wide road and an 80 m wide powerline corridor [P-57]. No possums were observed crossing the road or powerline corridor at ground level or residing in the intervening matrix due to the loss of canopy connectivity, which negatively impacts their movements. Considering that they spend most of their time above ground on trees, these creatures potentially experience low sensitivity to ground-borne vibration.

There is insufficient research or literature on vibration impacts on the Greater Mouse-eared Bats. However, a study was conducted on piling-induced vibration impacts on Pilbara Leaf-Nosed and Ghost Bat [P-58, P-59]. This study used a drill to penetrate a cavity at the rear of an unoccupied cave in the Pilbara region of Western Australia. Vibration levels PPV, 0.4 - 0.6 mm/s and a noise level of 60 dB(A) were measured at 50 m from the drill, and the study concluded that these impacts were unlikely to cause the bats to abandon the cave.

Roosting bats are negatively impacted by vibrations and are considered vibration sensitive (Voigt & Kingston, 2016). Considering the above, this Project assumes that the bats with the CR2005 Study Area behave similarly to roosting bats and hence have high sensitivity to ground-borne vibration.

Ground-dwelling species of birds are considered highly sensitive to vibration. Resident swiftlets breed and roost in caves and culverts and are also considered sensitive to vibrations (Chia et al., 2019).

Terrestrial bird species like the Red Junglefowl *(Gallus gallus)* are usually found in open ground and dense vegetation. Such places may be around human activities or living areas, and they travel through forests to other clearings or food sources. Assuming that these species are accustomed to vibration on the ground, they are less likely to be impacted by ground-borne vibration unless the levels become significantly higher than they are familiar with.

[11] Odonates are predaceous insects comprising the dragonflies and damselflies.

Aerial birds live most of their lives in flight; thus, they are less impacted by construction-induced vibration. Therefore, these birds are assumed to have a low sensitivity to ground-borne vibration.

Arboreal birds spend most of their time in trees and dense foliage. They perch and roost in trees and forage in holes and tree cavities, looking for insects and seeds. Little research or studies have shown the impacts of ground-borne vibration on them. Considering their behaviour, these birds are assumed to have a low sensitivity to ground-borne vibration.

There have been studies on the exposure of benthic invertebrates to sediment vibration and invertebrates to substrate-borne vibrations.

Concerning non-benthic invertebrates, there is insufficient evidence on the effects of vibration on behaviour, and hence it is assumed that the species have low sensitivity.

Spiders of all kinds are sensitive to vibratory stimulation as this is the method used to alert them to the presence of prey on their webs or foliage [W-44]. Spiders attack the vibration source if the vibrations are within a defined frequency and amplitude range. Vibrations with characteristics outside these biologically meaningful ranges do not induce an attack response. There is insufficient evidence to suggest that the ground-borne vibration emitted is within these ranges. Hence this assessment assumes that spider species have moderate sensitivity to ground-borne vibration.

Studies have been conducted on vibration in water bodies caused by underwater drilling, rock breaking and excavation. Based on the research, vibration propagation is frequency-dependent as the medium profile of land and water is not the same. Research shows that aquatic vertebrates have a lateral line to sense vibrations in the water and perceive their surroundings. Hence, this assessment assumes that the fishes are susceptible to ground-borne vibration.

Airbreathing walking catfish like the *Clarias cf. batrachus* and swamp eels (*Monopterus iavanensis*) can move overland for short distances. There is insufficient evidence to suggest their sensitivity to vibration. However, considering their behaviour on land, the assessment assumes that they have a high sensitivity to ground-borne vibration.

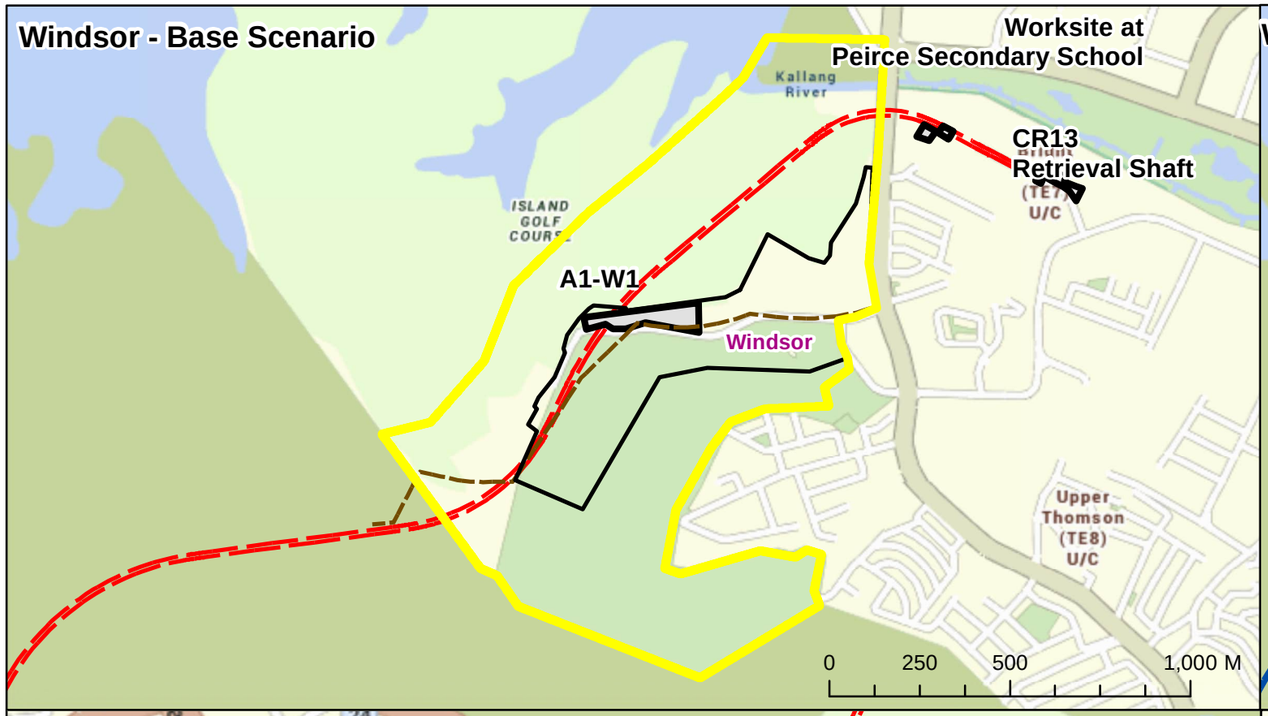
Snakeheads like the Channa striata can burrow in the mud during the dry season for survival. There is insufficient evidence to suggest their sensitivity to vibration. However, considering their behaviour in wetlands, the assessment assumes that they have a high sensitivity to ground-borne vibration.

Table 12-19 presents a summary of vibration thresholds for different species from the literature review.

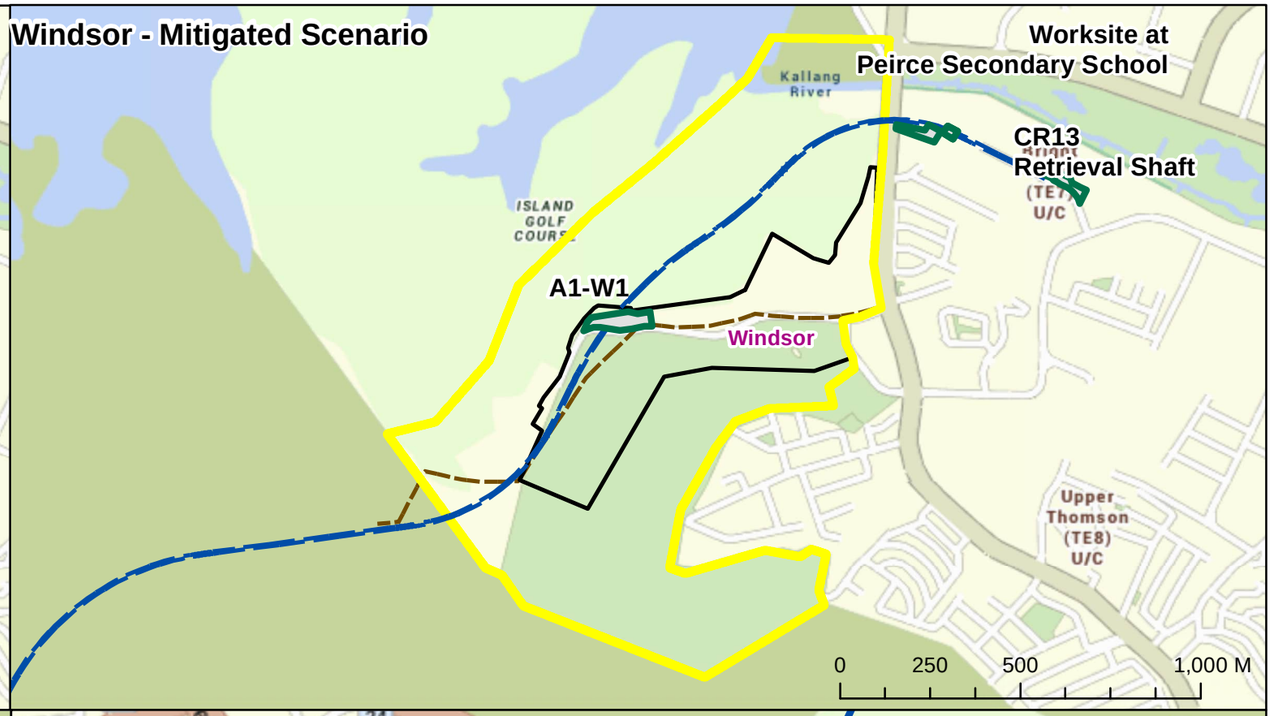
Table 12-19 Summary of Vibration Thresholds (PPV, mm/s) from Literature Review

Receptors	Vibration Thresholds, PPV, mm/s
Bees	0.02
Caterpillars (*Lipidopteran larvae)*	0.61
Fish	0.531 - 1.11
Frogs	0.00159
Pilbara Leaf-Nosed and Ghost Bat	0.40 - 0.60
Snakes	0.0016
Rats	0.30 – 9.70
Mice	0.40 – 1.80
Pigs	8.80
Tortoise	10.00 – 25.40
Rhesus monkeys	52.00

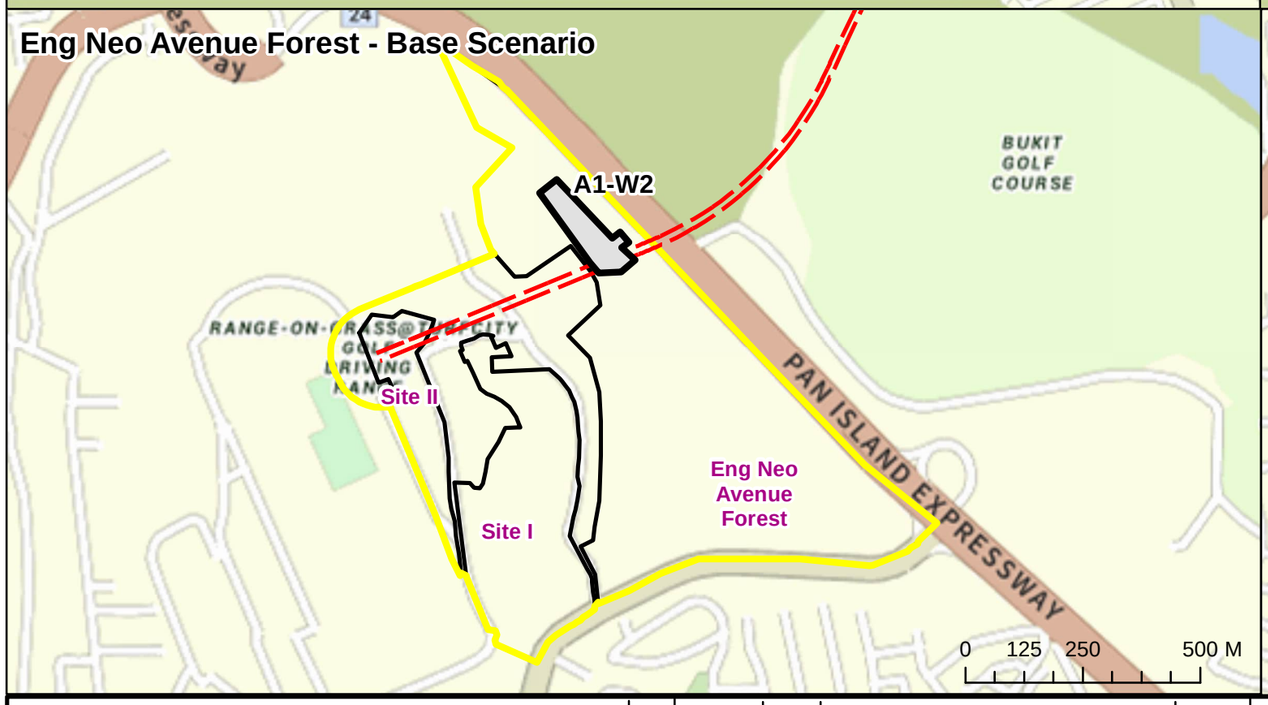
Windsor - Base Scenario



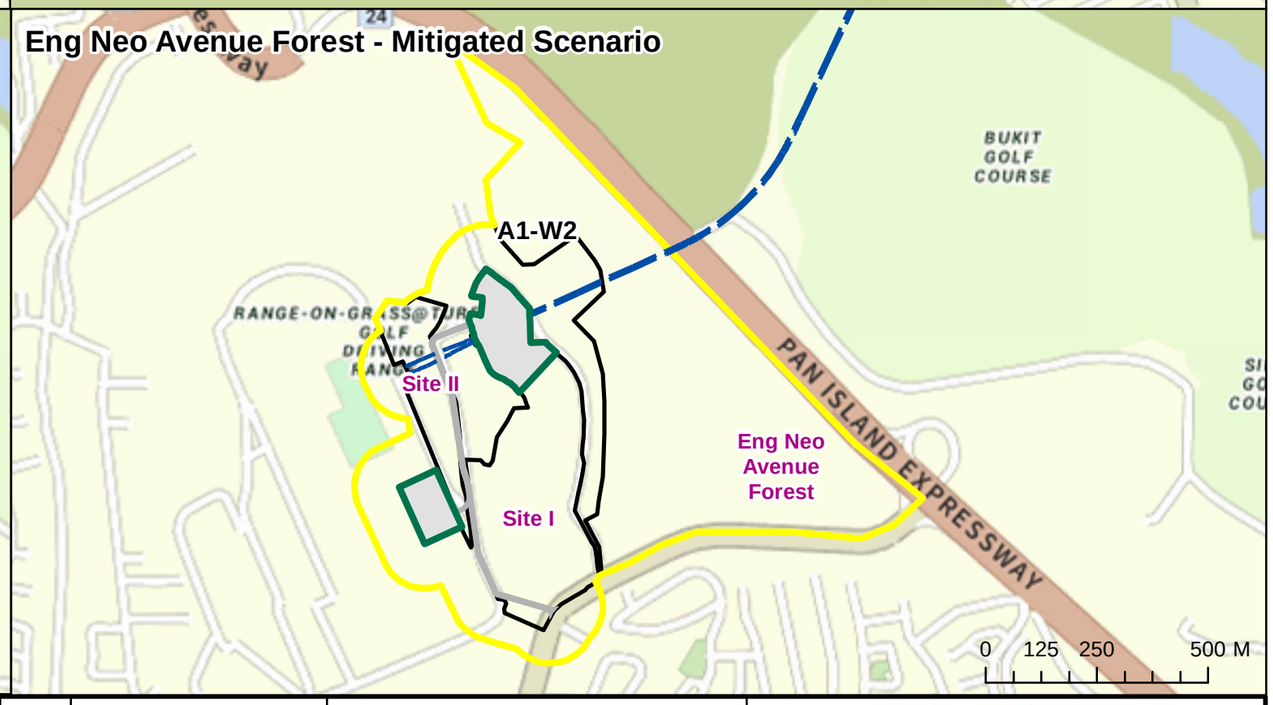
Windsor - Mitigated Scenario



Eng Neo Avenue Forest - Base Scenario



Eng Neo Avenue Forest - Mitigated Scenario



Legend

- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite
- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Study Area
- Temporary Access Roads
- Biodiversity Study Area

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
We Keep Your World Moving

Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
GROUND-BORNE VIBRATION SENSITIVE ECOLOGICAL RECEPTORS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 6	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

12.5 Baseline Ground-borne Vibration Levels

12.5.1 Secondary Data Collection (Review of Background Data)

Baseline vibration monitoring data were researched from other studies conducted in the past for review and understanding of the baseline conditions in the Project Study Area.

12.5.1.1 Data from a Separate Vibration Study by LTA

LTA conducted baseline vibration monitoring at the Biodiversity Study Area, BM1 (for Windsor) [O-13]. The vibration sources at BM1 are thought to be vehicles at Island Club Road and pedestrians/ hikers in the vicinity. Two (2) sets of triaxial accelerometers were set up at each vibration monitoring location.

Table 12-20 presents baseline vibration monitoring results.

Table 12-20 Baseline Vibration Monitoring Results (Vertical Axis) (Source: LTA) [O-13]

Baseline Vibration Monitoring Location	Sensor	Average PPV, mm/s	Maximum PPV, mm/s	99th Percentile Baseline Vibration Levels, PPV, mm/s
BM1 (Windsor)	1	0.016	0.091	0.063
	2	0.016	0.125	0.067
	Overall	**0.016**	**0.108**	**0.065**

12.5.1.2 Data from a Separate EIS Study by LTA

LTA's baseline vibration measurement was recorded over seven (7) days at nine (9) monitoring locations within CCNR. The vibration sources are the expressway, local vehicular traffic, nearby construction activities and joggers/ hikers using the internal trails within the nature reserve. For this assessment, the vital monitoring location is VL102 owing to its vicinity to the Island Club Road. The data from this location were used to analyse the baseline vibration for Windsor.

Table 12-21 lists the baseline vibration monitoring results of the vertical axis.

Table 12-21 Baseline Vibration Monitoring Results (Vertical Axis) from a Separate EIS Study by LTA [R-1]

Baseline Vibration Monitoring Location	Date	Average PPV, mm/s	Maximum PPV, mm/s	99th Percentile Baseline Vibration Levels, PPV, mm/s
VL102	25/06/2019	0.11	0.42	0.29
	26/06/2019	0.11	0.42	0.28
	27/06/2019	0.11	0.37	0.24
	28/06/2019	0.11	0.30	0.23
	29/06/2019	0.14	0.63	0.35
	30/06/2019	0.14	0.48	0.41
	01/07/2019	0.13	0.51	0.46
	02/07/2019	0.12	0.28	0.27
	Overall	**0.12**	**0.63**	0.36
*Note The baseline vibration monitoring location at VL102 is nearest to Windsor and CR2005 baseline vibration monitoring location, V08.				

12.5.1.3 Data from PUB BKSR EIA

Envirosolutions Pte Ltd stated that baseline vibration monitoring was conducted at four (4) locations from 13 February to 20 February 2020. Baseline vibration monitoring location A2 is nearest Windsor, and AECOM's baseline vibration monitoring location is V08.

Table 12-22 lists the baseline vibration data of the vertical axis.

Table 12-22 Baseline Vibration Monitoring Results (Vertical Axis) at A2 (Source: [R-59])

Baseline Vibration Monitoring Location	Date	Average PPV, mm/s	Maximum PPV, mm/s	99th Percentile Baseline Vibration Levels, PPV, mm/s
A1	13/02/2019	0.04	0.65	0.19
	14/02/2019	0.05	1.92	0.21
	15/02/2019	0.05	0.96	0.21
	16/02/2019	0.06	0.51	0.26
	17/02/2019	0.07	1.15	0.44
	18/02/2019	0.06	1.18	0.39
	19/02/2019	0.05	0.51	0.23
	20/02/2019	0.06	0.38	0.28
	Overall	**0.06**	**0.91**	**0.29**
A2*	13/02/2019	0.04	1.05	0.20
	14/02/2019	0.04	0.34	0.13
	15/02/2019	0.06	1.55	0.58
	16/02/2019	0.05	0.45	0.26
	17/02/2019	0.06	0.78	0.36
	19/02/2019	0.16	0.89	0.33
	20/02/2019	0.16	2.09	0.74
	Overall	**0.08**	**1.02**	**0.40**
A3	13/02/2019	0.04	2.41	0.22
	14/02/2019	0.04	0.80	0.22
	15/02/2019	0.07	1.39	0.52
	16/02/2019	0.06	1.19	0.32
	17/02/2019	0.06	1.59	0.35
	18/02/2019	0.10	0.85	0.39
	19/02/2019	0.12	6.86	0.78
	20/02/2019	0.09	3.65	0.49
	Overall	**0.07**	**2.34**	**0.41**

Note:

*Data for 18th February was deleted on request of LTA Technical Advisor as it was reported to be disturbed by some roadworks near the monitor.

12.5.2 Primary Data Collection (CR2005 Baseline Monitoring)

CR2005 carried out baseline vibration monitoring at four (4) locations (V07(2020), V07 (2022), V07A (2022) and V08) in proximity to the sensitive receptors and represented the baseline vibration levels of the sensitive receptors. Single-axis transducers were used, orientated in the vertical direction. At the beginning and end of the monitoring period, the vibration data have been omitted to exclude the vibration caused by setting up and removing the equipment. Vibration induced by rainfall on the transducer depends on many variables, including the rainfall rate and size of droplets. Therefore, periods of rain have been excluded from the analysis. For example, in Windsor

from 25th June 2020 07:51 am onwards for one (1) full day as seen in Table 12-23. The baseline vibration monitoring report prepared by CR2005 is presented in Appendix P.

Baseline vibration monitoring location V07 is on an open area within Eng Neo Avenue Forest, and CR2005 noticed transient pass-bys from horses and small loaders. These activities within the vicinity are assumed to be critical vibration sources in Eng Neo Avenue Forest. The vibration sources at Windsor are traffic on the Island Club Road. Other sources potentially include local vibration on the pedestrian paths and boardwalks, plus a pump station in the area.

Table 12-23 presents the summary of the baseline vibration monitoring results.

Table 12-23 Primary Baseline Ground-borne Vibration Monitoring Results

Baseline Vibration Monitoring Location	Date	Average PPV, mm/s	Maximum PPV, mm/s	99th Percentile Baseline Vibration Levels, PPV, mm/s
V07 (2020): Within Eng Neo Avenue Forest*	25 June 2020 Thursday	0.29	2.29	1.72
	26 June 2020 Friday	0.20	2.40	1.22
	Overall	0.24	2.34	1.42
V07 (2022): Within Eng Neo Avenue Forest	14 January 2022 Friday	0.01	0.08	0.03
	15 January 2022 Saturday	0.01	0.04	0.02
	16 January 2022 Sunday	0.01	0.04	0.02
	17 January 2022 Monday	0.01	0.04	0.02
	18 January 2022 Tuesday	0.01	0.04	0.02
	19 January 2022 Wednesday	0.01	0.12	0.03
	20 January 2022 Thursday	0.01	0.04	0.02
	21 January 2022 Friday	0.01	0.04	0.02
	Overall	0.01	0.12	0.02
V07A (2022): Deeper Within Eng Neo Avenue Forest	14 January 2022 Friday	0.01	0.02	0.02
	15 January 2022 Saturday	0.01	0.03	0.02
	16 January 2022 Sunday	0.01	0.05	0.02
	17 January 2022 Monday	0.01	0.04	0.02
	18 January 2022 Tuesday	0.01	0.04	0.02
	19 January 2022 Wednesday	0.01	0.06	0.02

Baseline Vibration Monitoring Location	Date	Average PPV, mm/s	Maximum PPV, mm/s	99th Percentile Baseline Vibration Levels, PPV, mm/s
	20 January 2022 Thursday	0.01	0.04	0.02
	21 January 2022 Friday	0.01	0.03	0.02
	Overall	0.01	0.12	0.02
V08: Within Windsor Nature Park	24 June 2020 Wednesday	0.03	0.12	0.07
	25 June 2020 Thursday	0.03	0.11	0.07
	Overall	0.03	0.12	0.07
*Note that the baseline measurements were conducted during the Circuit Breaker; thus, monitoring results may be lower as less human and vehicular traffic near the monitoring locations.				

12.5.3 Baseline Analysis at Eng Neo Avenue Forest

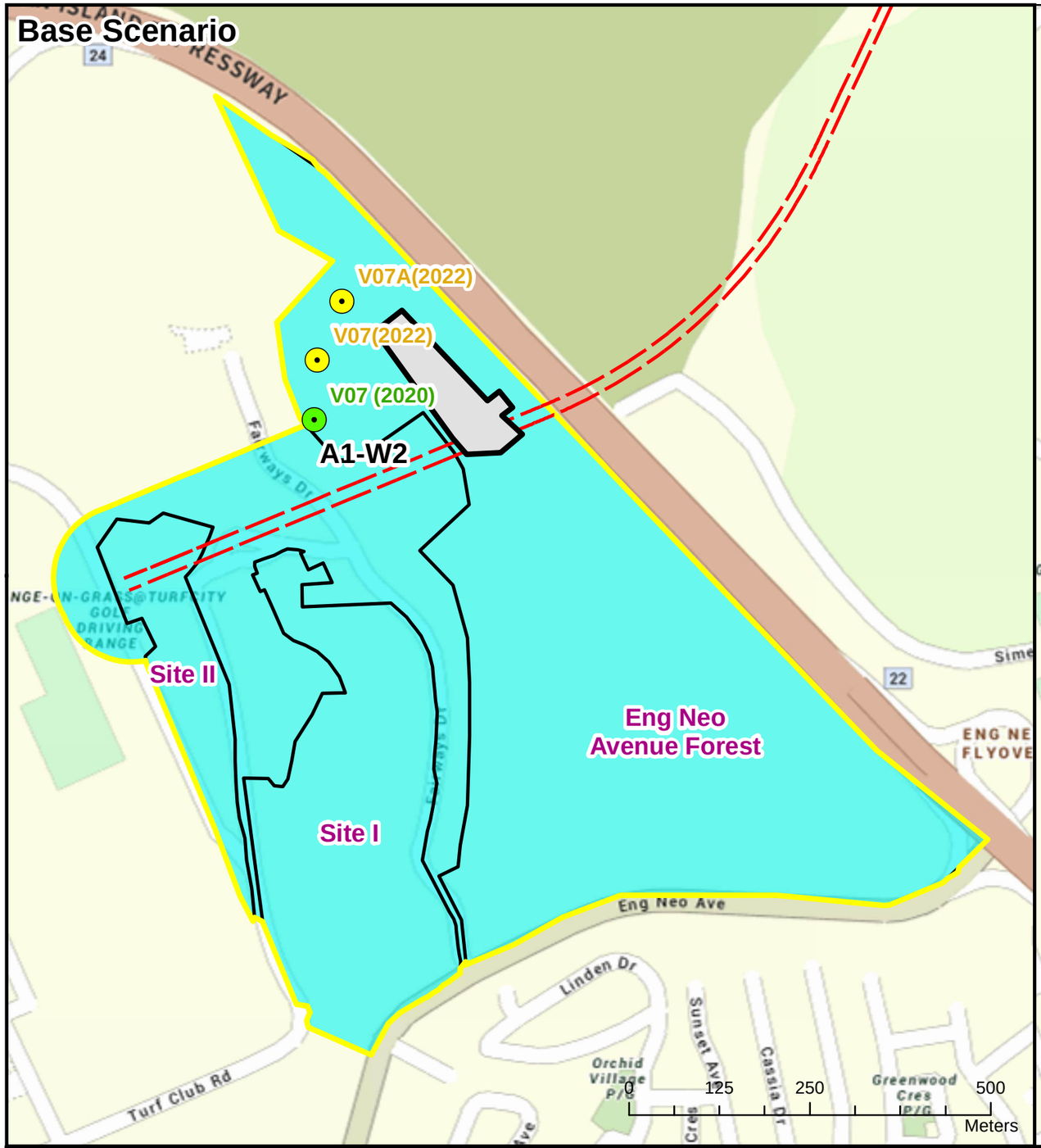
There are three baseline monitoring data at Eng Neo Avenue Forest for this Project. This area was used for horse walks, and this seems to be the vibration source in the forested area rather than traffic from the nearest road.

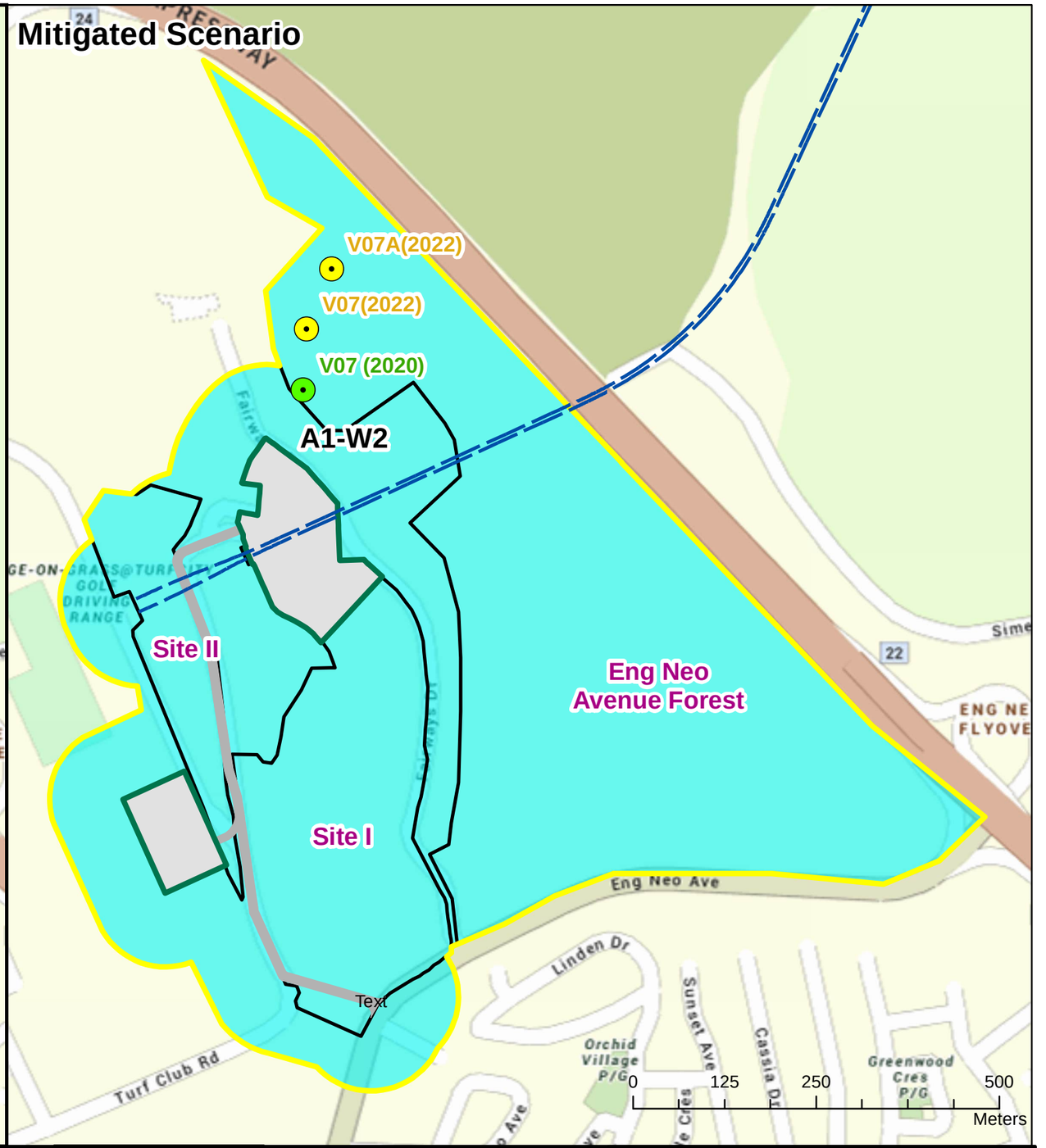
LTA monitored the north (opposite side) of Pan Island Expressway (PIE) in the CCNR rather than Eng Neo Avenue Forest for a Separate EIS Study. A brief review of these data seems to be significantly influenced by the PIE traffic, which is not the primary vibration source in Eng Neo Avenue Forest. Therefore, the data from LTA cannot be used for this location. Due to the limited data availability, the baseline has been taken as a constant value across the woods to evaluate impact intensity.

There are no other concurrent projects ongoing in this area; no secondary data were available for this study.

For consistency of the assessment, the 99th percentile data represents the baseline vibration level of the Biodiversity Study Area in Eng Neo Avenue Forest.

Figure 12-7 shows the baseline vibration level for construction and operational vibration impact assessment in Eng Neo Avenue Forest.





Legend

- Vibration Monitoring Location (2022)
- Vibration Monitoring Locations (2020)
- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite
- Study Area
- Biodiversity Study Area
- Temporary Access Roads

Ambient PPV (mm/s)

- 0.02

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
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LTA Endorsement :
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Drawing Title :
AMBIENT
VIBRATION LEVELS
AT ENG NEO AVENUE FOREST

Designed	Checked	Approved	Drawing No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 7	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

12.5.4 Baseline Analysis at Windsor

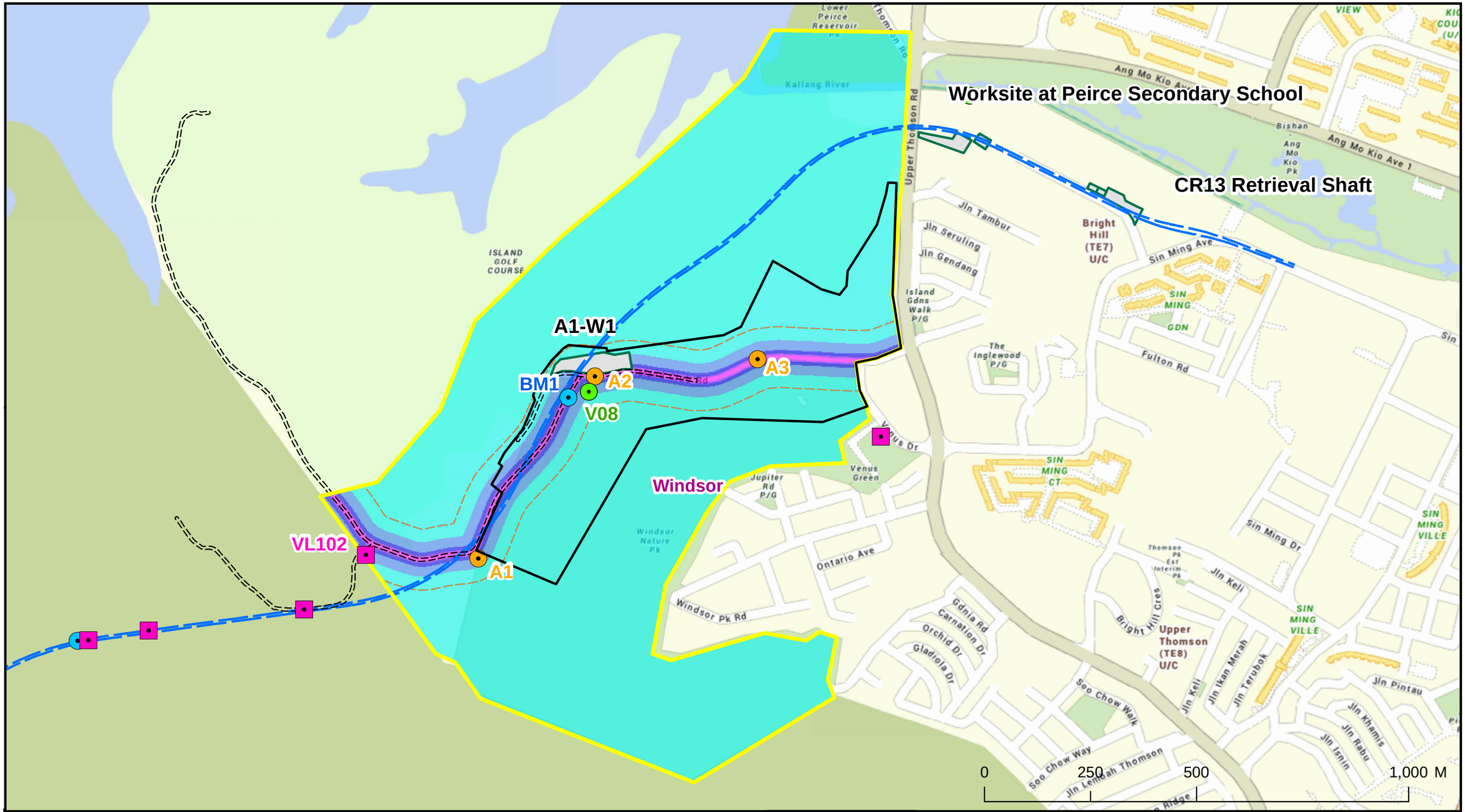
CR2005 uses measured baseline data and the linear regression line (Gaussian) analysis to determine the vibration decay with distance to predict the ambient vibration levels throughout the Study Area in Windsor.

The road is assumed to be the dominant source of vibration amongst other sources of vibration in the vicinity. The lower threshold of the predicted ambient vibration should be equivalent to the 99th percentile vibration baseline level monitored in Windsor. Based on Sections 12.5.1 and 12.5.2, the lowest threshold of the predicted ambient vibration is PPV, 0.07 mm/s. Therefore, at distances where the predicted ambient vibration levels are below PPV, 0.07 mm/s, the vibration levels are assumed to be PPV 0.07 mm/s. Technically the decay with distance eventually gets to zero at a distance from the source. Apart from this road traffic vibration, there are other sources (other roads, foot/horse traffic on paths, sewage pumps), but these have not been quantified.

Therefore, the predicted ambient vibration levels assume that the Island Club Road is the dominant vibration source. The empirical relationship between predicted vibration level, PPV (mm/s), and distance, x (m), is:

$$\boldsymbol{PPV = 1.53x^{-0.72}}$$

Appendix T details regression calculation.



Legend

- Biodiversity Study Area
- Vibration Monitoring - CCNR EIA [R-1]
- Baseline Vibration Monitoring Locations
- CR2008 Vibration Monitoring Location
- Bukit Kallang Pipeline Proposed Vibration Monitoring Location
- Vibration Study Area
- Road
- Proposed CRL Alignment (Mitigated)
- 0.07 PPV Contour
- Mitigated Scenario Construction Worksite Footprint

Predicted Ambient Levels

PPV (mm/s)

- 0.07 - 0.10
- 0.10 - 0.19
- 0.19 - 0.34
- 0.34 - 0.54
- 0.54 - 0.69

N

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Project Title :

CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Drawing Title :

PREDICTED AMBIENT VIBRATION LEVELS AT WINDSOR

Designed	Checked	Approved	Drawing No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 8	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

12.6 Minimum Control for Potential Impacts

12.6.1 Construction Phase

This section proposes minimum controls, or standard practices commonly implemented in Singapore for similar construction activities, that are assumed to be implemented for impact assessment. The minimum control measures are summarised in Table 12-24.

Table 12-24 Minimum Controls (Ground-borne Vibration)

Potential Source of Impacts	Minimum Controls
• Compacting concrete using the vibrator equipment • Piling works for the foundations of the facility building • Rotary piling works for ground improvements and underpinning works • Tunnel boring using the TBM • Rock breaking and excavation • Vibratory sheet piling for temporary works. • Heavy construction vehicles such as bulldozers and vibratory compactors • Other Construction Equipment • Stationary equipment with diesel engines	• Conduct dilapidation surveys of burrows when the predicted vibration levels approach or exceed a level of 80 % of the lowest criteria, in this case, ecological criteria. • Use low vibration equipment and construction techniques. • Impact bore piling shall not be used for this Project inside the Biodiversity Study Area. • Limit the rotational speed of the cutting surface of the TBM or the thrust force and the progress rate of the tunnel boring. • See minimum controls in rock breaking and excavation in Section 12.6.1.2. • Impose and signpost a maximum speed limit of 25 km/hr on paved or surfaced haul roads and 15 km/hr on unpaved haul roads and work areas.

12.6.1.1 Utility Works

The construction activities for utility work emit low vibration levels. Thus the activities do not cause significant vibration impacts on the receptors. Therefore, no assessment is required.

12.6.1.2 Rock Breaking and Excavation

Rock breaking and excavation are proposed for worksite A1-W1 within Windsor, for the base and mitigated scenarios for the launch shaft at Eng Neo Avenue Forest and NATM process (as part of mitigated scenario) at Eng Neo Avenue Forest. Typically, an assessment report and the statement method shall be produced before conducting such works. It should be noted that vibration estimates are difficult to be precise due to the local geological profile and site conditions at these worksites.

Before the actual works, a trial of a rock breaking and excavation activity shall be critical data on the vibration transmitted through the ground on the structures. These data can refine the vibration predictions and re-assess the impact.

The vibration shall be monitored during the work to provide a real-time reading. It should be noted that these serve as knowledge purposes only, and a rock breaking and excavation engineer shall be responsible for designing this activity that meets the Project requirements.

It should be noted that ground-borne vibration from the rock breaking and excavation cannot be eliminated; it can, however, be managed to the criteria set by adopting a proper dose for combustion at various depths and frequency/ timing of conduct. Parameters that affect rock breaking and excavation induced ground-borne vibration, and air overpressure impacts are detailed in Table 12-25.

Table 12-25 Parameters Affecting Rock Breaking and Excavation induced Ground-borne Vibration (and Air Overpressure)

Uncontrollable Parameters	Controllable Parameters	
	Charge Dependant	Design Dependant
• Geological characteristics and properties • Distance from the source of combustion	• Charge type • Amount of charge per delay • Number of charge holes per delay • Delay times	• Rock breaking hole diameter and depth • Burden and spacing • Charge length and stemming • Sub-drilling

Uncontrollable Parameters	Controllable Parameters	
	Charge Dependant	Design Dependant
	• Decoupling charge	

The minimum controls expected for ground-borne vibration estimation for the Biodiversity Study Area are as below:

i. The maximum instantaneous charge per delay must be calculated, planned, and controlled using delay detonators. These provide an effective initiation sequence that delays the rock breaking of each charge. Hence, the charges detonate in a controlled sequence, each separated by a few thousandths of a second. Therefore, to control ground-borne vibration generated, charge weight was minimised at any instant area of impact, timing, duration, and frequency.

ii. Promoting forward movement of the rock ensures that the charge energy is directed to break towards an open face. Multi-row rock breakings are fired using a time delay between successive rows of rock breaking. The burden on each rock breaking hole needs time to move after the commencement of rock breaking to create a practical free face. The fire towards this new free face developed during the rock breaking and excavation in the subsequent rows. Promoting the rock break and excavation activity in this sequence and directing it away from critical receptors reduces the vibration generated. Therefore, to control ground-borne vibration, it is necessary to ensure that the design of the activities promotes forward movement of the rock mass and allocate proper delay timings between rock breaking holes.

Implementing minimum controls is sufficient to alleviate any significant environmental construction impacts; contract-specific final mitigation measures are proposed in this section.

12.6.1.3 Tri-axle Trucks

In general, tri-axle trucks, compared to tandem trucks, have an extra axle and suspension, allowing better loading on the frame and giving additional stability. Therefore, the load they carry on each trip is higher than the standard truck and can significantly minimise the number of truckloads required along this road during the construction phase. Thus, as the tri-axle truck travels along the access roads, the vibration caused by the wheels and road surfaces can be minimised more due to the reduction in the number of trips. As discussed with LTA, there is also a need for the traffic controller to release three trucks at a time.

12.6.2 Operational Phase

This section proposes minimum controls or standard practices commonly implemented as ground-borne vibration control measures. A summary of minimum control measures is presented in Table 12-26. The Contractor shall determine concrete material/density at a later stage.

Table 12-26 Minimum Control Measures

Minimum Controls
Train, track, and tunnel design
Maintenance of vertical track alignment at the relevant longitudinal wavelengths
Maintenance of roughness of the railhead and wheel tread at the relevant longitudinal and circumferential wavelengths, respectively.
Maintenance of resilient elements in track construction, e.g. rail pads.
Maintenance of rail joints, switches, and crossings.

12.7 Prediction and Evaluation of Ground-borne Vibration Impacts

This section details the vibration impact assessment for construction and operational activities on the biodiversity areas Windsor, Eng Neo Avenue Forest, and Sites I and II. The predicted vibration levels from the activities are assessed for the following:

1. Impacts on the structural integrity of fossorial species' burrows.
2. Behavioural impacts on the ecologically sensitive receptors.

12.7.1 Construction Phase (Base Scenario)

The base case here is the worksites proposed at the onset of the construction of the alignment and station.

12.7.1.1 Structural Integrity of Burrows

Based on the baseline fauna survey, burrows of fossorial species have been sighted and recorded at the Biodiversity Areas – Windsor, Eng Neo Avenue Forest, Sites I and II. Construction vibration levels are predicted, and the maximum levels for each activity are listed.

In the screening process, vibration caused by rock breaking and excavation is likely to impact the burrows in Eng Neo Avenue Forest and Windsor as the predicted vibration levels are greater than PPV, 5.00 mm/s. The vibration levels could potentially exceed PPV, 8.00 mm/s causing damage/collapse to the burrows. A damage/collapse could result in the entombment of the impacted fauna, causing mortality.

As the depth of the source becomes more significant than 25 m below ground, the predicted vibration levels decrease and eventually have fewer exceedances against the vibration threshold level for partial burrow collapse. Nevertheless, for precautionary purposes and to further ensure no damage/collapse of burrows, the appointed Contractor should hold conversations with a wildlife expert to ensure that the impact's magnitude and duration are appropriate. It should be noted that minimal or no ecological use of the A1-W1 worksite happens during the active construction and rock breaking and excavation phases because of high levels of human activity. This type of communication can prove beneficial for controlling the impact and learning about the local fauna and their behaviour from this activity. The study recommends controlling the threshold value in the Biodiversity Study Areas accompanied by constant trigger monitoring.

Table 12-27 Predicted Vibration Levels of Construction Activities for Base Scenario

Construction Worksite	Construction Activities	Max Predicted PPV, mm/s	
		Biodiversity Area - Eng Neo Avenue Forest	**Biodiversity Area - Sites I and II**
A1-W2	Rock Breaking and Excavation, BS/ T207	8.30/5.67	0.42/0.33
	Rotary Bore Piling	0.31	0.0002
	Bulldozing	2.00	0.01
	Tunnel Boring (entire tunnel), BS/Esvelt	0.84/0.43	0.11/0.05
	Tunnel Boring Esvelt (at spot)	0.47	0.05
Construction Worksite	**Construction Activities**	**Max Predicted PPV, mm/s**	
		Biodiversity Area - Windsor	
A1-W1	Rock Breaking and Excavation, BS/ T207	9.36/10.80	
	Rotary Bore Piling	0.30	
	Bulldozing	0.30	
	Tunnel Boring (entire tunnel) , BS/ Esvelt	0.51/0.77	
	Tunnel Boring (at spot 1)	0.07	
	Tunnel Boring (at spot 2)	0.45	
	Tunnel Boring (at spot 3)	0.23	

12.7.1.2 Behavioural Impacts on Fauna

The assessments in this section focus on the behavioural impacts on Priority 1 fauna receptors within Windsor, Eng Neo Avenue Forest, and Sites I and II.

12.7.1.2.1 *A1-W2 Worksite (Base Scenario)*

The assessment predicts the vibration impacts from construction activities at the A1-W2 worksite (base scenario).

12.7.1.2.1.1 Rock Breaking and Excavation

In the base scenario, there is one vibration source for the rock breaking and excavation activity at the A1-W2 worksite. The study predicts the vibration levels from the activity using the guidelines of BS 6472-2-2008 and an equation referenced from Contract T207.

The assessment using the guidelines of BS 6472-2-2008 gives a highly conservative outcome for the impact study as the vibration levels are predicted to represent the “worst-case scenario” for any geological conditions at the worksite. Based on the impact assessment results in Figure 12-9, the impact intensity result at Eng Neo Avenue Forest is **Negligible – Medium**. The impact consequence for Priority 1 habitat and fauna is **Very Low – Medium**; when the likelihood is **Certain**, the impact significance is **Minor – Major**. In Table 12-28, the impacted area for **Moderate – Major** impact significance is 24.5 ha and 9.8 ha in Eng Neo Avenue Forest.

For the Sites I and II assessment, the impact intensity result is **Low**. The impact consequence for Priority 1 habitat and fauna is **Very Low – Low**; when the likelihood is **Certain**, the impact significance is **Minor – Moderate**. Regarding Table 12-28, the impacted area for **Moderate** impact significance is estimated to be 4.1 ha at Site I and 10 ha at Site II.

The equation referenced from Contract T207 predicts vibration levels for geological conditions similar to the A1-W2 worksite, the predicted vibration level is low, and the impacted area is small. Regarding Table 12-28, the impacted area for **Moderate – Major** impact significance is estimated to be 20.1 ha and 8.2 ha in Eng Neo Avenue Forest. Based on the impact assessment results in Figure 12-10, the impact intensity result at Eng Neo Avenue Forest is **Negligible – Medium**. The impact consequence for Priority 1 habitat and fauna is **Very Low – Medium**; when the likelihood is **Certain**, the impact significance is **Minor – Major**

For the Sites I and II assessment, the impact intensity result is **Low**. The impact consequence for Priority 1 habitat and fauna is **Very Low – Low**; when the likelihood is **Certain**, the impact significance is **Minor – Moderate**. About Table 12-28, the impacted area for **Moderate** impact significance is 10 ha at Site I and 3.6 ha at Site II.

For **Minor** impact significance**,** vibration generated from rock breaking and excavation may impact sensitive fauna. At the same time, other species may avoid the area because of the increased levels of activity in the area. However, many species would become habituated to the rock breaking and excavation activity and return to regular activity.

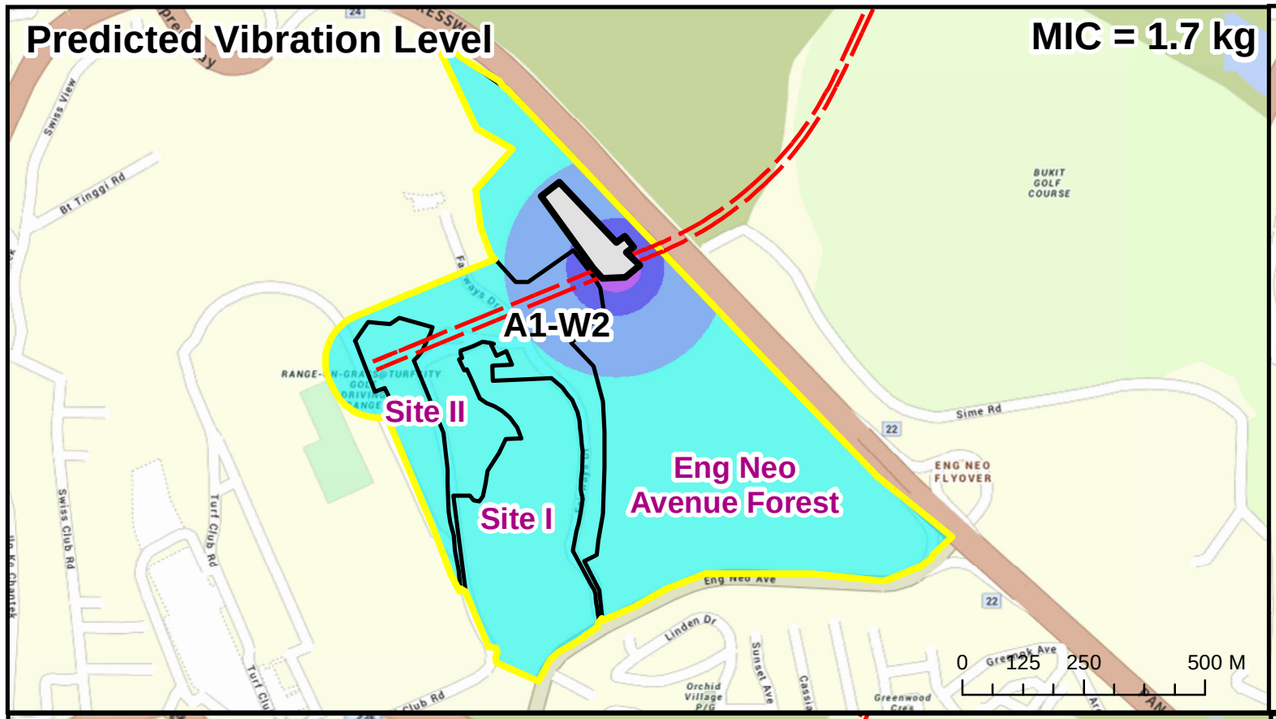
For **Major** impact significance, vibration generated from rock breaking and excavation may cause permanent effects and affected indicator species are not expected to adapt to using this area.

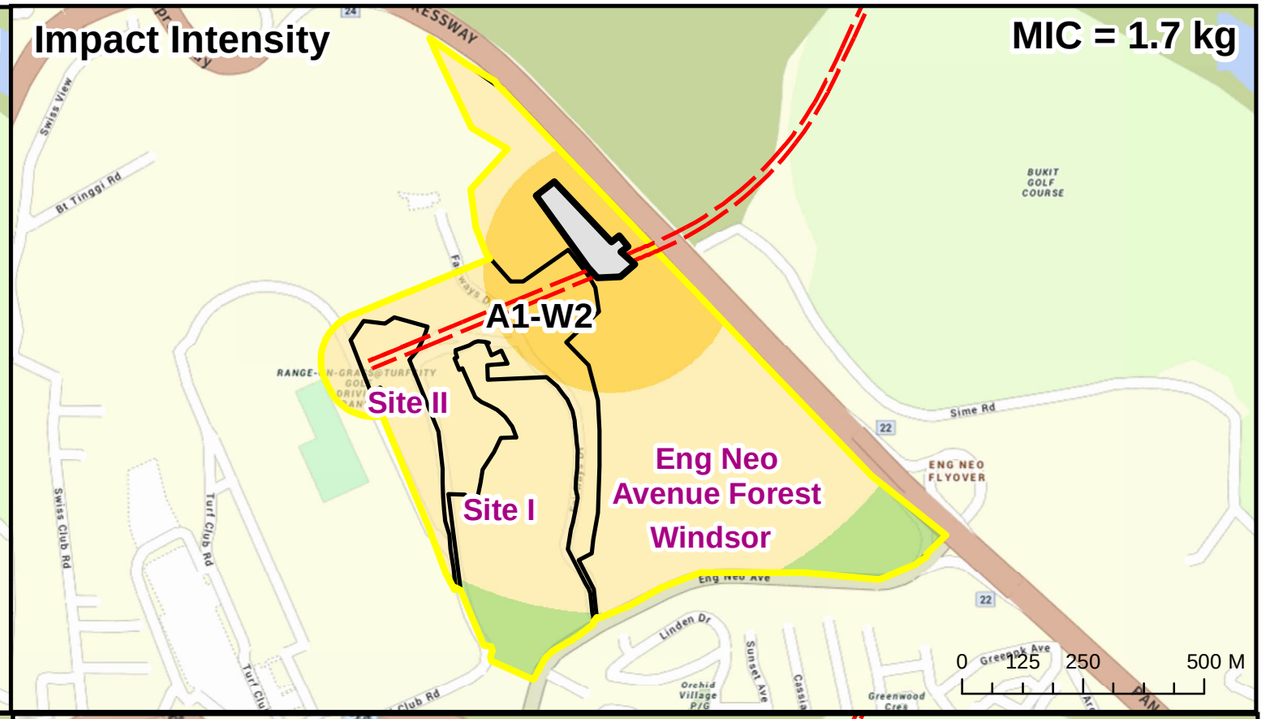
The impacts can be reversed once A1-W2 has been excavated and rock breaking and excavation have been completed, and when high levels of human activity become more manageable.

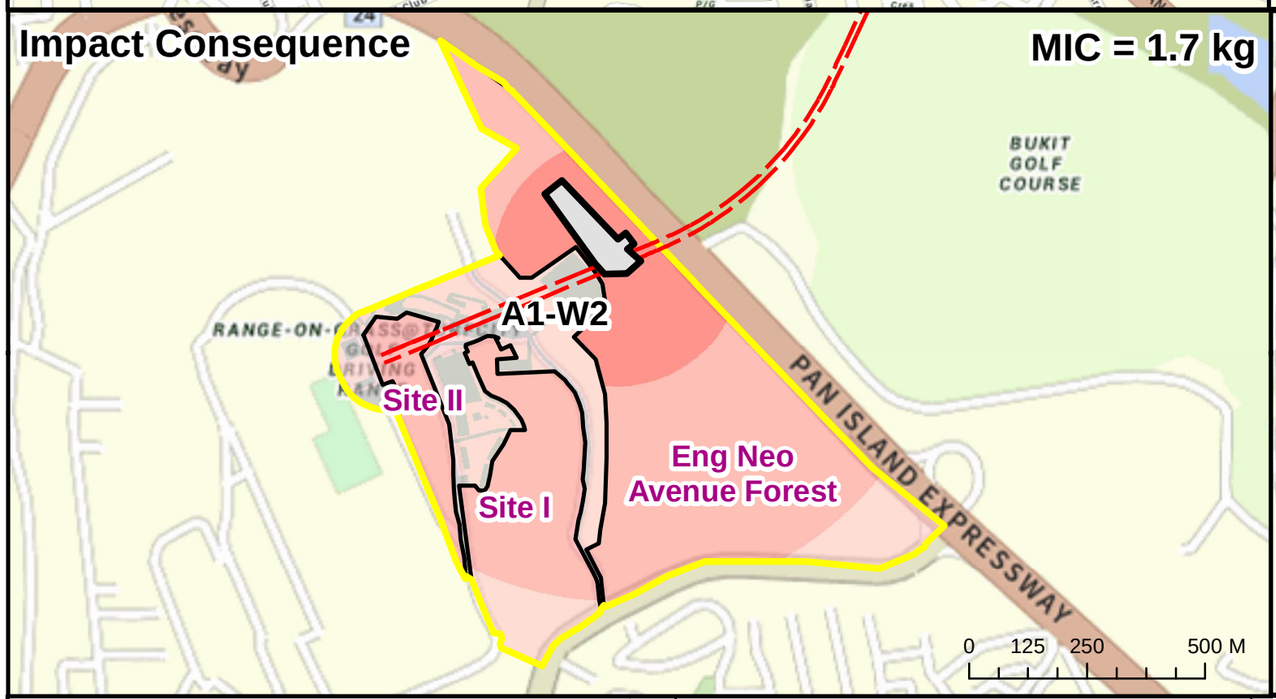
The presence of mousedeer (*Tragulus kanchil*) and sunda pangolin (*Manis javanica*) was recorded during the baseline fauna survey. These species are assessed as Priority 1 ecologically sensitive receptors as they are sensitive to vibration and are classified as locally threatened species. However, there is no significant literature and research on the adaptability of these species in tropical habitats here. It is reasonable to assume that vibration from rock breaking and excavation may impact part of their habitat (pangolins' burrows), and foraging opportunities. The mousedeer (*Tragulus kanchil*) and sunda pangolin (*Manis javanica*) may move out of affected areas during the day and return at night to forage in these areas where food sources are available nearby. With controls to restrict/stop work at a vibration threshold of PPV, 8.00 mm/s, this can prevent burrow damage/collapses in fossorial species.

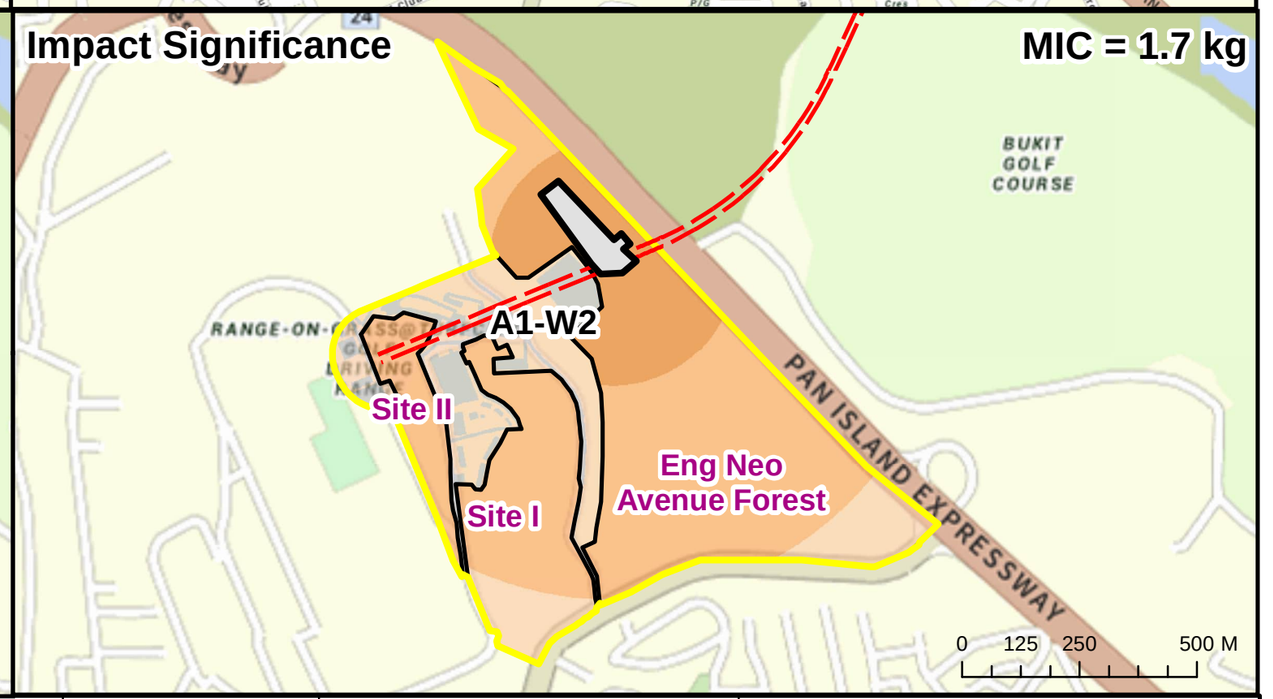
Table 12-28 A1-W2 Worksite Rock Breaking and Excavation Impact Significance Area

Construction Worksite	Construction Activities	Impact Significance	Impacted Area, ha		
			Eng Neo Avenue Forest	Site I	Site II
A1-W2	Rock Break and Excavation BS MIC = 1.7 kg	Moderate	24.5	4.1	10
		Major	9.8	NA	NA
	Rock Break and Excavation T207 MIC = 2.9 kg	Moderate	20.1	6.8	3.6
		Major	8.2	NA	NA









Legend

- Base Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Base)
- Study Area (Base)
- Biodiversity Study Area

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.07 - 0.55	Negligible	Very Low	Minor
0.56 - 1.81	Low	Low	Moderate
1.82 - 4.27	Medium	Medium	Major
4.28 - 8.41		Not Assessible	Not Assessible
8.41 - 15.36			

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

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NA

Consultant : AECOM

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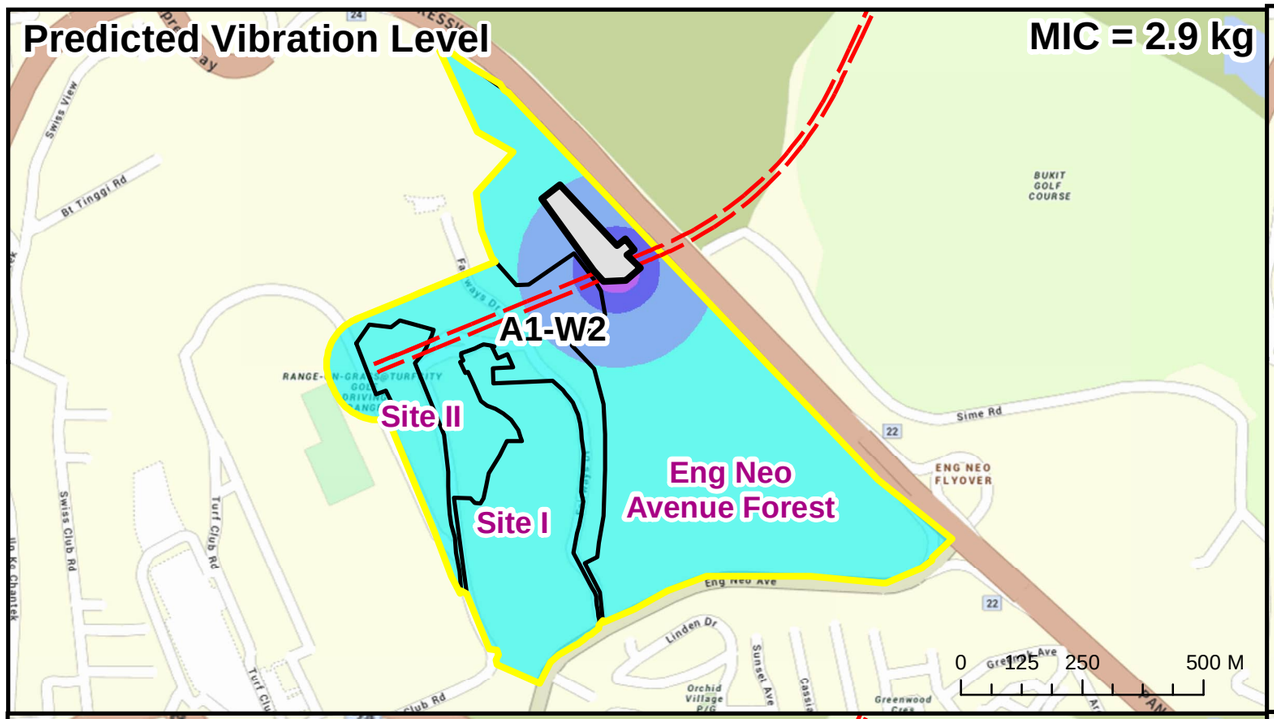
	Drawn: EGY	Date: MAR 2022

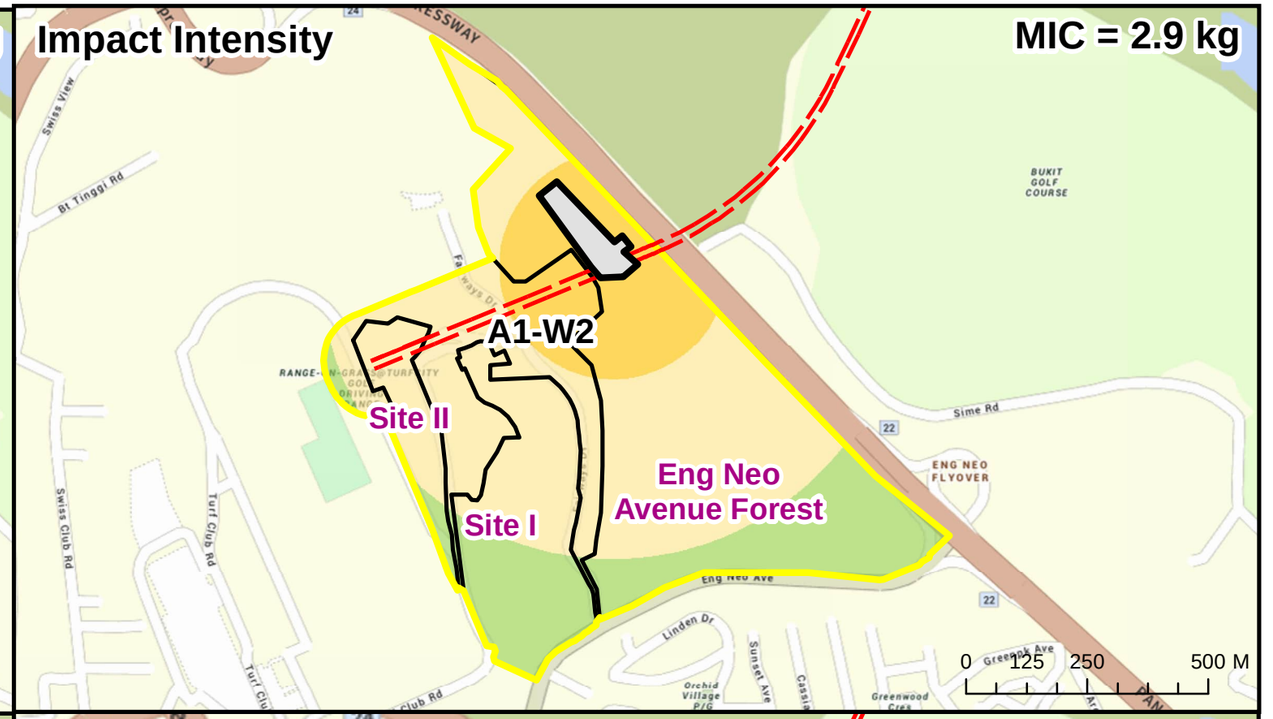
Figure Title :
VIBRATION ASSESSMENT FOR ROCK BREAKING AND EXCAVATION WORKS USING BS METHOD AT A1-W2 (1.7 KG) (BASE SCENARIO)

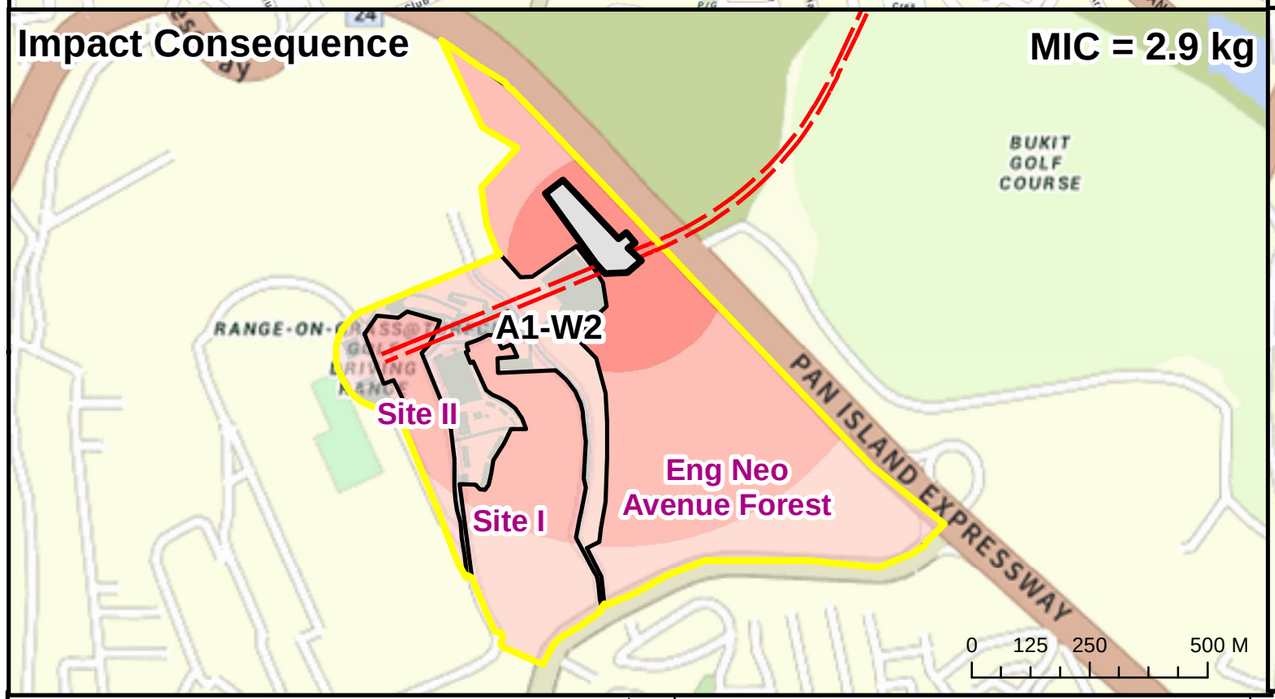
Figure No. :	Rev.	Sheet
12 - 9	-	1 of 1

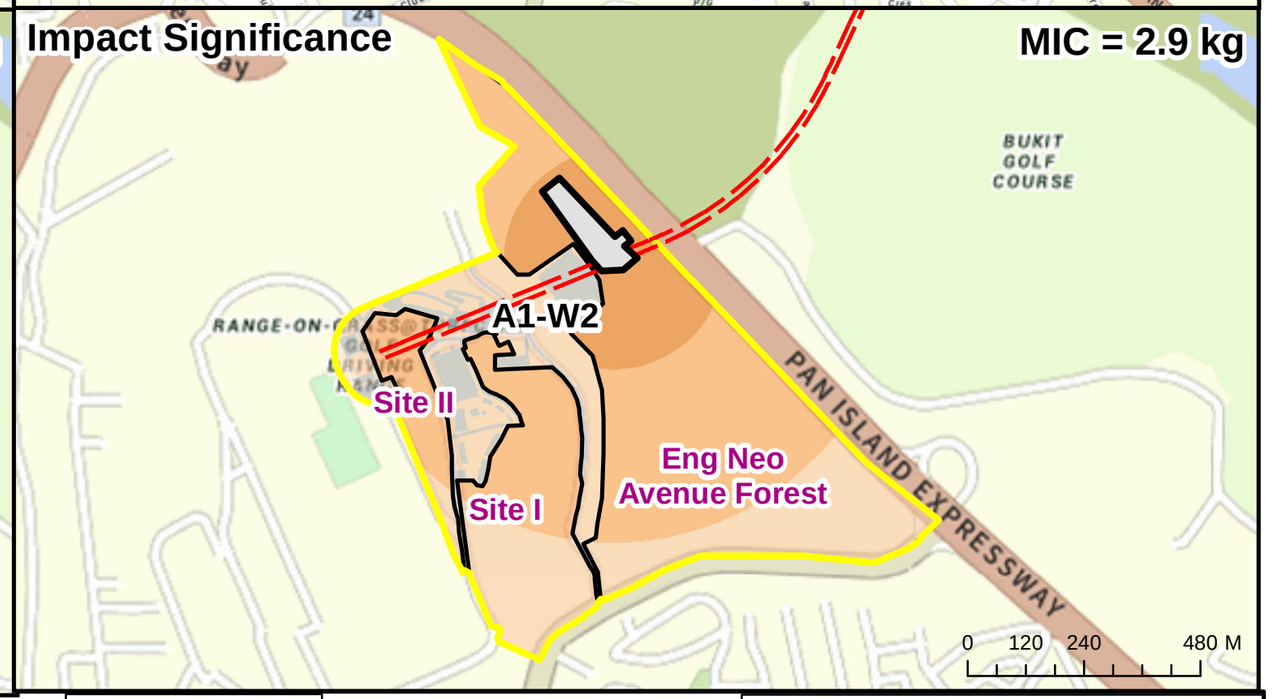
CAD File Name : NA — A3

Note: Source of basemap - OneMap









Legend

- Base Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Base)
- Study Area (Base)
- Biodiversity Study Area

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.05 - 0.56	Negligible	Imperceptible	Negligible
0.57 - 1.96	Low	Very Low	Minor
1.97 - 4.51	Medium	Low	Moderate
4.52 - 8.91		Medium	Major
8.91 - 16.29		Not Assessible	Not Assessible

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

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Consultant : AECOM

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Designed	Checked	Approved
EGY	JAG	JAG
	Drawn: EGY	Date: MAR 2022

Figure Title :
**VIBRATION ASSESSMENT FOR
ROCK BREAKING AND
EXCAVATION WORKS
USING T207 METHOD AT A1-W2 (2.9 KG)
(BASE SCENARIO)**

Figure No. :	Rev.	Sheet
12 - 10	-	1 of 1

CAD File Name : NA | A3

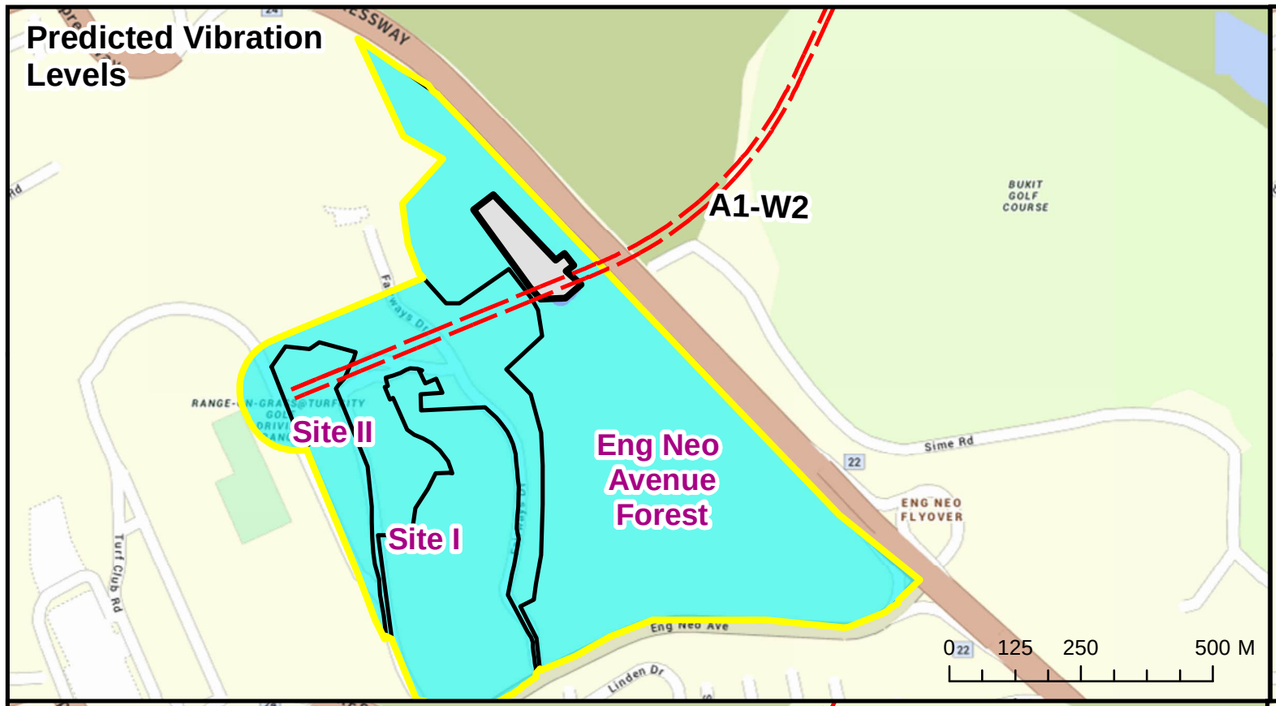
Note: Source of basemap - OneMap

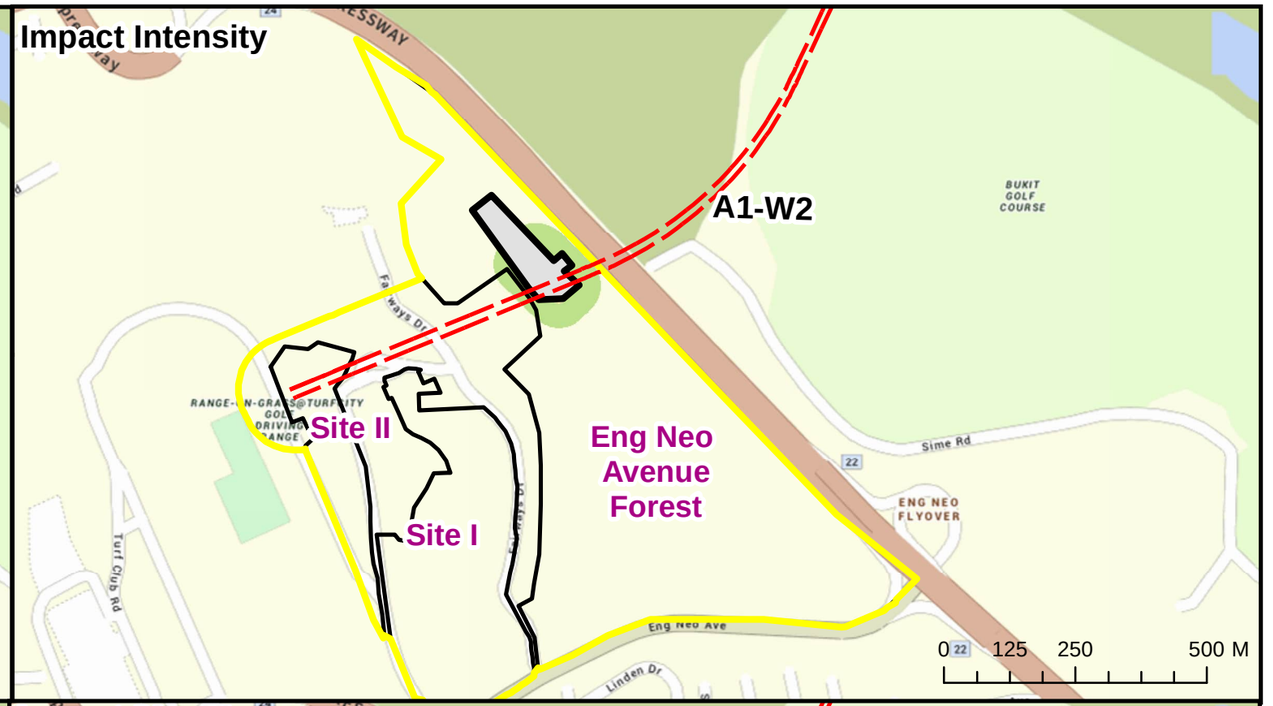
12.7.1.2.1.2 Rotary Bore Piling

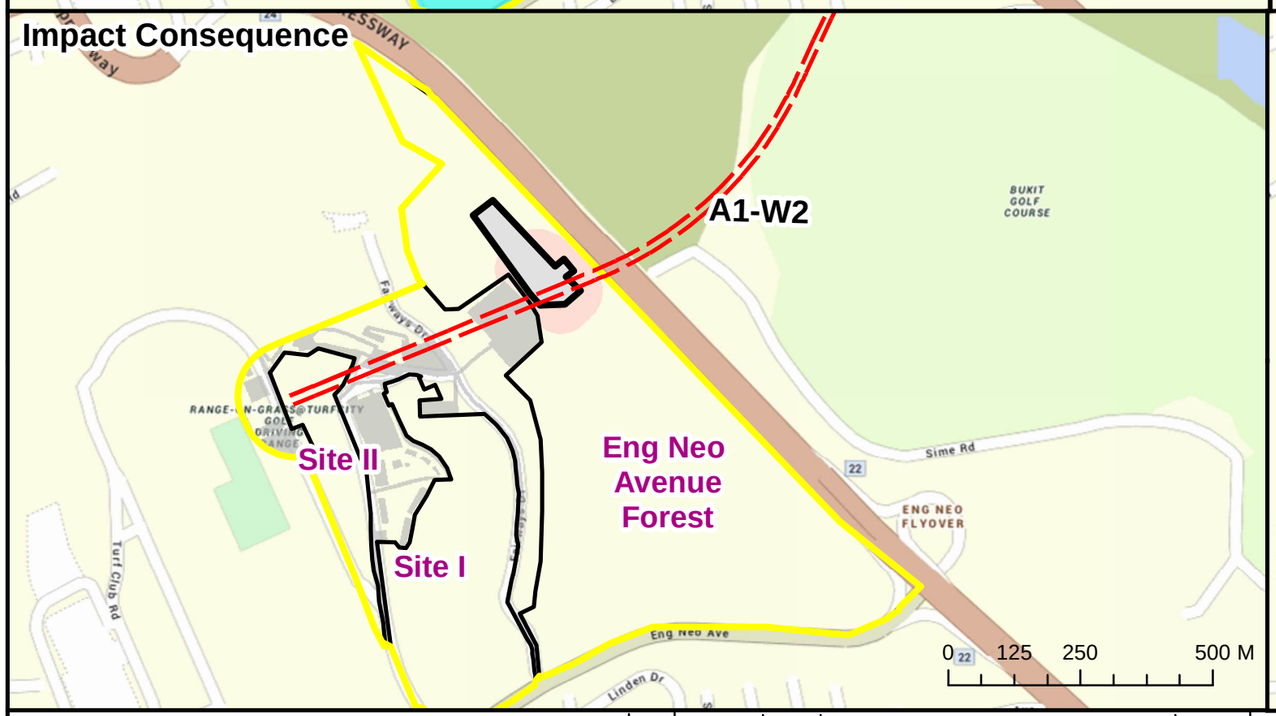
For the base scenario at the A1-W2 worksite, the piling rig is within Eng Neo Avenue Forest. Figure 12-12 shows the impact assessment results on Eng Neo Avenue Forest, Sites I and II.

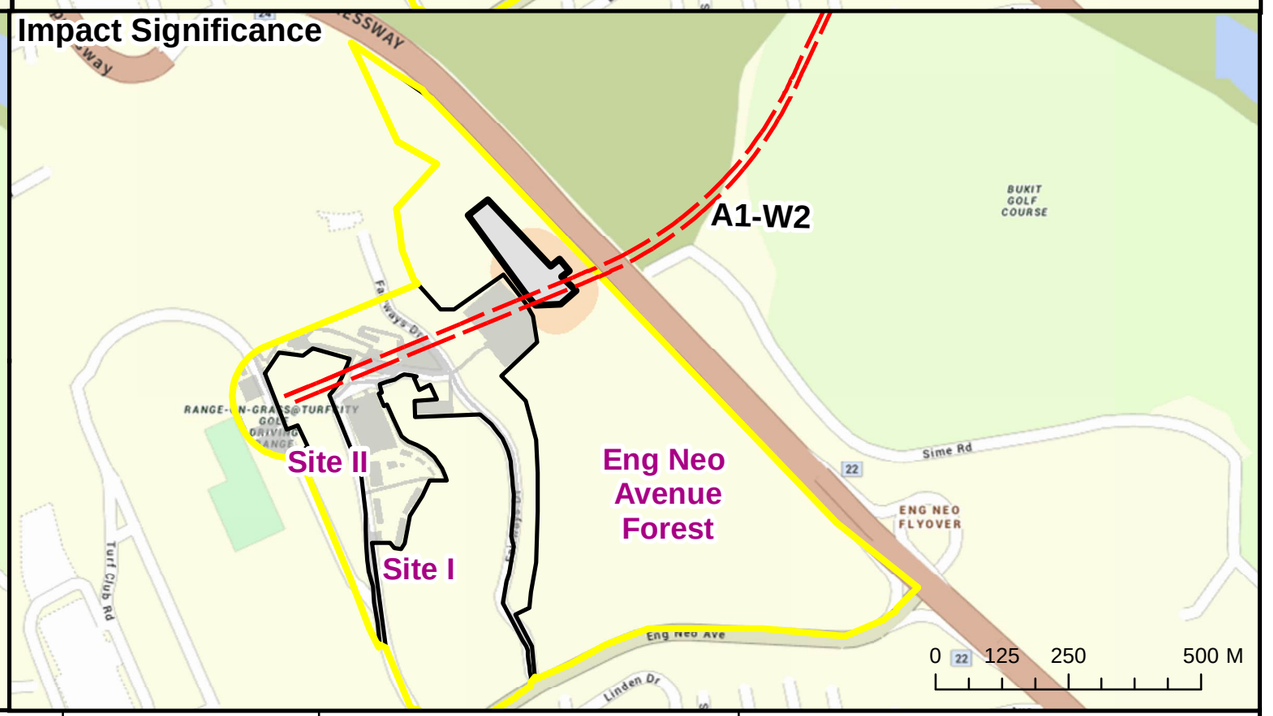
Priority 1 habitat receptors potentially experience a maximum PPV, 2.00 mm/s (see Table 12-27) and **Negligible** intensity in Eng Neo Avenue Forest. The impact consequence is I**mperceptible,** and when the likelihood is **Possible**, the overall impact significance is **Minor**. The impacted area is estimated to be 1.5 ha and likely to cause disturbance to the fauna. Vibration generated by the rotary bore piling may impact sensitive fauna, while other species may avoid the area because of the increased levels of activity in the area. However, the fauna species are likely to be habituated to the rotary bore piling rigs and would return to regular activity and habitat.

The maximum predicted vibration level in Sites I and II is PPV, 0.0002 mm/s (see Table 12-27). This level is assessed to be **Negligible** impact significance, and there should be no detectable behavioural change to fauna.









Legend

- Proposed CRL Alignment (Base)
- Base Scenario Construction Worksite Footprint
- Study Area (Base)
- Biodiversity Study Area

Predicted Vibration Levels	Impact Intensity	Impact Consequence	Impact Significance
PPV (mm/s)	Below Ambient	Below Ambient	Below Ambient
0.00 - 0.21	Negligible	Imperceptible	Negligible
0.21 - 0.91	Low	Very Low	Minor
0.91 - 1.95	Medium	Low	Moderate
1.95 - 3.04		Medium	Not Assessible
3.04 - 3.64		Not Assessible	

Note:
No bored piling at the relocated tunnel shaft
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
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Figure Title :
VIBRATION ASSESSMENT FOR ROTARY BORE PILING AT A1-W2 (BASE SCENARIO)

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 11	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

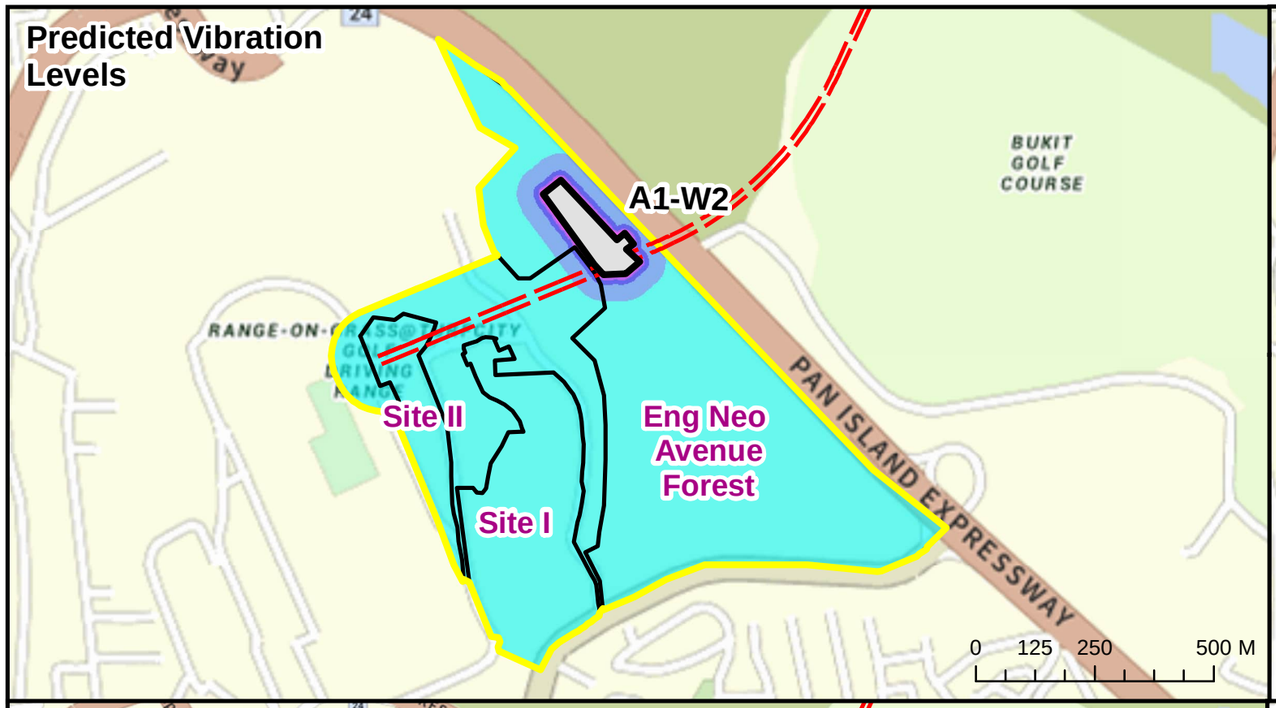
Note: Source of basemap - OneMap

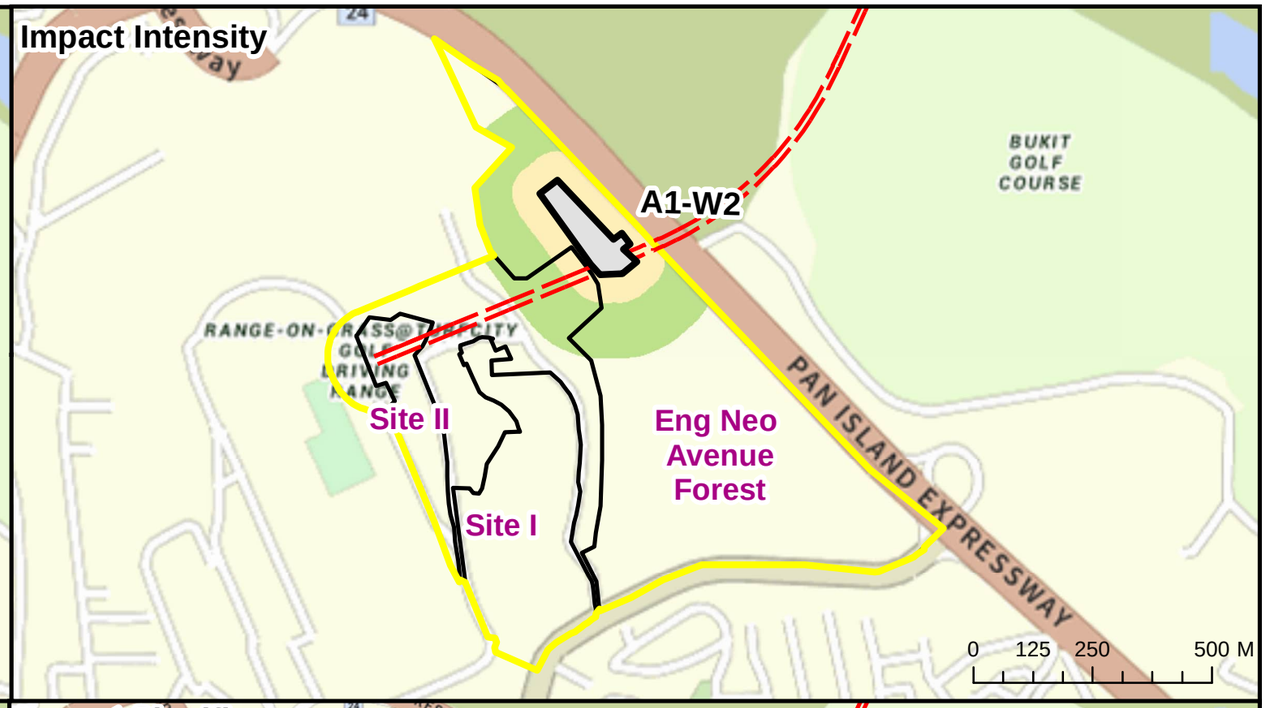
12.7.1.2.1.3 Bulldozer

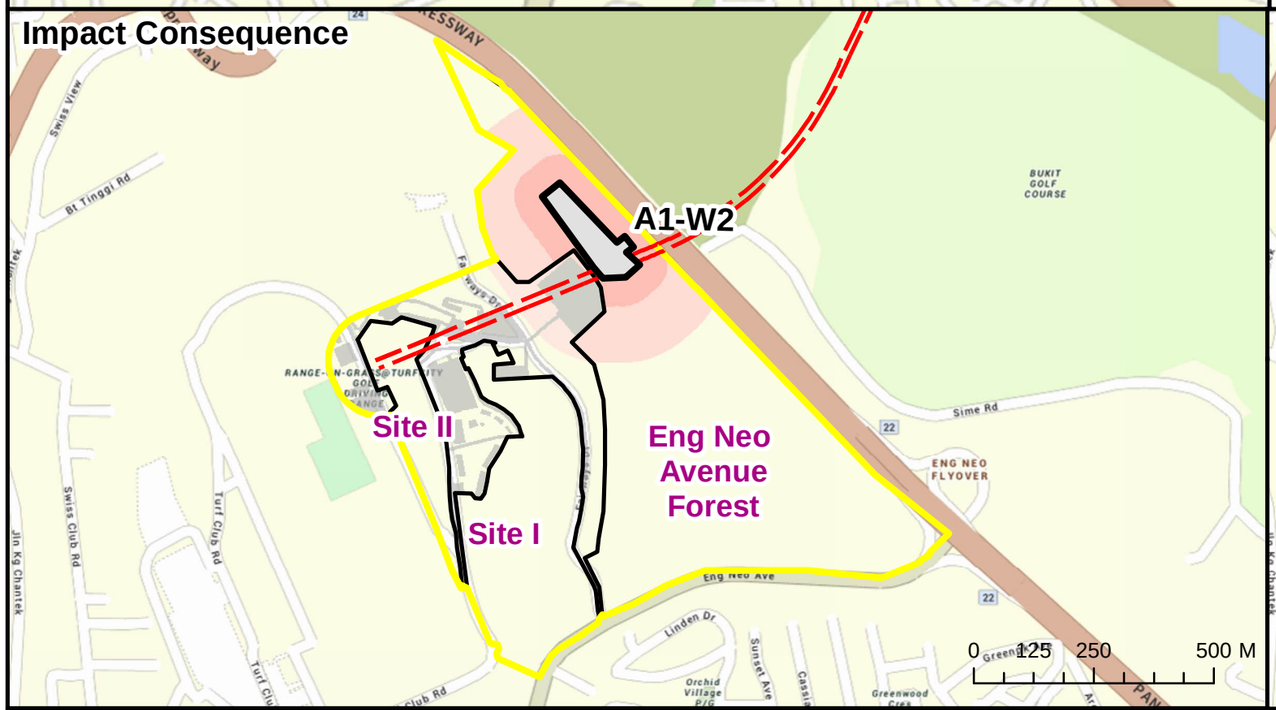
For the base scenario at the A1-W2 worksite, bulldozers might be used. Figure 12-12 shows the impact assessment results on Eng Neo Avenue Forest, Sites I and II.

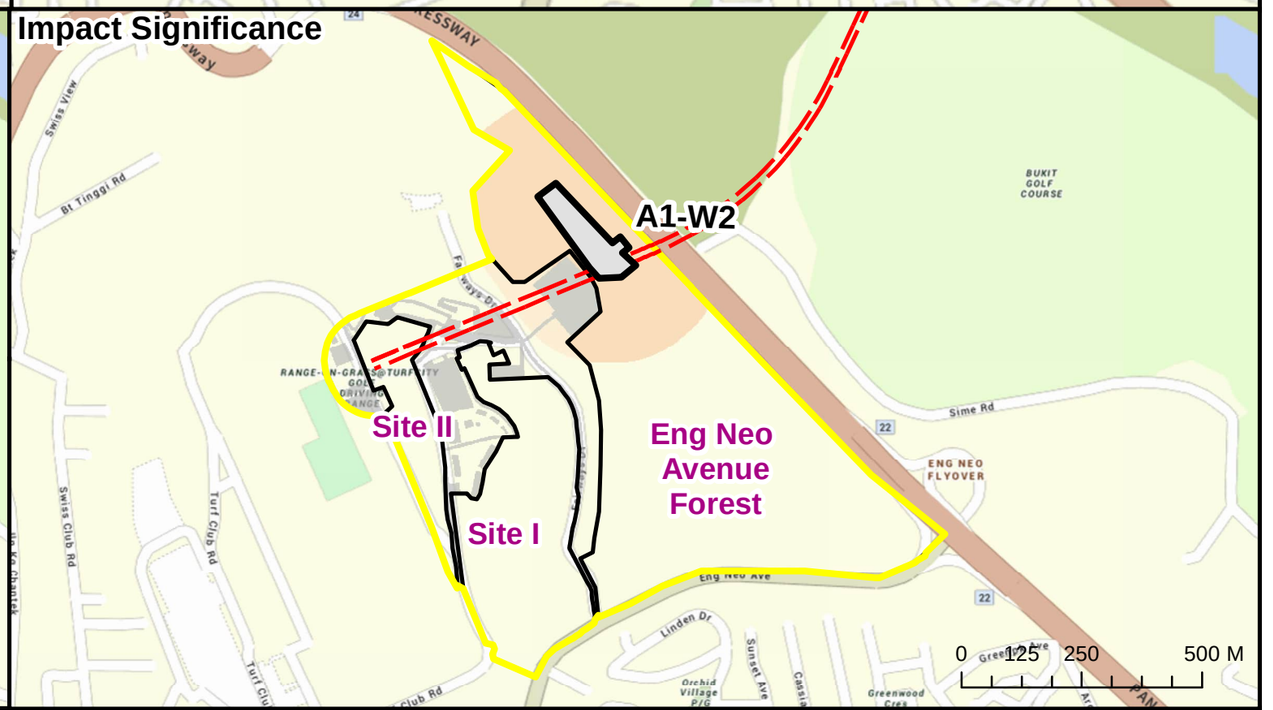
Priority 1 habitat receptors potentially experience a maximum PPV, 2.00 mm/s (see Table 12-27) and **Negligible** intensity in Eng Neo Avenue Forest. The impact consequence is **Imperceptible,** and when the likelihood is **Possible**, the overall impact significance is **Minor**. The impacted area is estimated to be 9.6 ha and likely to cause disturbance to the fauna. Vibration generated by the bulldozers may impact sensitive fauna, while other species may avoid the area because of the increased levels of activity in the area. However, the fauna species are likely to be habituated to the bulldozers and would return to regular activity and habitat.

The maximum predicted vibration level in Sites I and II is PPV, 0.01 mm/s (see Table 12-27). This level is assessed to be **Negligible** impact significance, and there should be no detectable behavioural change to fauna.









Legend

- Base Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Base)
- Study Area (Base)
- Biodiversity Study Area

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0 - 0.11	Below Ambient	Below Ambient	Below Ambient
0.12 - 0.44	Negligible	Imperceptible	Negligible
0.45 - 1.03	Low	Very Low	Minor
1.04 - 1.82		Low	Not Assessible
1.83 - 2.26		Not Assessible	

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
VIBRATION ASSESSMENT FOR BULLDOZER AT A1-W2 (BASE SCENARIO)

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 12	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

12.7.1.2.1.4 Tunnel Boring Machine (TBM)

The study predicts the vibration levels from the activity using the guidelines of BS 6472-2-2008 and the Esvelt Equation from the CRL1 EIS Report [R-1].

The assessment using the guidelines of BS 6472-2-2008 gives a highly conservative outcome for the impact study as the vibration levels are predicted to represent the “worst-case scenario” for any geological conditions in the Biodiversity Study Areas. The detailed impact assessment results are found in Appendix CC.

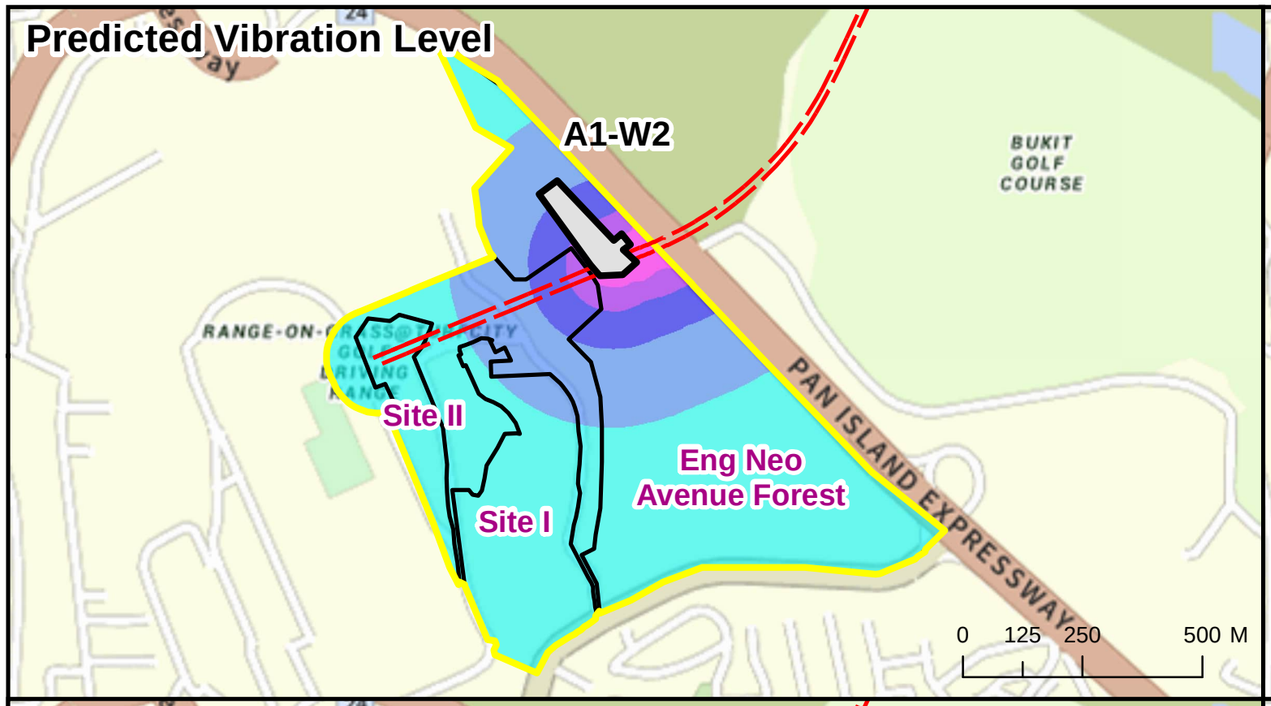
The Esvelt Equation predicts vibration levels for geological conditions similar to the Biodiversity Study Area, the predicted vibration level is low, and the impacted area is small. The vibration levels for the tunnel boring machine are predicted, and the overall impacts are assessed for the complete alignment in Eng Neo Avenue, Sites I and II. However, it should be noted that during actual works, the tunnel boring machine bores at a rate of 7 m / day (see Section 3.2.2.6.1). Therefore, the vibration impacts potentially impact only the affected area where the machine is on the day.

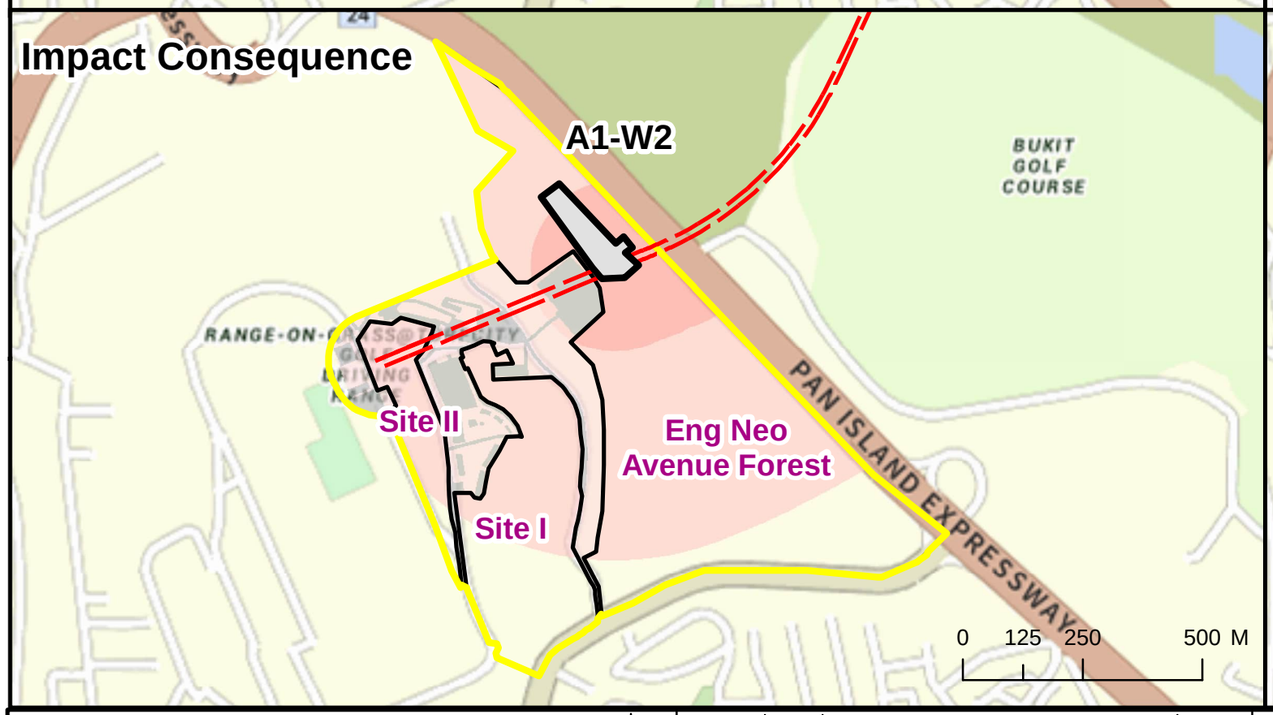
A hypothetical assessment for the tunnel boring machine impacting the entire Study Area simultaneously (i,e, overall footprint of the tunnel in the Biodiversity Study Area) is carried out, and the assessment results are shown in Figure 12-13.

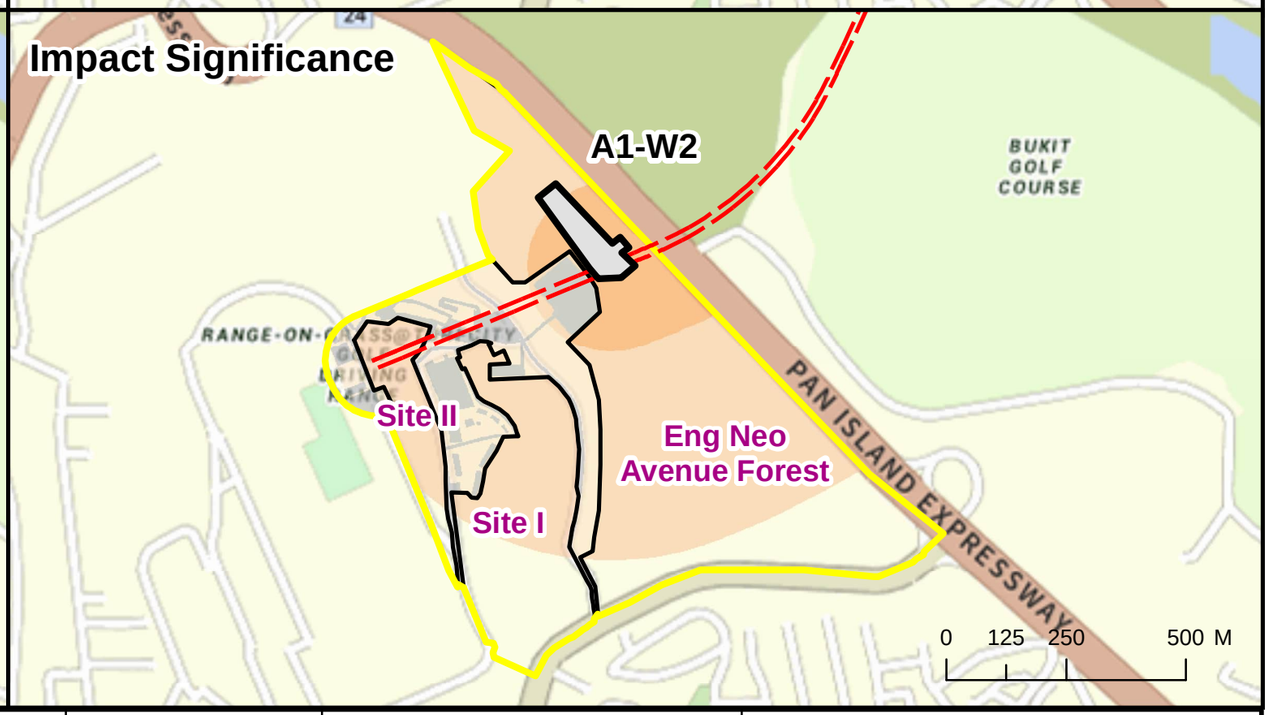
Priority 1 fauna potentially experience a maximum predicted PPV of approximately 0.47 mm/s at Eng Neo Avenue Forest and 0.05 mm/s at Sites I and II. The full impact significance is **Moderate** over 12.3 ha in Eng Neo Avenue Forest. Sites I and II potentially experience a **Minor** impact significance over 12.2 ha and 4.2 ha, respectively. This initial assessment helps to identify the critical spot to conduct a detailed analysis of vibration impacts caused by the tunnel boring machine on fauna at any particular time. In this case, one hotspot was identified in Eng Neo Avenue Forest, and the assessment result is shown in Figure 12-14.

For **Minor** impact significance**,** vibration generated from tunnel boring may impact some sensitive fauna. At the same time, other species may avoid the area because of the increased levels of activity in the area. However, many species would become habituated to the tunnel boring machine and would return to regular activity in a few days when the machine has passed by.

For **Moderate** impact significance, vibration generated from tunnel boring may impact sensitive fauna on their day to day activities (communication/ foraging/ breeding activities) for a short period in the zone of impact and may leave the area. However, this displacement is expected to be temporary, and they are expected to return after a while. Hence, the impact significance of **Moderate** seems to be a reasonable deduction from the assessment, and hence no additional mitigation measures are proposed for this case. The potential behavioural impacts predicted above have limited research backup in the local context. Hence, a comprehensive, adaptive monitoring plan has been proposed during this activity, as provided in Section 13.11.







Legend

- Base Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Base)
- Study Area (Base)
- Biodiversity Study Area

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.012 - 0.04	Below Ambient	Below Ambient	Below Ambient
0.04 - 0.09	Negligible	Imperceptible	Negligible
0.09 - 0.19	Low	Very Low	Minor
0.19 - 0.32		Low	Moderate
0.32 - 0.53		Not Assessible	Not Assessible

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Land Transport Authority
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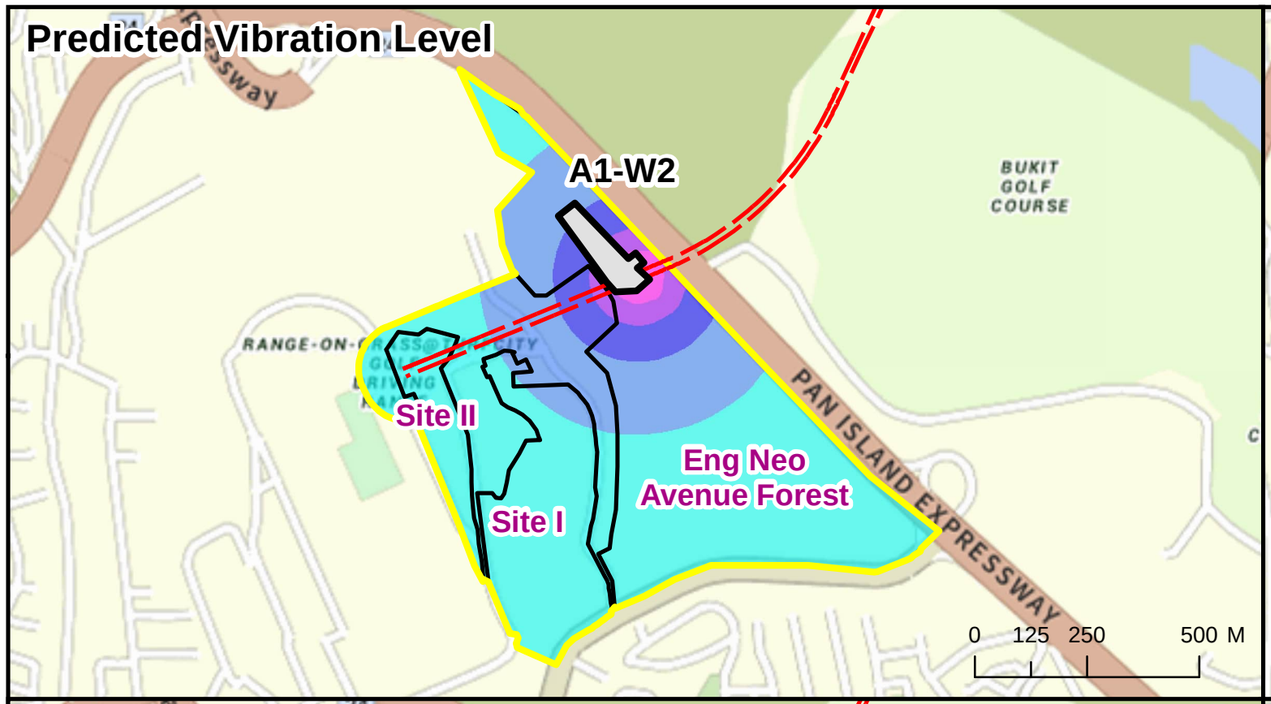
Drawing Title :
HYPOTHETICAL OVERALL VIBRATION ASSESSMENT FOR TUNNEL BORING AT A1-W2 USING ESVELT METHOD (BASE SCENARIO)

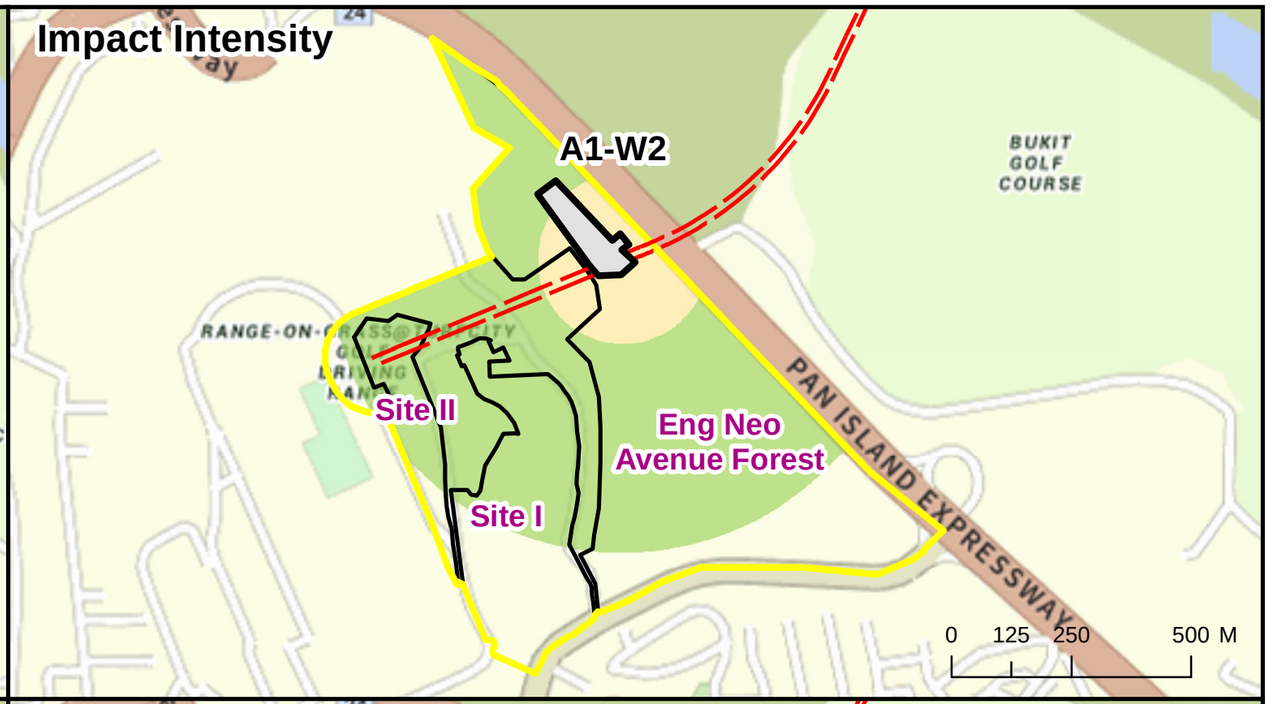
Designed	Checked	Approved
EGY	JAG	JAG
	Drawn: EGY	Date: MAR 2022

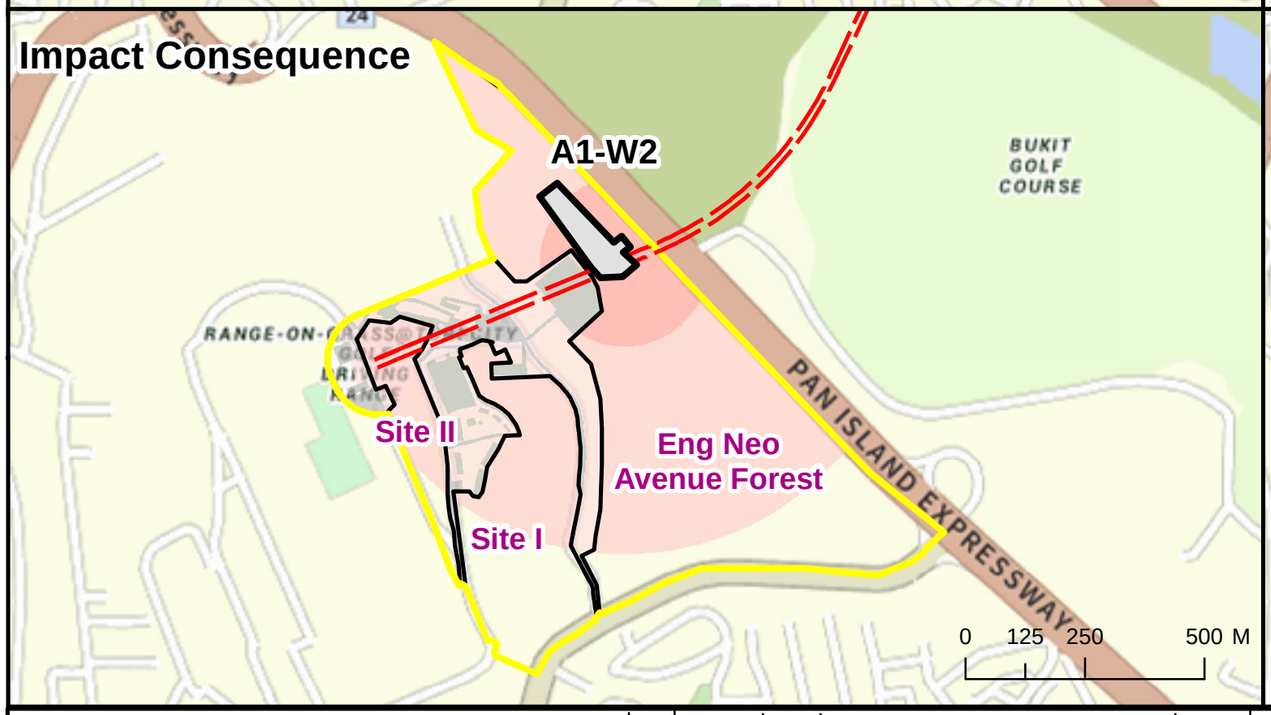
Drawing No. : 12 - 13 | Rev. : - | Sheet : 1 of 1

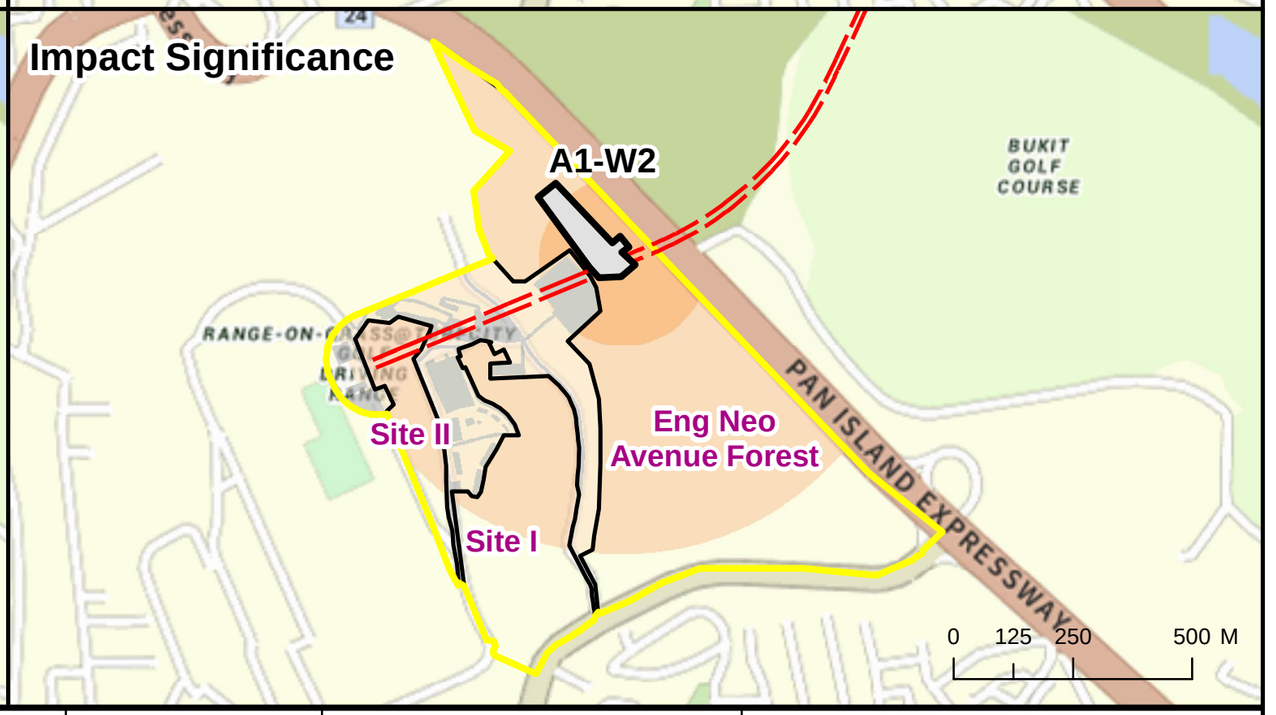
CAD File Name : NA | A3

Note: Source of basemap - OneMap









Legend

- Base Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Base)
- Study Area (Base)
- Biodiversity Study Area

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.01 - 0.04	Below Ambient	Below Ambient	Below Ambient
0.05 - 0.09	Negligible	Imperceptible	Negligible
0.10 - 0.17	Low	Very Low	Minor
0.18 - 0.29		Low	Moderate
0.30 - 0.45		Not Assessible	Not Assessible

N

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
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Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)

Drawing Title :
VIBRATION ASSESSMENT FOR SPOT TUNNEL BORING AT A1-W2 USING ESVELT METHOD (BASE SCENARIO)

Designed	Checked	Approved	Drawing No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 14	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

12.7.1.3 A1-W1 Worksite (Base Scenario)

The A1-W1 worksite was initially planned to be located in the forest fragments north of the Windsor Nature Park (outside of the Park) connected to a larger forest patch to the east. The optimised A1-W1 worksite (mitigated scenario, tunnel boring machine pass below ground only) does not connect to the larger forest patch. Thus, only a tunnel vent shaft is constructed in the mitigated scenario. However, the decision to move the tunnel boring machine launch shaft away from this worksite may have substantial savings in the number of truck trips to and from the site. Lesser truck trips reduce the effects of ground-borne vibration due to truck traffic.

12.7.1.3.1 *Rock Breaking and Excavation*

There is one vibration source for the rock breaking and excavation activity at the A1-W1 worksite in the base scenario. The study predicts the vibration levels from the activity using the guidelines of BS 6472-2-2008 and an equation referenced from Contract T207.

The equation referenced from Contract T207 predicts vibration levels for geological conditions similar to the A1-W2 worksite. Based on the impact assessment results in Figure 12-15, the impact intensity result at Windsor is **Negligible – Medium**. The impact consequence for Priority 1 habitat and fauna is **Very Low – Medium**; when the likelihood is **Certain**, the impact significance is **Minor – Major**. In Table 12-29, the impacted area for **Moderate** impact significance is 9.9 ha, and for **Major** impact significance, the affected area is 5.7 ha in Windsor.

The assessment using the guidelines of BS 6472-2-2008 gives a highly conservative outcome for the impact study as the vibration levels are predicted to represent the “worst-case scenario” for any geological conditions at the worksite. However, as the predicted levels are very low, the impact assessment results and size of the affected area for **Moderate** and **Major** impact significance are the same as those using the alternative calculation method.

For **Moderate** impact significance, vibration generated from rock breaking and excavation may impact sensitive fauna on their day to day activities (communication/ foraging) for a short period in the zone of impact and may leave the area. However, this displacement is expected to be temporary, and they are expected to return after a while.

For **Major** impact significance, vibration generated from rock breaking and excavation can cause permanent effects, and affected indicator species are not expected to adapt to this area.

Red-legged crake
(Source:https://singaporebirdgroup.wordpress.com/2017/06/06/red-legged-crakes-in-singapore/)

Red junglefowl
(Source:https://www.nparks.gov.sg/nparksbuzz/issue-05-vol-2-2010/conservation/on-the-trail-of-the-red-junglefowl)

Long-tailed parakeet
(Source:https://singaporebirds.com/species/long-tailed-parakeet/#jp-carousel-5861)

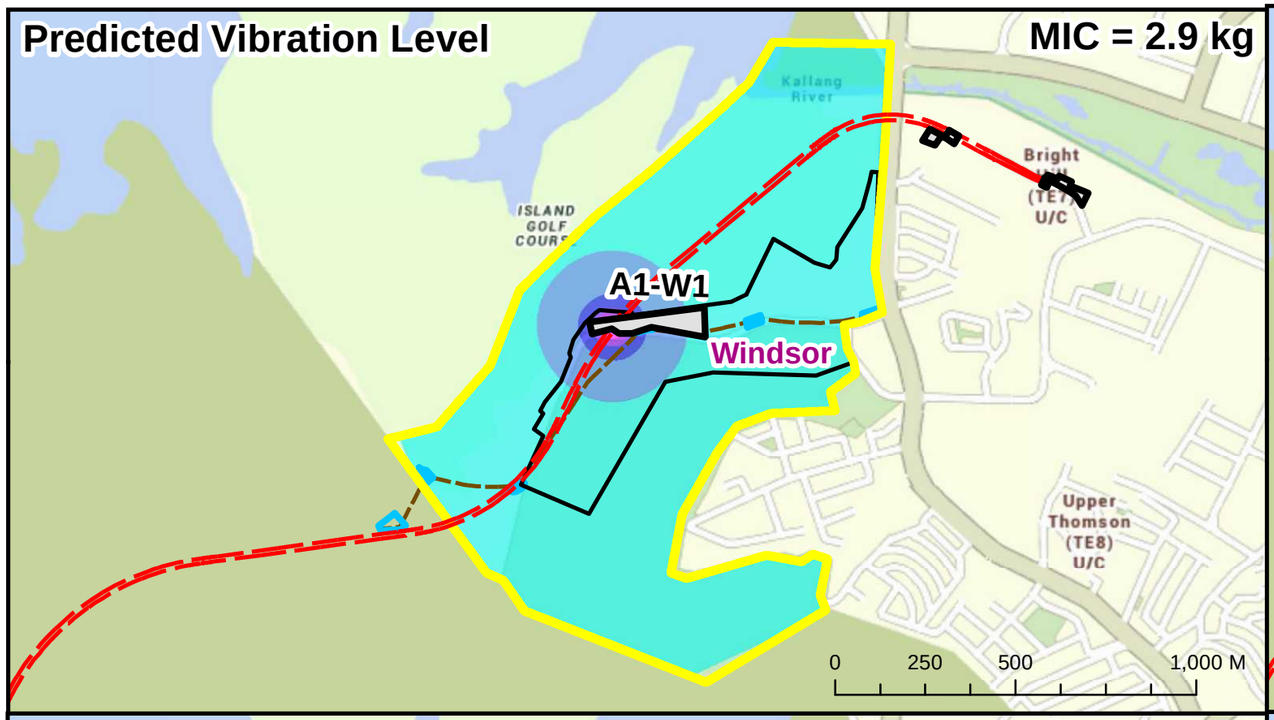
The presence of mousedeer *(Tragulus kanchil*) and Sunda pangolin (*Manis javanica*) was recorded during the baseline fauna survey. These species are assessed as Priority 1 ecologically sensitive receptors as they are sensitive to vibration and are classified as locally threatened species. However, there is no significant literature and research on the adaptability of these species in tropical habitats here. It is reasonable to assume that vibration from rock breaking and excavation may impact part of their habitat (pangolins’ burrows) and foraging opportunities. The mousedeer (Tragulus kanchil) and sunda pangolin (Manis javanica) may move out of affected areas during the day and return at night to forage in these areas where food sources are available nearby.

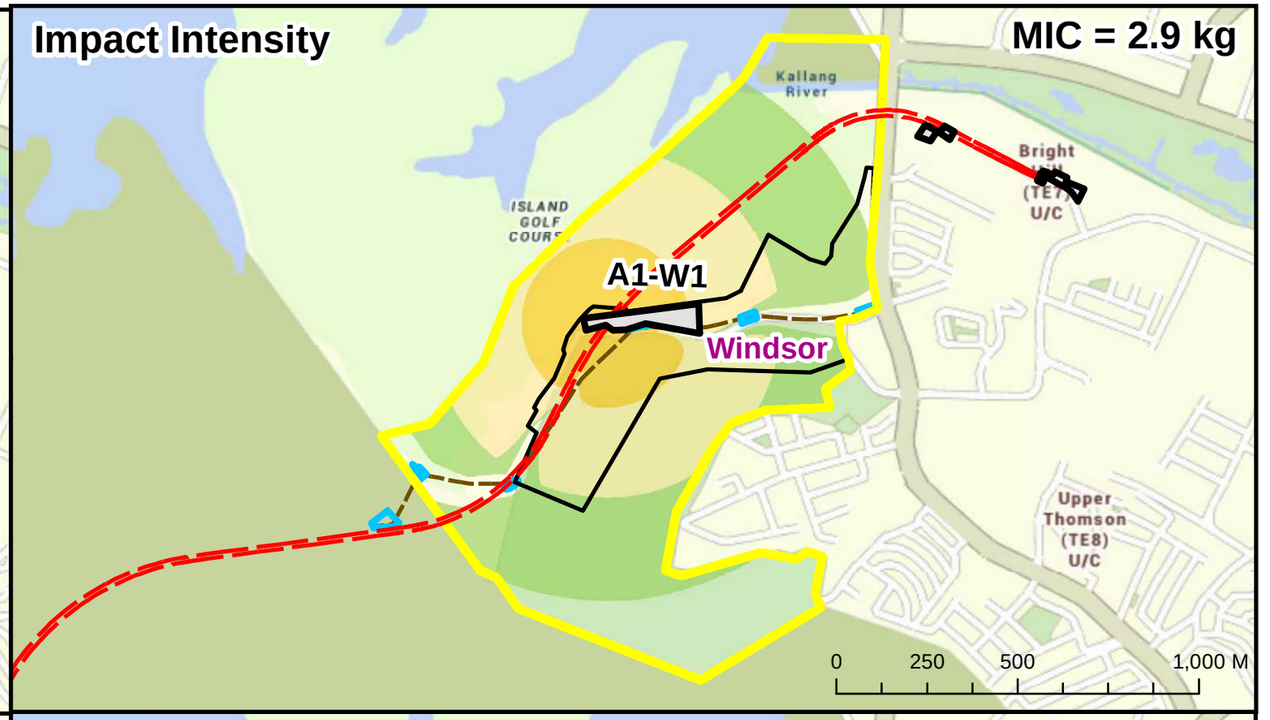
As the vibration source for rock breaking and excavation is near Island Club Road, rock breaking and excavation may also result in fauna, especially ground-dwelling and fossorial species, exhibiting flee response behaviour. Species/species groups that are likely to demonstrate a response to rock breaking and excavation would include:

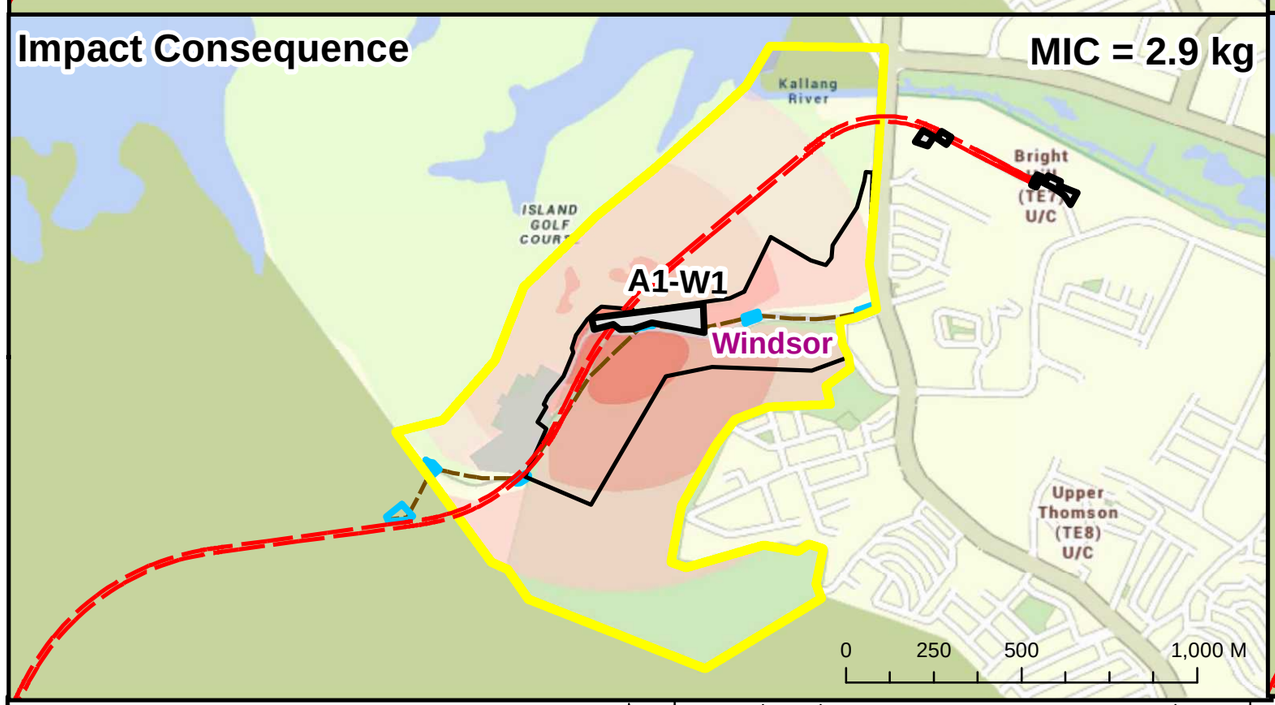
1. Pangolins are likely to curl into a ball and remain stationary. With controls to restrict/stop work at a vibration threshold of PPV, 8.00 mm/s, this can prevent burrow damage/collapses in fossorial species.
2. Mousedeers are likely to dash from cover to cover. However, it is unlikely to dash on the road due to its timid nature.
3. Fossorial snakes and reptiles are also unlikely to dash on the road.
4. Being a highly adaptable urban species, wild boar are potentially the only species that might exhibit flee response and end up on the road.

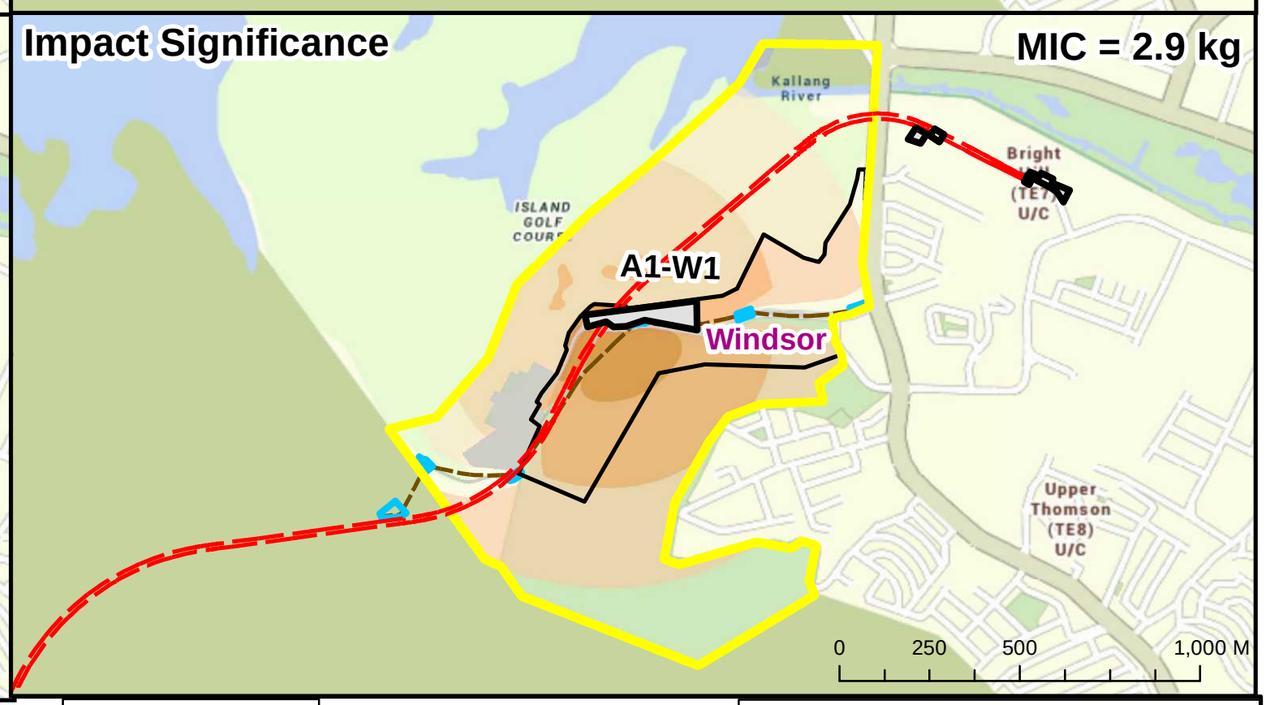
Table 12-29 A1-W1 Worksite Rock Breaking and Excavation Impact Significance Area for Windsor

Impact Significance	Impacted Area (BS MIC = 1.7 kg), ha	Impacted Area (T207 MIC = 2.9 kg), ha
Moderate	9.9	9.9 ha
Major	5.7	5.7 ha









Legend

- Base Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Base)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.03 - 0.59	Below Ambient	Below Ambient	Below Ambient
0.59 - 2.30	Negligible	Imperceptible	Negligible
2.30 - 5.77	Low	Very Low	Minor
5.77 - 11.37	Medium	Low	Moderate
11.37 - 18.11		Medium	Major
		Not Assessible	Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
HYPOTHETICAL OVERALL VIBRATION ASSESSMENT FOR ROCK BREAKING AND EXCAVATION AT A1-W1 USING T207 APPROACH (BASE SCENARIO)

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 15	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

12.7.1.3.2 *Rotary Bore Piling*

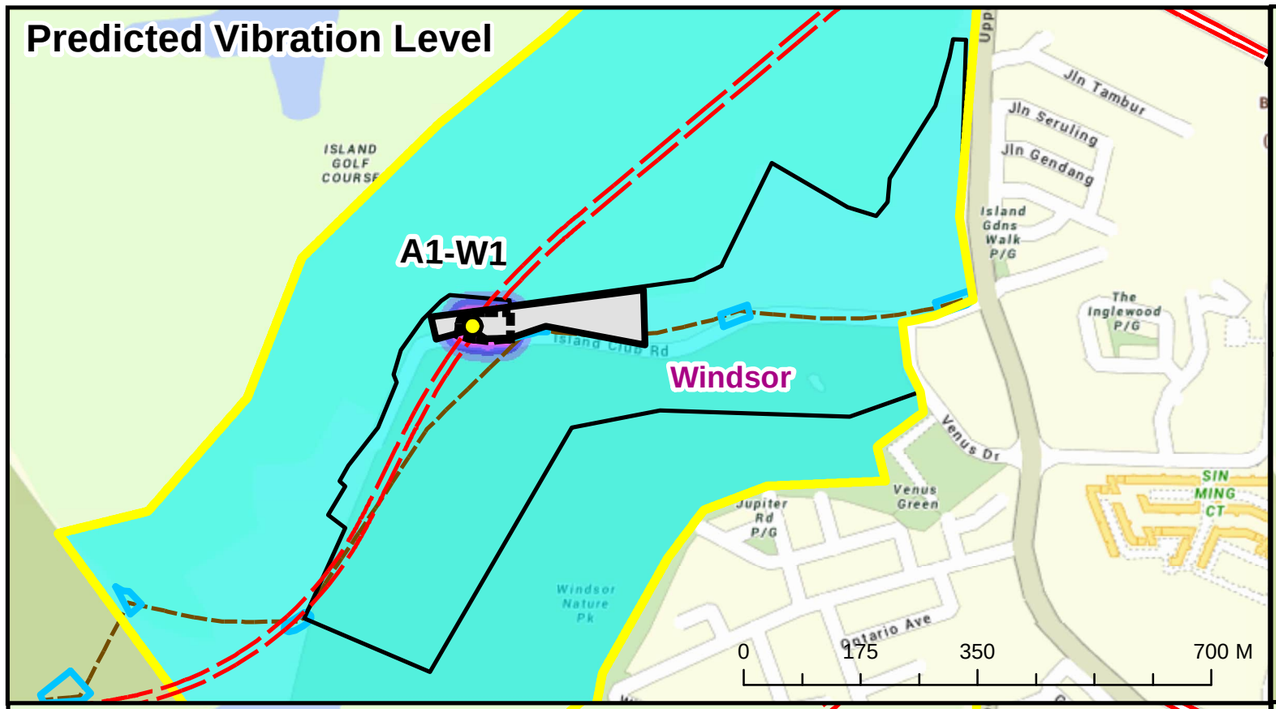
For the base scenario at the A1-W1 worksite, the piling rig is within Windsor. Figure 12-16 shows the impact assessment results on Windsor.

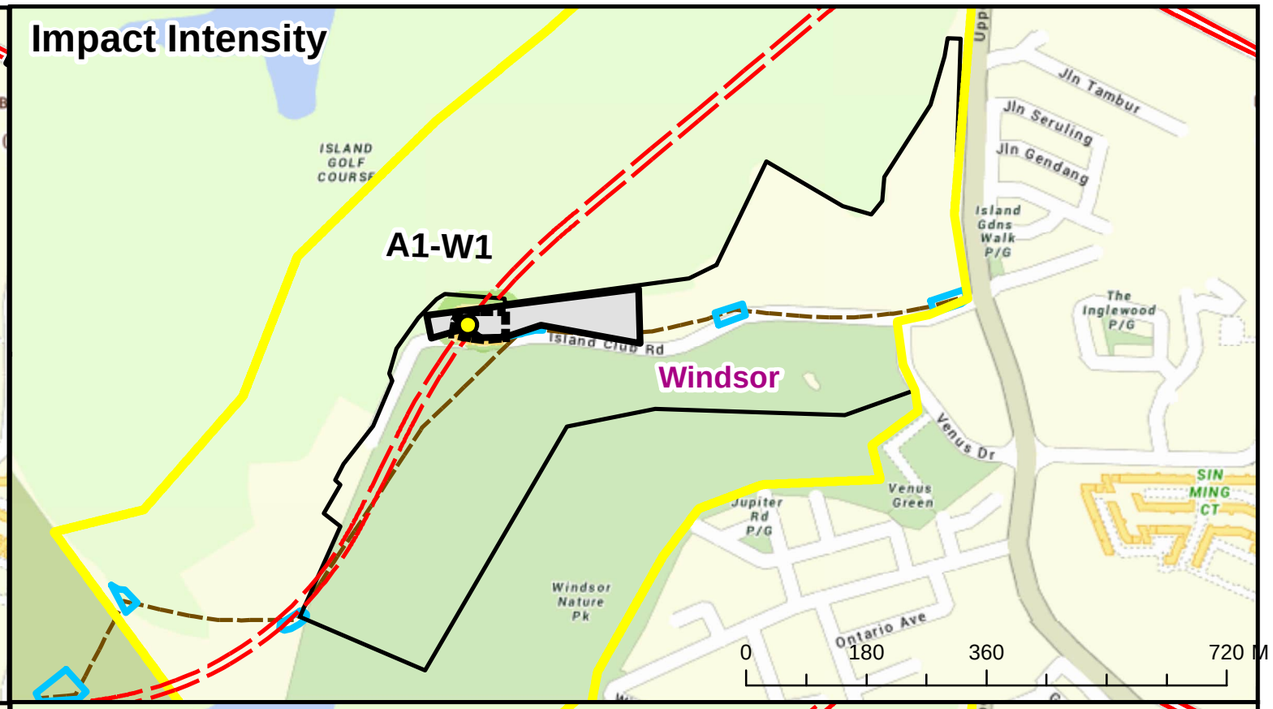
Priority 1 habitat receptors potentially experience a maximum PPV, 0.30 mm/s (see Table 12-27) and **Negligible** impact intensity in Windsor. The impact consequence is **Imperceptible,** and when the likelihood is **Possible**, the overall impact significance is **Minor**. Vibration generated by the rotary bore piling may impact sensitive fauna, while other species may avoid the area because of the increased levels of activity in the area. However, the fauna species are likely to adapt to the rotary bore piling rigs and return to regular activity and habitat.

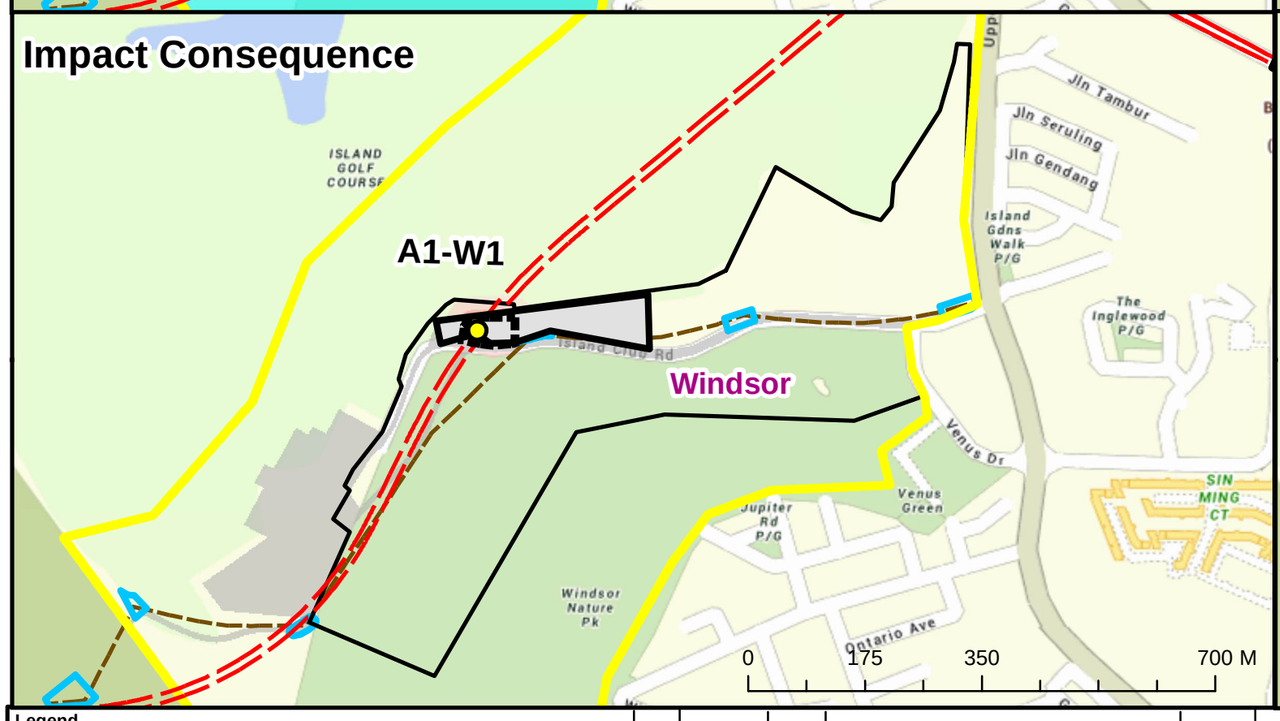
12.7.1.3.3 *Bulldozer*

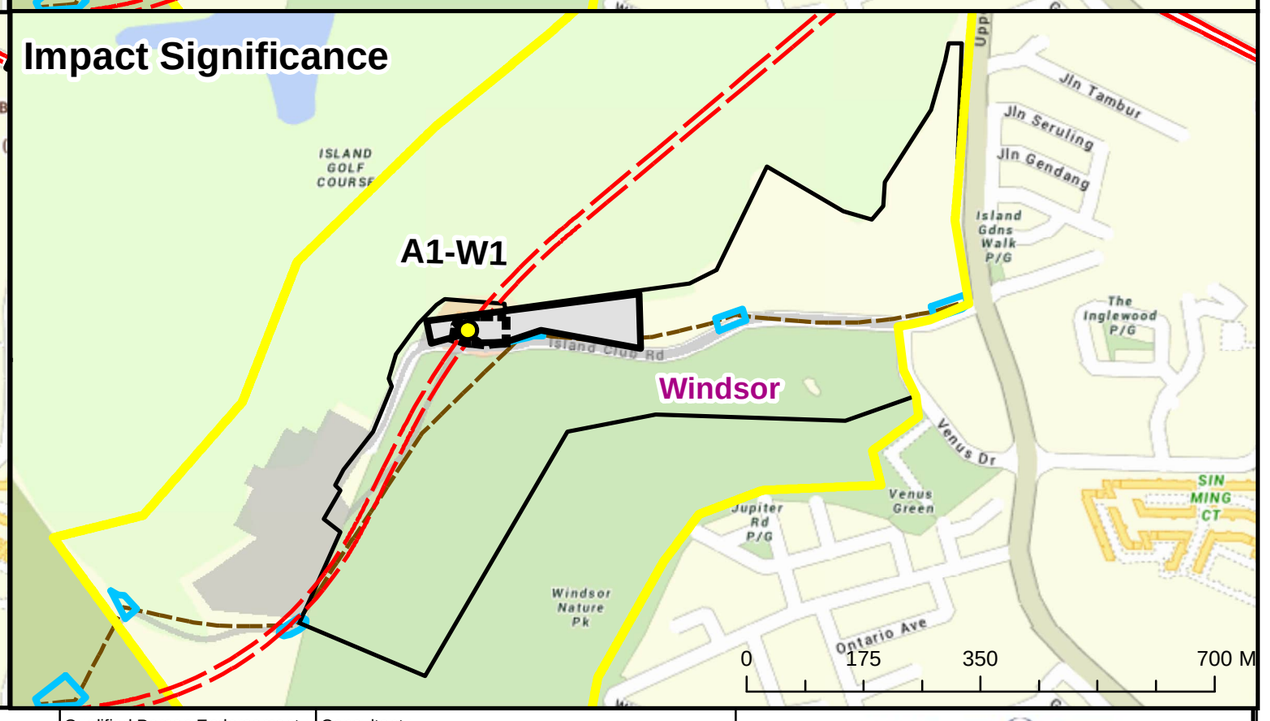
For the base scenario at the A1-W1 worksite, bulldozers might be used. Figure 12-17 shows the impact assessment results on Windsor.

Priority 1 habitat receptors potentially experience a maximum PPV, 1.02 mm/s (see Table 12-27), and the maximum impact significance is **Minor**. The impacted area is estimated to be 2.5 ha and likely to cause disturbance to the fauna. Vibration generated by the bulldozers may impact sensitive fauna, while other species may avoid the area because of the increased levels of activity in the area. However, the fauna species are likely to be habituated to the bulldozers and would return to regular activity and habitat.









Legend

- Facility Building (Above-ground)
- Facility Building (Underground)
- Base Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Base)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.00 - 0.07	Below Ambient	Below Ambient	Below Ambient
0.07 - 0.15	Negligible	Imperceptible	Negligible
0.15 - 0.50	Low	Very Low	Minor
0.50 - 2.49	Medium	Low	Moderate
2.49 - 4.99		Medium	Not Assessible
		Not Assessible	

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)

Figure Title :
VIBRATION ASSESSMENT FOR ROTARY BORE PILING AT A1-W1 (BASE SCENARIO)

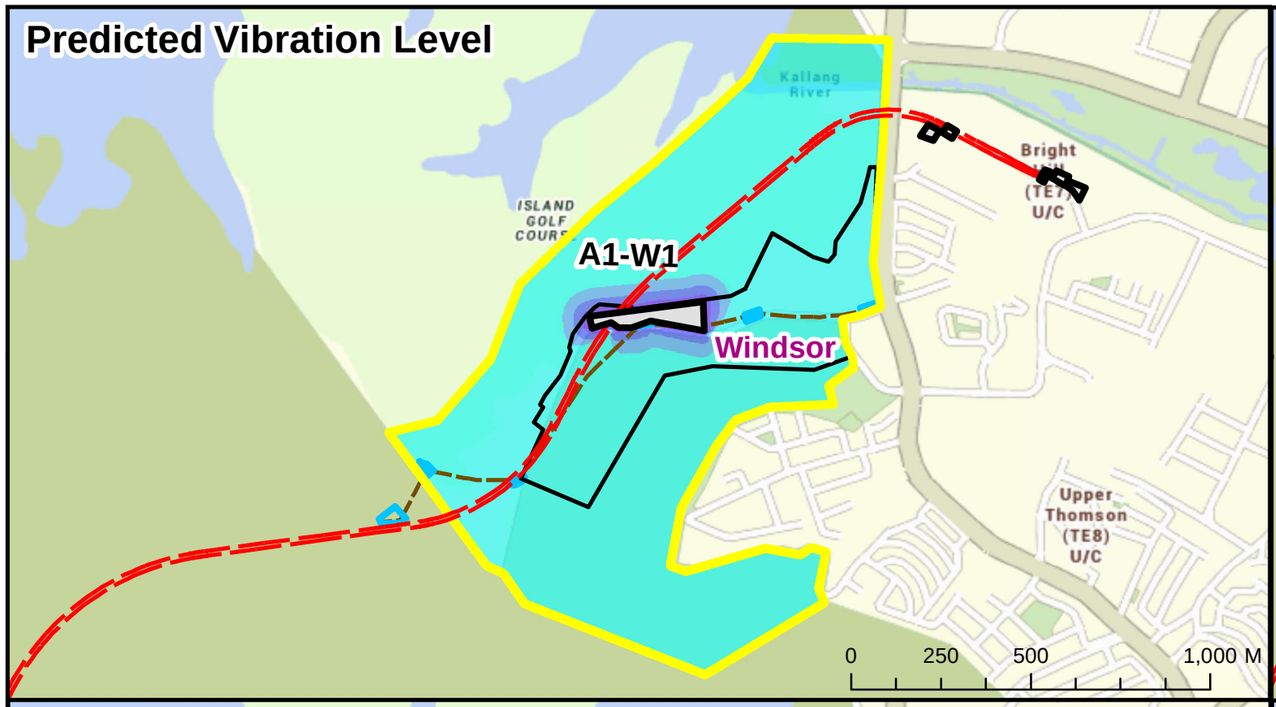
Designed	Checked	Approved
EGY	JAG	JAG
	Drawn: EGY	Date: MAR 20222

Figure No. : 12 - 16 | Rev. : - | Sheet : 1 of 1

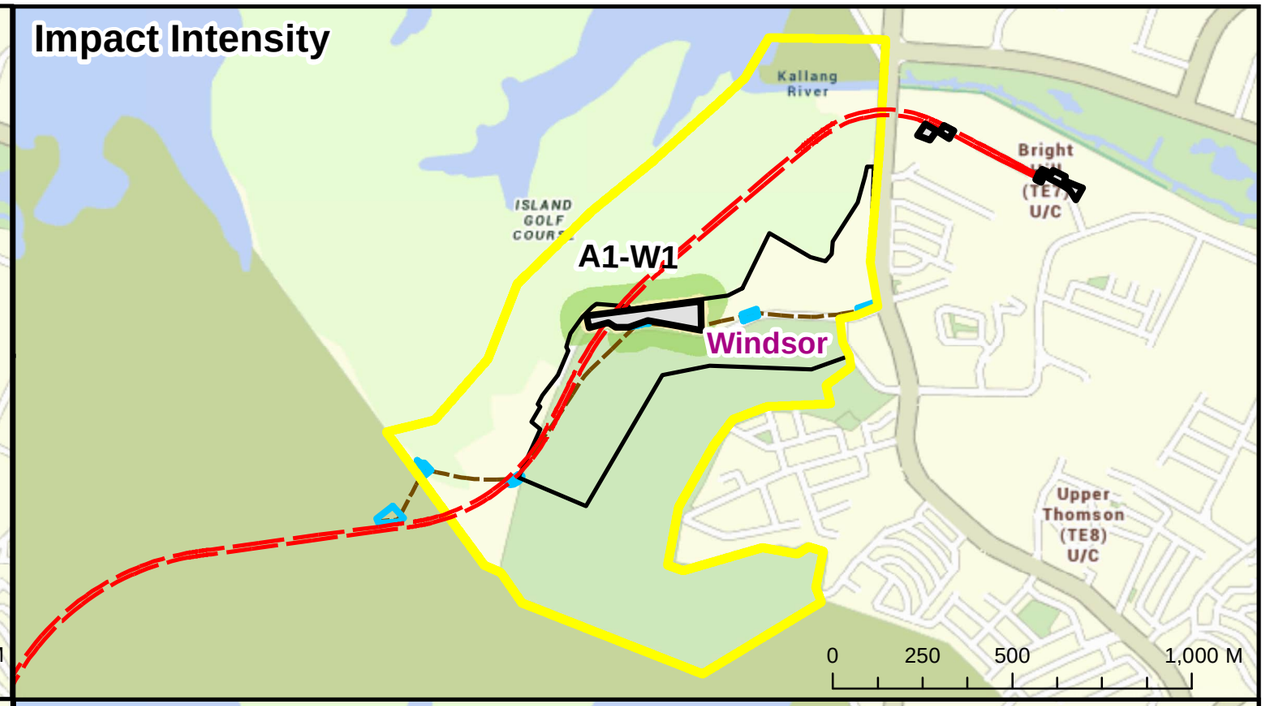
CAD File Name : NA | A3

Note: Source of basemap - OneMap

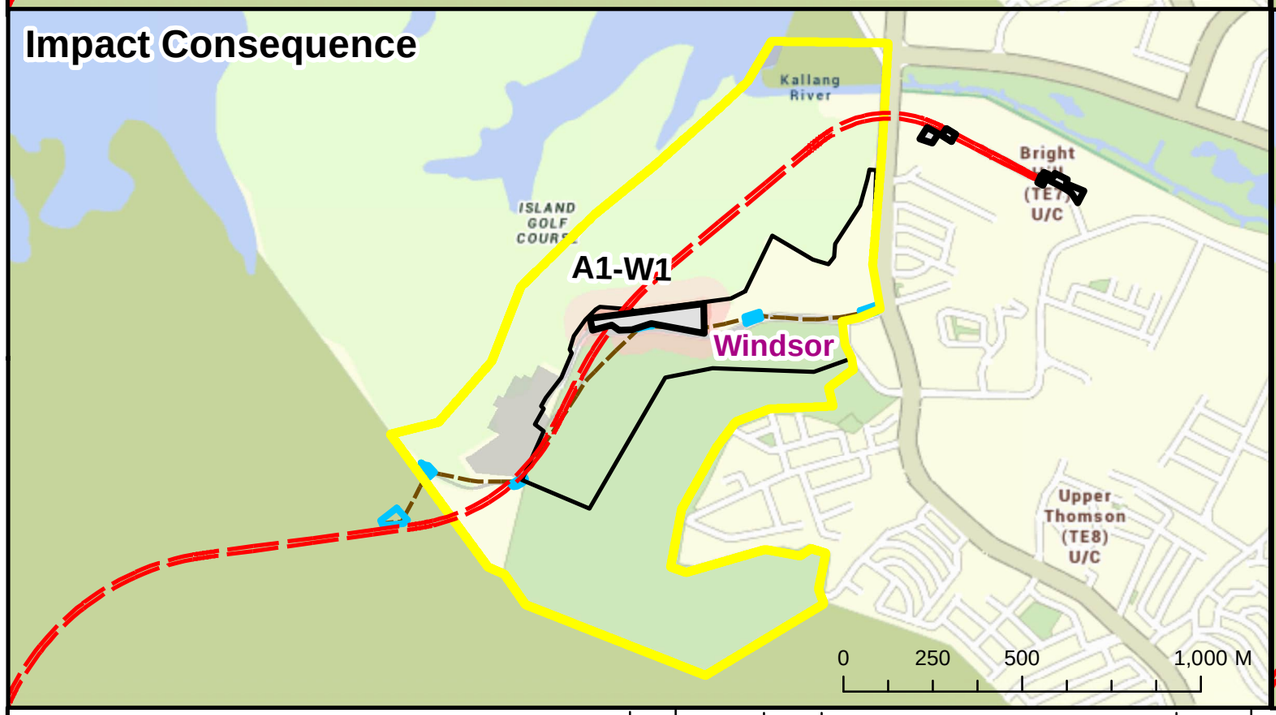
Predicted Vibration Level



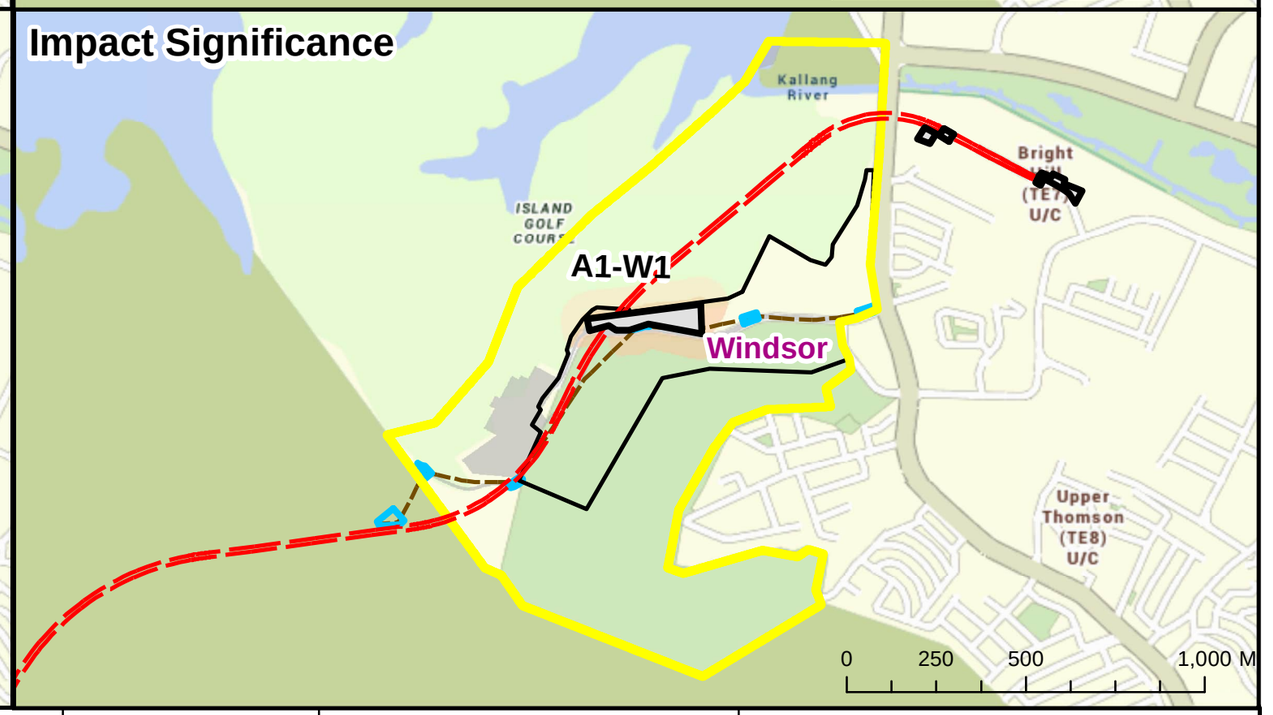
Impact Intensity



Impact Consequence



Impact Significance



Legend

- Base Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Base)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.00 - 12.80	Below Ambient	Below Ambient	Below Ambient
12.80 - 93.91	Negligible	Imperceptible	Negligible
93.91 - 311.62	Low	Very Low	Minor
311.62 - 691.54	Medium	Low	Moderate
691.54 - 1,088.54		Medium	Not Assessible
		Not Assessible	

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
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LTA Endorsement :
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Consultant : AECOM

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Project Title :

CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)

Designed	Checked	Approved
EGY	JAG	JAG
	Drawn: EGY	Date: MAR 2022

Figure Title :

VIBRATION ASSESSMENT
FOR BULLDOZER
AT A1-W1 (BASE SCENARIO)

Figure No. :	Rev.	Sheet
12 - 17	-	1 of 1

CAD File Name : NA — A3

Note: Source of basemap - OneMap

12.7.1.3.4 *Tunnel Boring Machine (TBM)*

The study predicts the vibration levels from the activity using the guidelines of BS 6472-2-2008 and the Esvelt Equation from the CRL1 EIS Report [R-1].

The assessment using the guidelines of BS 6472-2-2008 gives a highly conservative outcome for the impact study as the vibration levels are predicted to represent the “worst-case scenario” for any geological conditions in the Biodiversity Study Area. The detailed impact assessment results are found in Appendix CC.

The Esvelt Equation predicts vibration levels for geological conditions similar to the Biodiversity Areas, the predicted vibration level is low, and the impacted area is small. The vibration levels for the tunnel boring machine are predicted, and the overall impacts are assessed for the complete alignment in Windsor. However, it should be noted that during actual works, the tunnel boring machine bores at a rate of 7 m / day (see Section 3.2.2.6.1). Therefore, the vibration impacts are in the affected area where the machine is on the day.

A hypothetical assessment is carried out for the tunnel boring machine that impacts the entire Study Area simultaneously (i,e overall footprint of the tunnel in the Biodiversity Study Area). Based on the impact assessment results shown in Figure 12-18, the impact significance is **Negligible – Moderate**.

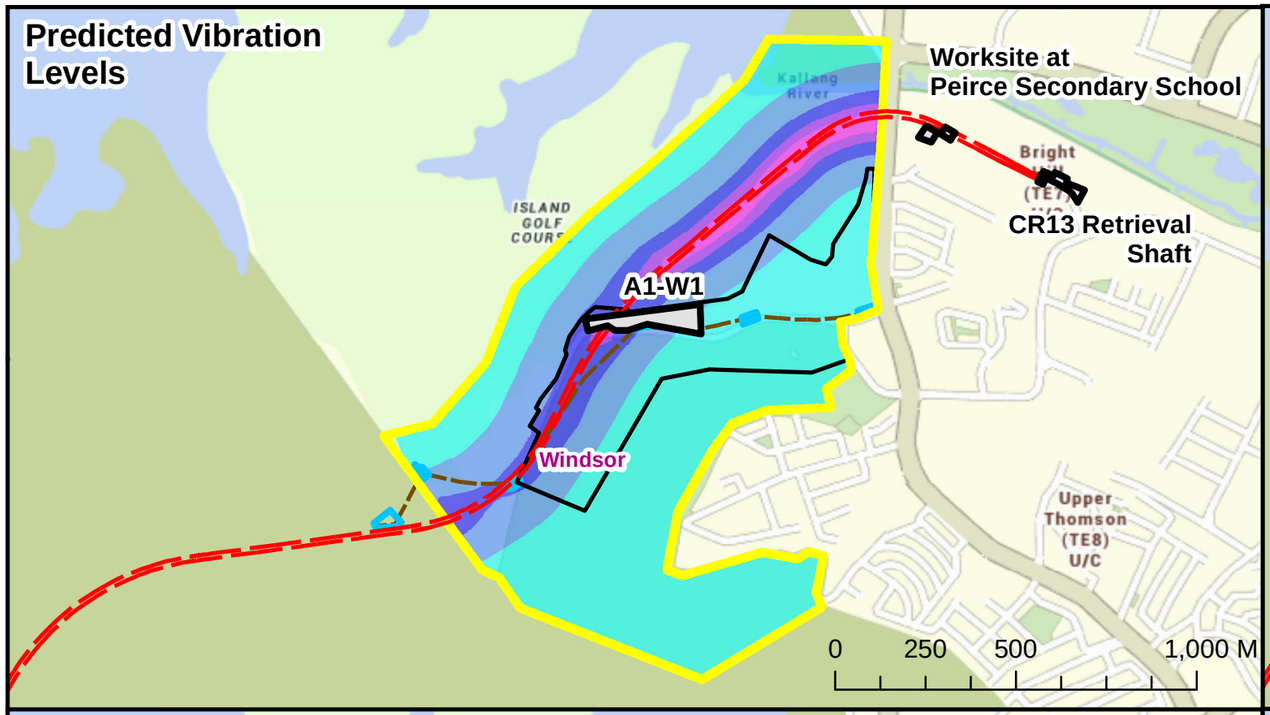
This initial assessment helps to identify the critical spot to conduct a detailed analysis of vibration impacts caused by the tunnel boring machine on fauna at any particular time. In this case, three hotspots are identified in Windsor. The sizes of the impacted area with **Minor** and **Moderate** impact significance for the three hotspots are listed in Table 12-30.

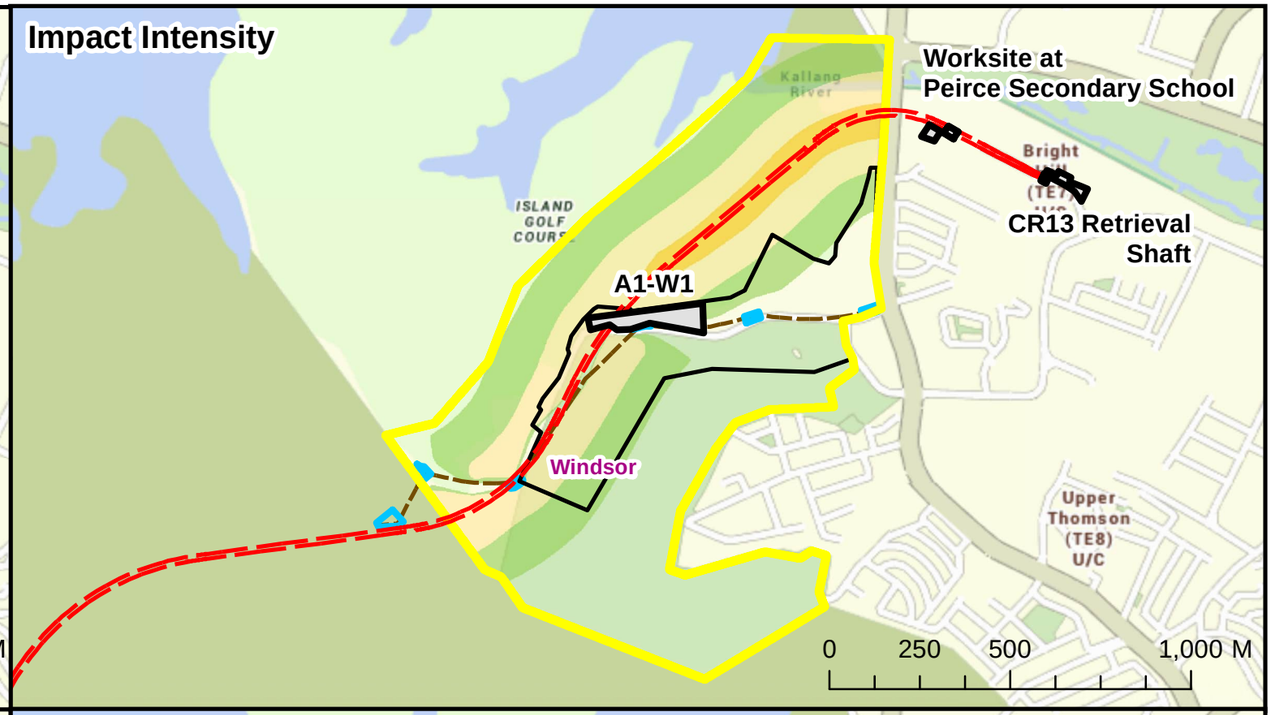
For **Minor** impact significance**,** vibration generated from tunnel boring may impact some sensitive fauna. At the same time, other species may avoid the area because of the increased levels of activity in the area. However, many species would become habituated to the tunnel boring machine and would return to regular activity in a few days when the machine has passed by.

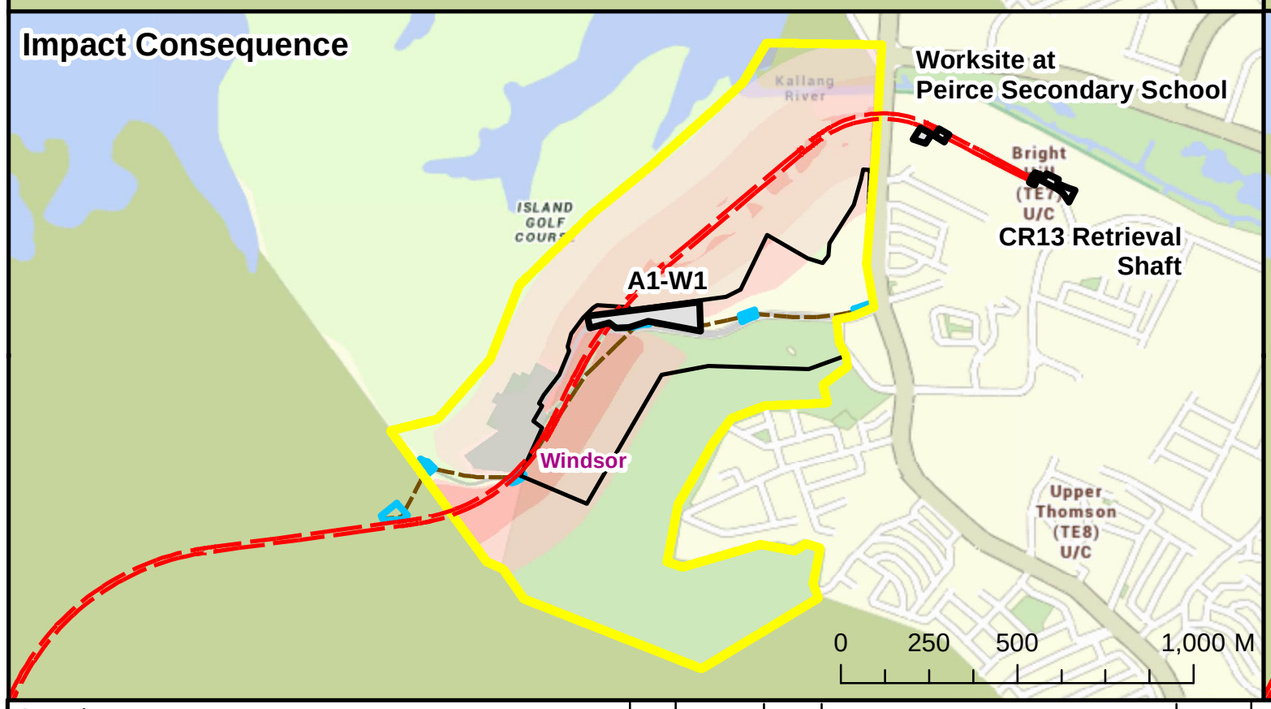
For **Moderate** impact significance, vibration generated from tunnel boring may impact sensitive fauna on their day to day activities (communication/ foraging/ breeding activities) for a short period in the zone of impact and may leave the area. However, this displacement is expected to be temporary, and they are expected to return after a while. Hence, the impact significance of **Moderate** seems to be a reasonable deduction from the assessment, and hence no additional mitigation measures are proposed for this case. The potential behavioural impacts predicted above have limited research backup in the local context. Hence, a comprehensive, adaptive monitoring plan has been proposed during this activity, as provided in Section 13.11.

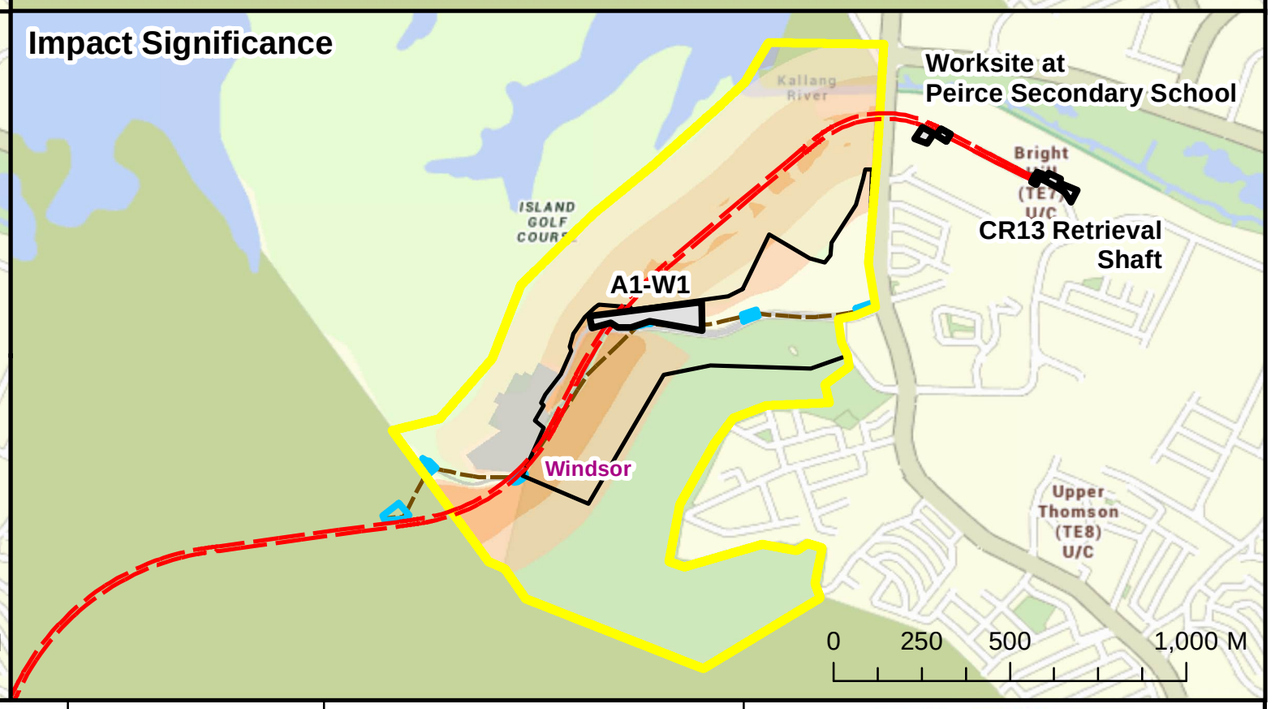
Table 12-30 A1-W1 Worksite Tunnel Boring Machine Impact Significance Area for Windsor

Impact Significance	Impacted Area Spot 1, ha	Impacted Area Spot 2, ha	Impacted Area Spot 3, ha
Minor	0.1	5.2	3.1
Moderate	-	2.2	0.3









Legend

- Base Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Base)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.01 - 0.11	Below Ambient	Below Ambient	Below Ambient
0.11 - 0.25	Negligible	Imperceptible	Negligible
0.25 - 0.46	Low	Very Low	Minor
0.46 - 0.78	Medium	Low	Moderate
0.78 - 1.58		Not Assessible	Not Assessible

N

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ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Drawing Title :

HYPOTHETICAL OVERALL VIBRATION ASSESSMENT FOR TUNNEL BORING AT WINDSOR USING ESVELT METHOD (BASE SCENARIO)

Designed	Checked	Approved	Drawing No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 18	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

12.7.1.4 Peirce Secondary School Worksite (Windsor)

The rotary bore piling is carried out at Peirce Secondary School (base scenario) worksite. The worksite is far from the Windsor, with the primary receptors being urban areas such as houses and roads. Hence based on the impact assessment results, the overall impact significance results for construction vibration impact assessments on ecological behaviour at Peirce Secondary School worksite (base scenarios) are not significant to the Biodiversity Study Areas. The predicted ground-borne vibration levels are below PPV, 8.00 mm/s; thus, burrow collapse is unlikely.

For a detailed assessment, refer to Appendix DD.

12.7.1.5 CR13 Retrieval Shaft Worksite (Windsor)

Ground improvement works are potentially carried out at CR13 Retrieval Shaft (base scenarios) worksite. The rotary bore piling and bulldozer are suitable construction equipment on the CR13 Retrieval Shaft worksite. The worksite is far away from Windsor, with the main receptors being urban areas such as houses and roads. Hence based on the impact assessment results, the overall impact significance results for construction vibration impact assessments on ecological behaviour at CR13 Retrieval Shaft worksite (base scenarios) are not significant to the Biodiversity Study Areas. The predicted ground-borne vibration levels are below PPV, 8.00 mm/s; thus, burrow collapse is unlikely.

For a detailed assessment, refer to Appendix EE.

12.7.2 Operational Phase (Base Scenario)

LTA predicted operational vibrational levels during train operation. The trackform was modelled as a standard track form for the base scenario without track mitigation measures. Relevant calculations depicting the detailed working of these findings are in Appendix CC.

For human response, the ground-borne vibration range of interest is 1 to 80 Hz – this is reflected in the use of vibration weightings in LTA's study. The vibration from passing trains is typically between 1 Hz to 100 Hz – depending on many factors, most notably the geological conditions (as these affect frequencies propagated from a source and attenuated). Ground-borne sound typically peaks between 1 and 160 Hz (ground dependent).

As explained in Section 12.4.1, the literature review explains how fauna uses substrate vibration to communicate. However, more research is required to assess how low frequency used by fauna can be impaired due to operational vibration impacts from trains. Therefore, the outcome of the impact significance provides a conservative impact assessment result for all the ecologically sensitive receptors.

An applicable criterion for the operational phase is the same as the one used for construction phase impact evaluation.

12.7.2.1 Structural Integrity of Burrows

Based on the baseline fauna survey, burrows of fossorial species have been sighted and recorded at the Biodiversity Study Area – Windsor, Eng Neo Avenue Forest, Sites I and II.

The predicted vibration results of the "base scenario" for Windsor [O-15] were calculated by LTA, and the maximum vibration levels are presented in Table 12-31. In the screening process, vibration caused by train operation is unlikely to impact the burrows in Windsor as the predicted vibration levels are less than PPV, 5.00 mm/s. Train operational levels at Eng Neo Avenue Forest and Sites I and II for the base scenario are not available for assessment.

Table 12-31 Predicted Vibration Levels of Operational Train for Base Scenario

Operational Train Scenarios	Max Predicted PPV, mm/s		
	Biodiversity Area - Windsor	Biodiversity Area - Eng Neo Avenue Forest	Biodiversity Area - Sites I and II
Complete alignment	0.09	There are no predicted vibration levels due to train operations for the base scenario.	
Spot 1	0.06		
Spot 2	0.13		
Spot 3	0.09		

12.7.2.2 Windsor

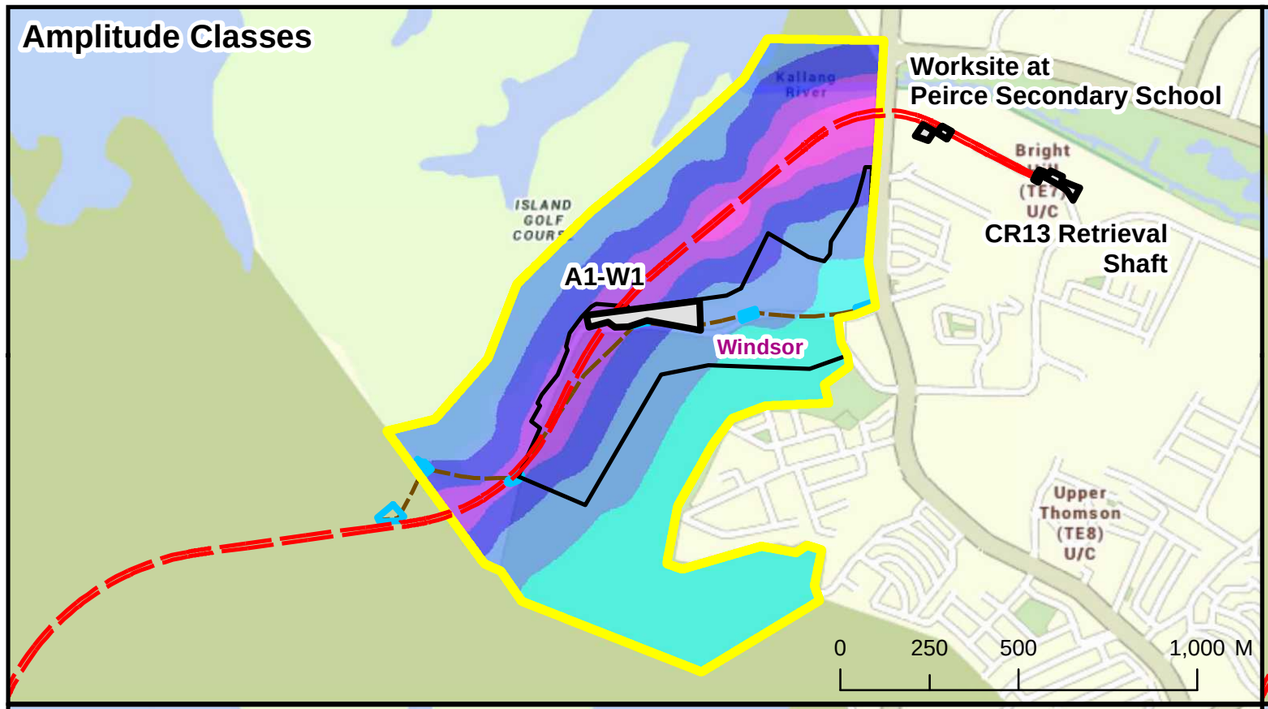
The maximum vibration levels for the operational trains are predicted, and the overall impacts are assessed for the complete alignment in Windsor. However, it should be noted that during actual operations, the vibration impacts are based on the train passing in the affected area by the train at that moment.

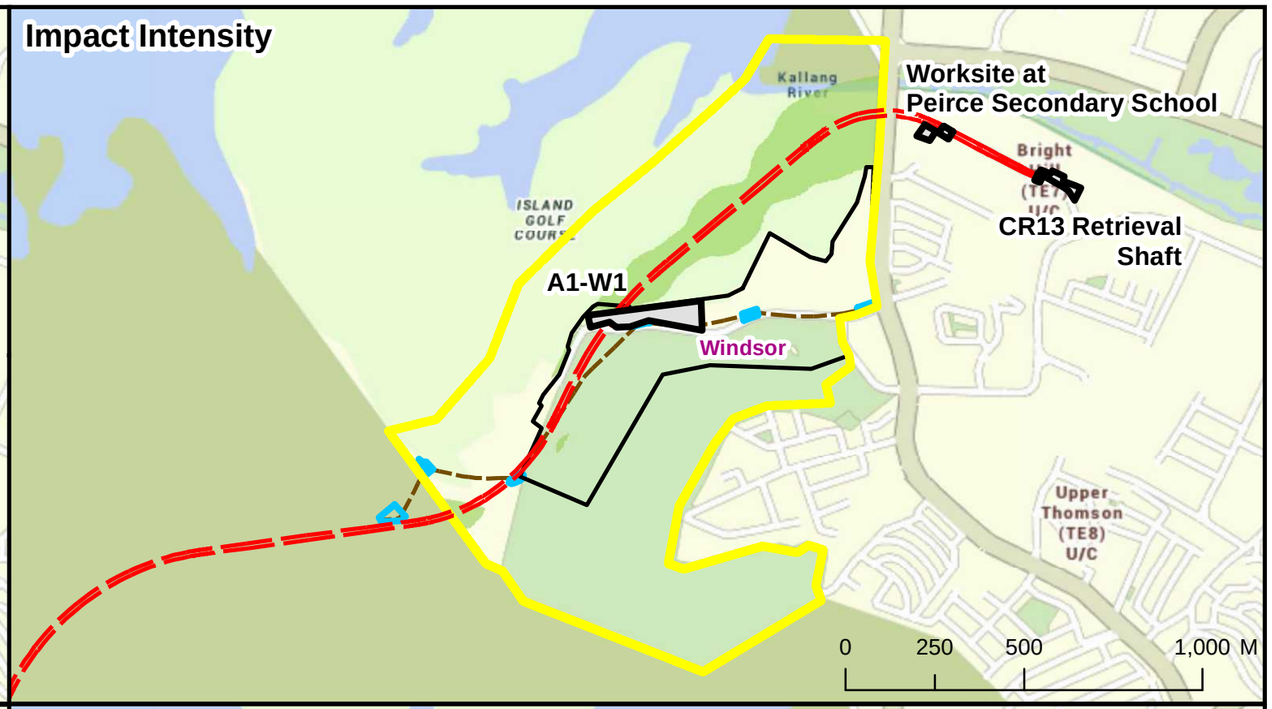
A hypothetical assessment is carried out for the operational train that impacts the entire Study Area simultaneously (i,e overall footprint of the tunnel in Windsor). Based on the impact assessment results shown in Figure 12-19, the impact intensity is **Negligible**, the impact consequence is **Very Low**, and the impact significance is **Minor** when the likelihood is **Possible**.

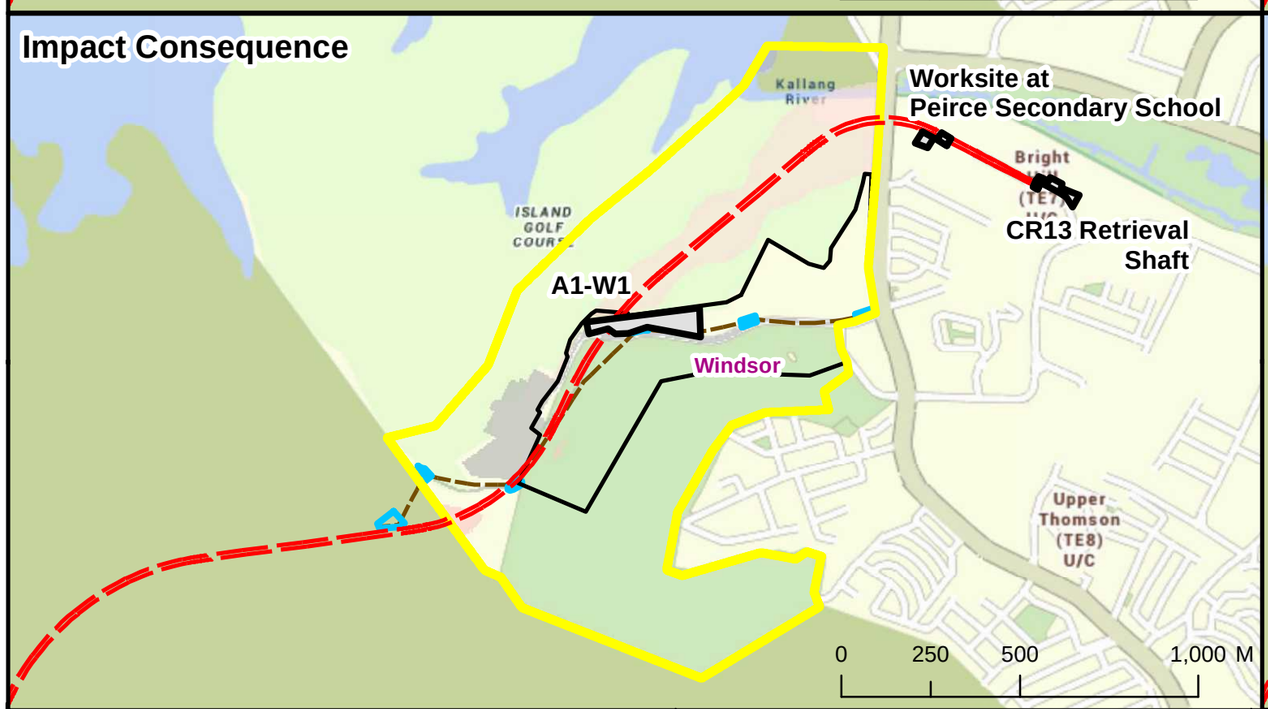
This initial assessment helps to identify the hotspots to conduct a detailed analysis of vibration impacts caused by the operational train on fauna at any particular time. In this case, Windsor identified three hotspots, and the assessment results are presented in Figure 12-20, Figure 12-21 and Figure 12-22, respectively.

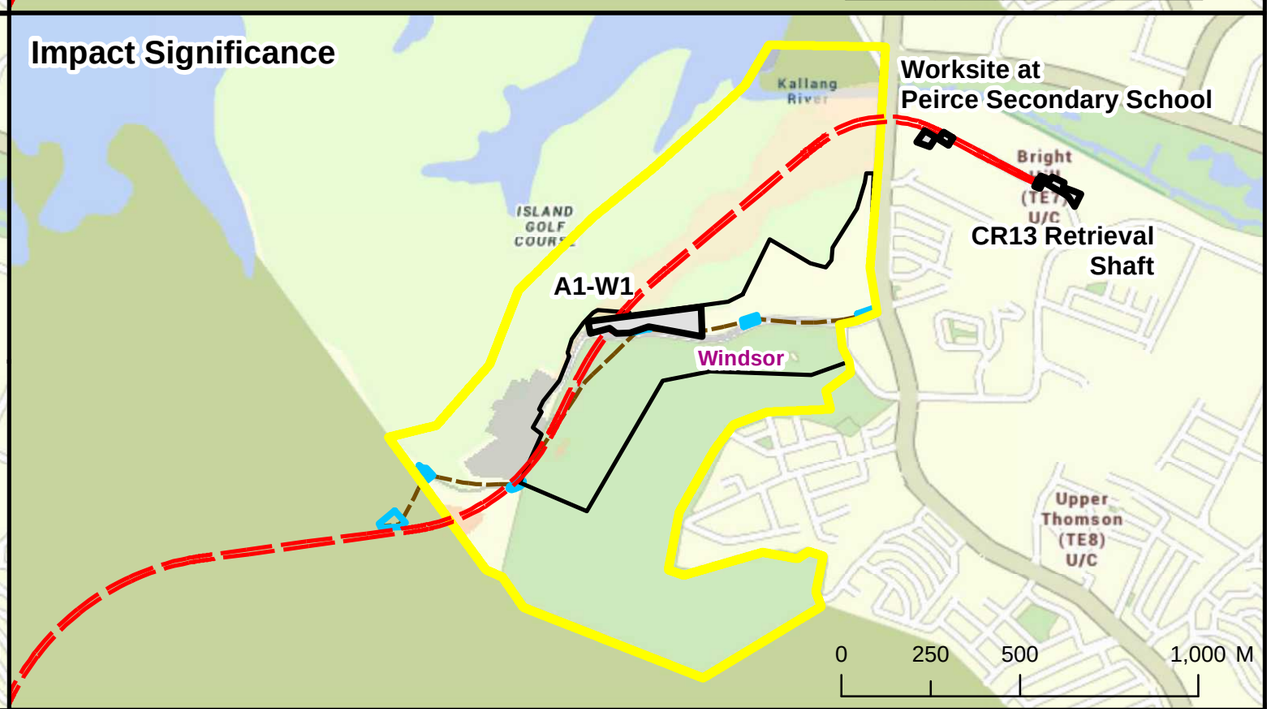
For Spot 1 and Spot 3, the predicted vibration levels from operational trains do not impact Windsor - Priority 1 habitat receptor. Hence, no impact consequences and impact significances are identified. At Spot 2, the predicted vibration levels result in **Negligible** impact intensity and **Very low** impact consequences, and since the likelihood is **Possible**, the overall impact significance is **Minor**. The size of the impacted area for **Minor** impact significance at Spot 2 is 0.6 ha, and at Spot 3, it is 0.4 ha.

For **Minor** impact significance**,** vibration generated from operational trains may impact some sensitive fauna. At the same time, other species may avoid the area because of the increased levels of activity in the area. However, many species would adapt to the operational trains and return to regular activity over a few days.









Legend

- Base Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Base)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.00 - 0.02	Below Ambient	Below Ambient	Below Ambient
0.02 - 0.04	Negligible	Imperceptible	Negligible
0.04- 0.06		Very Low	Minor
0.06 - 0.09		Not Assessible	Not Assessible
0.09 - 0.12			

N

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Qualified Person Endorsement :
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Consultant :
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(WINDSOR AND
ENG NEO AVENUE FOREST)

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VIBRATION ASSESSMENT
FOR OPERATIONAL PHASE
IN WINDSOR
(BASE SCENARIO)

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Drawing No. : 12 - 19 | Rev. : - | Sheet : 1 of 1

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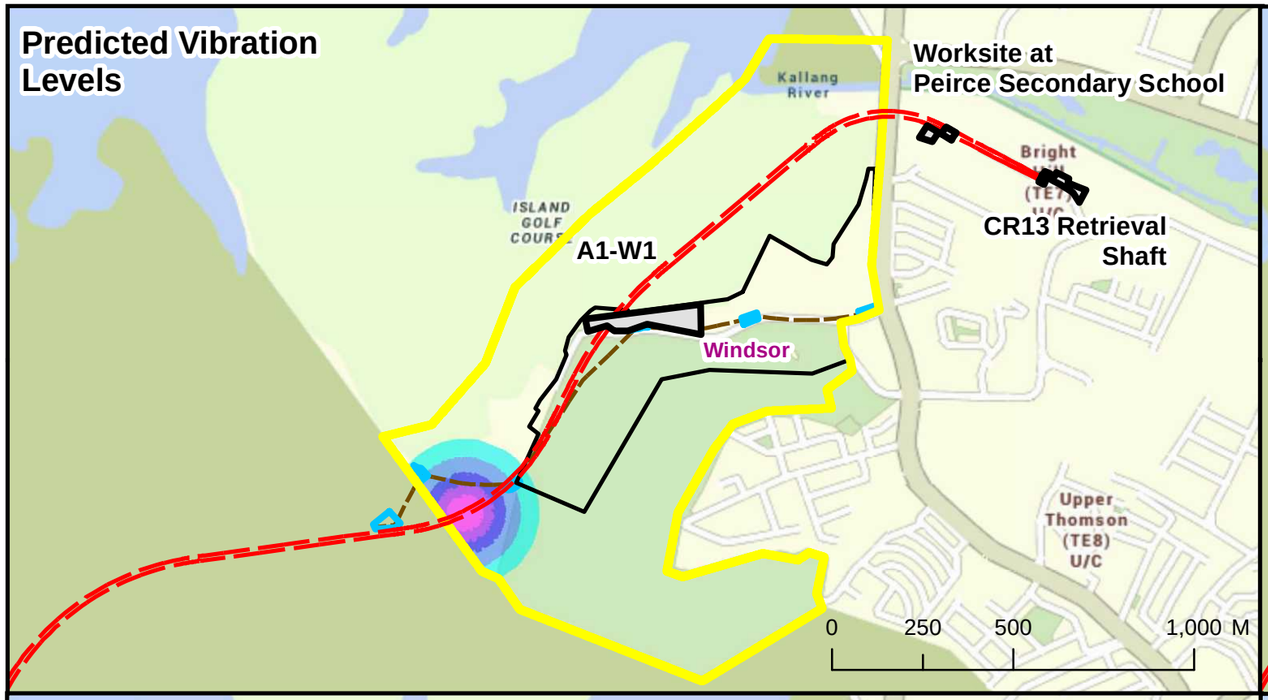

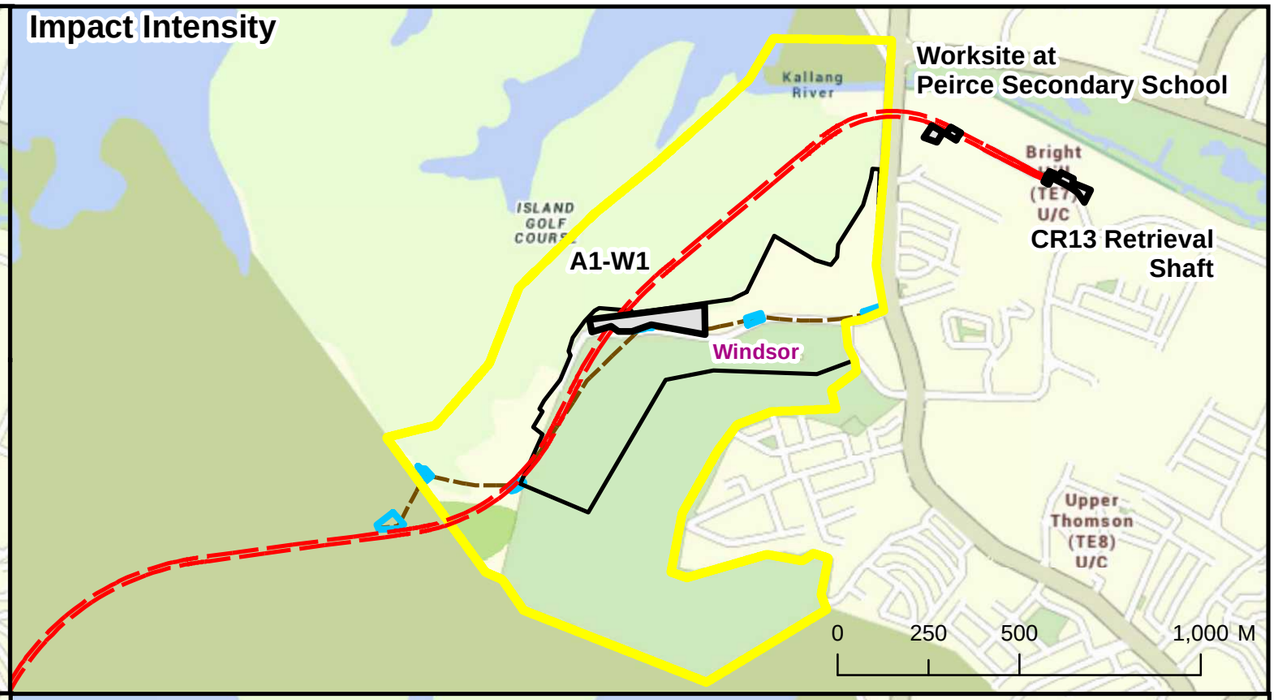

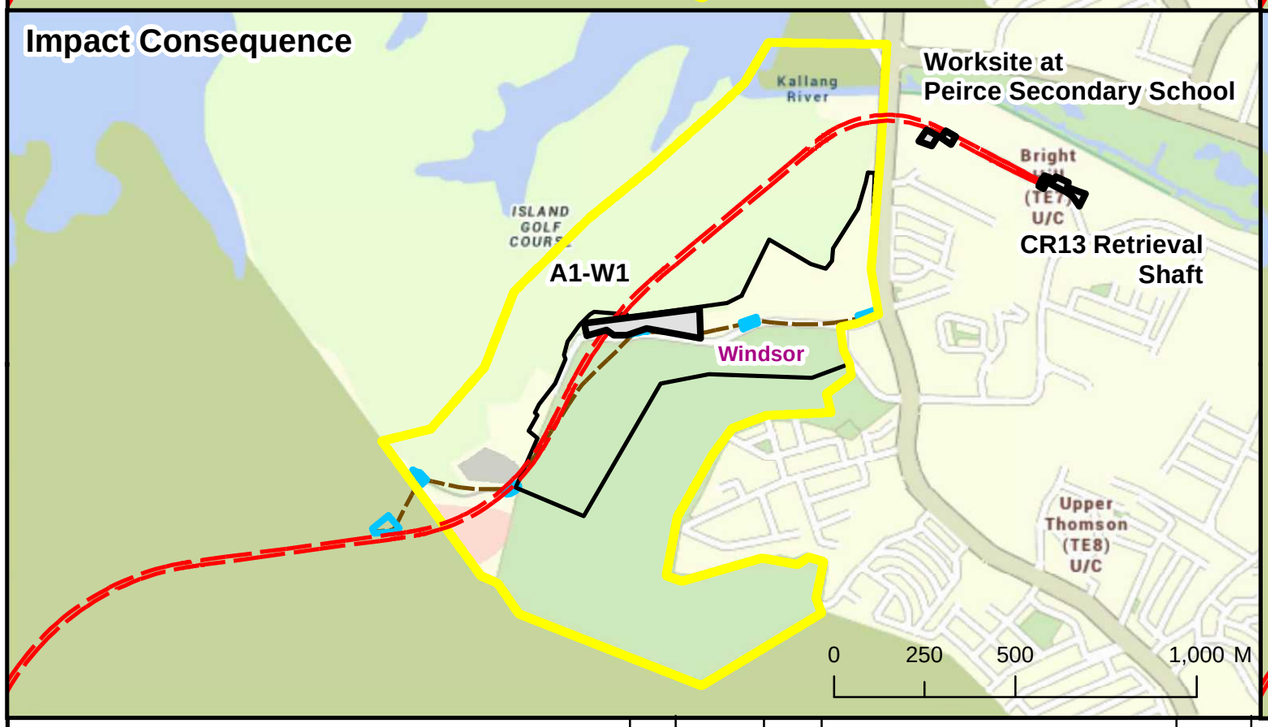

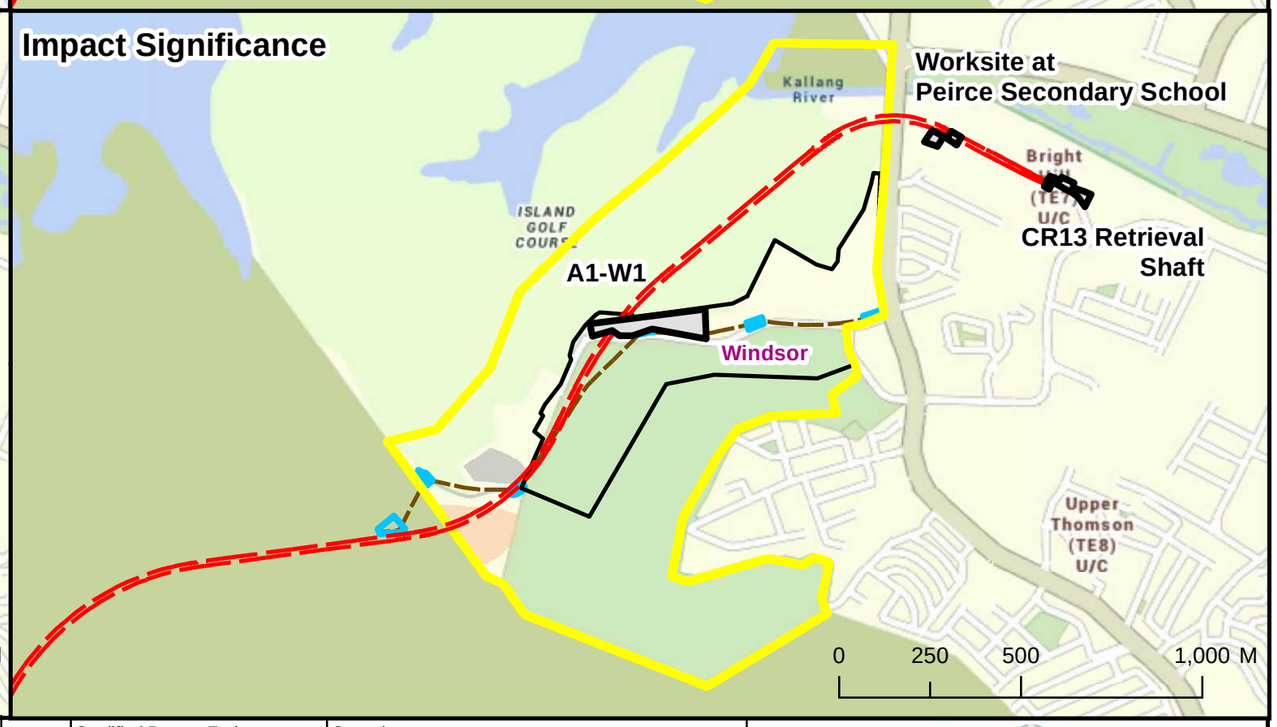

Legend

- Base Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Base)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level PPV (mm/s)	Impact Intensity Value	Impact Consequence Value	Impact Significance Value
0.04 - 0.05	Below Ambient	Below Ambient	Below Ambient
0.05 - 0.07	Negligible	Imperceptible	Negligible
0.07 - 0.09		Very Low	Minor
0.09 - 0.11		Not Assessible	Not Assessible
0.11 - 0.13			

N

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CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Drawing Title :
VIBRATION ASSESSMENT FOR OPERATIONAL PHASE IN WINDSOR - SPOT 1 (BASE SCENARIO)

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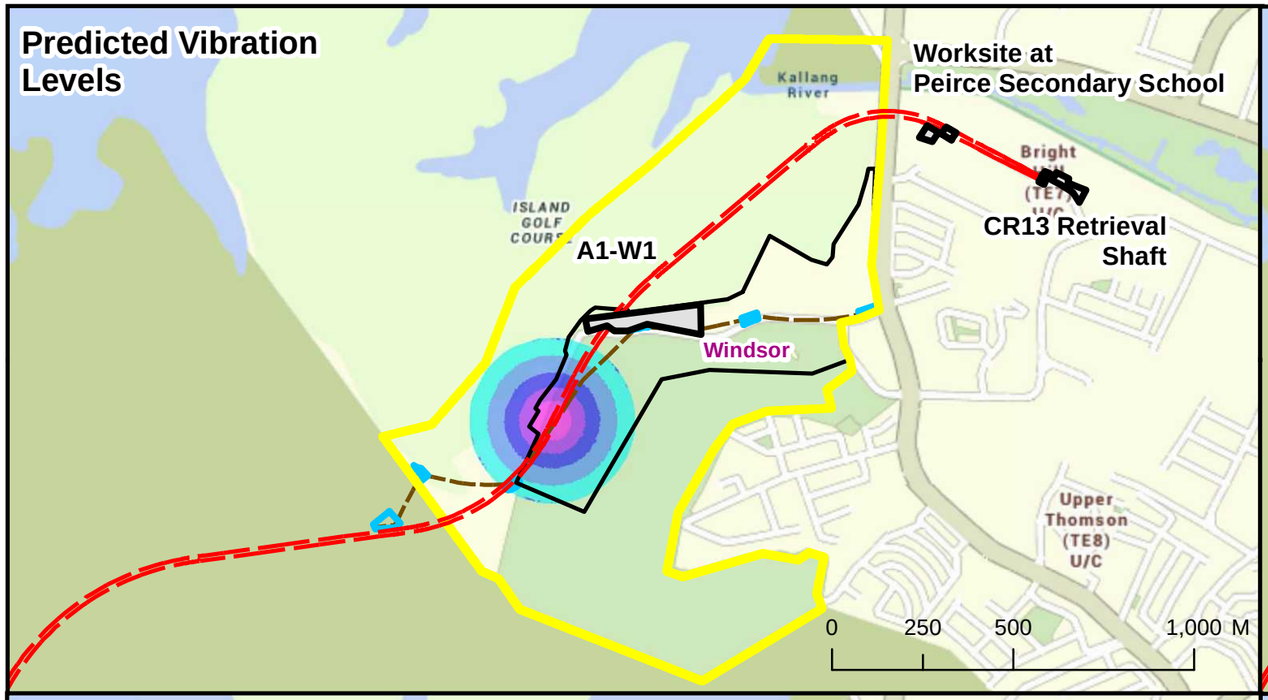

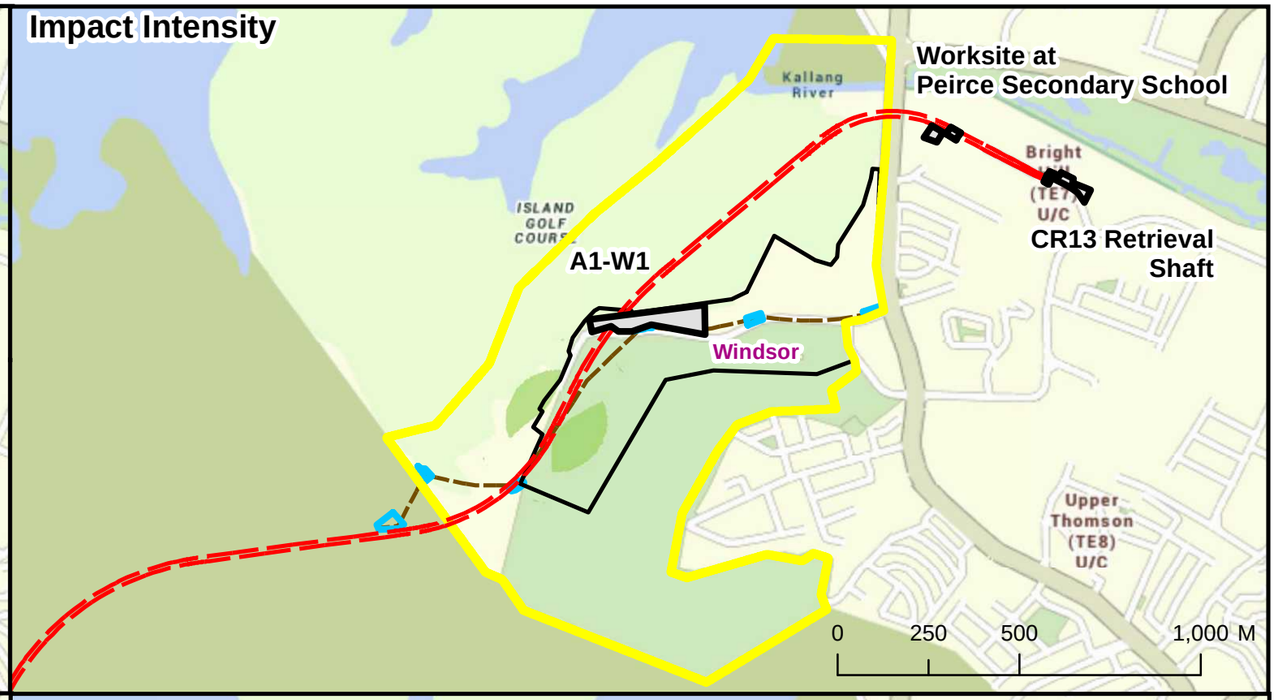

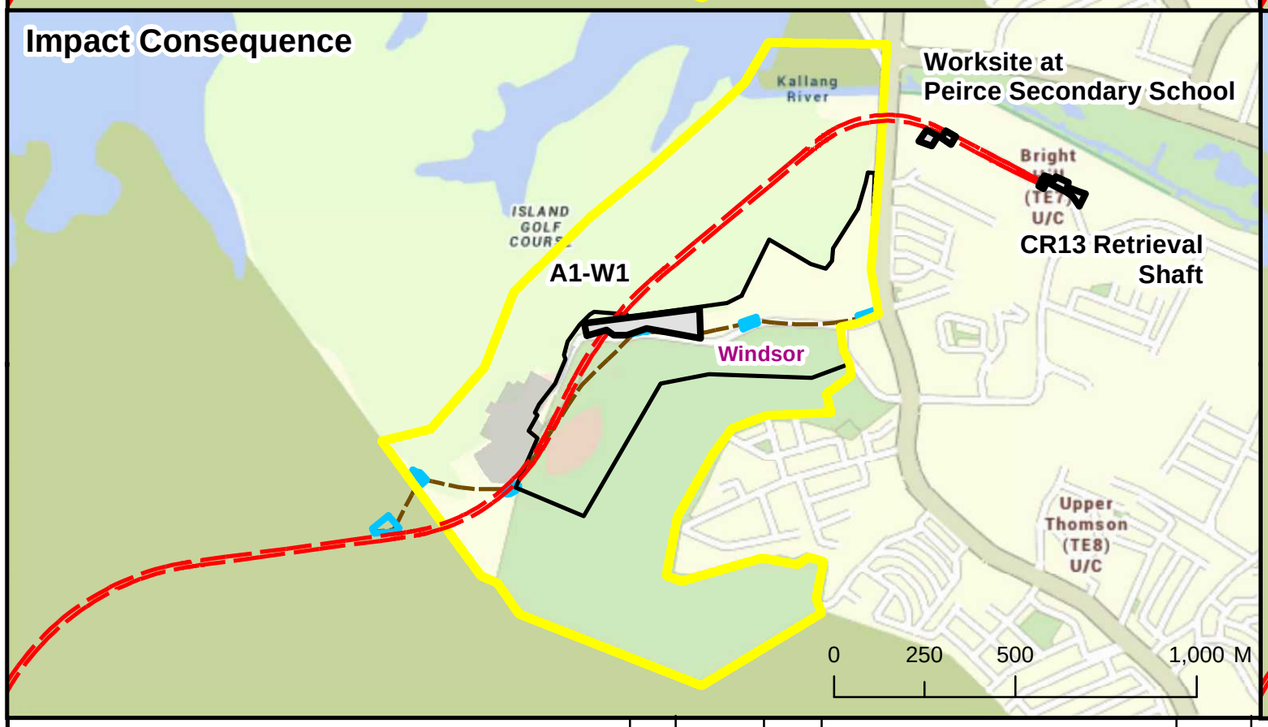

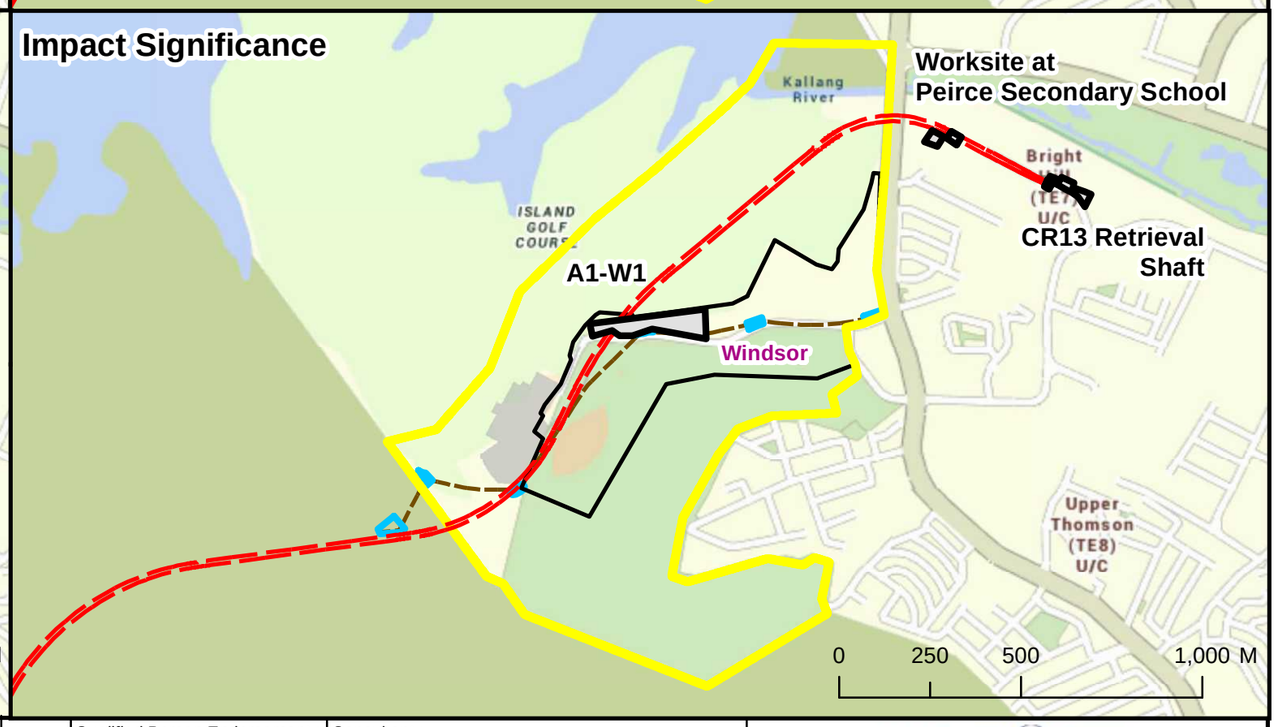

Legend

- Base Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Base)
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- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level PPV (mm/s)	Impact Intensity Value	Impact Consequence Value	Impact Significance Value
0.04 - 0.05	Below Ambient	Below Ambient	Below Ambient
0.05 - 0.07	Negligible	Imperceptible	Negligible
0.07 - 0.09		Very Low	Minor
0.09 - 0.11		Not Assessible	Not Assessible
0.11 - 0.13			

N

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Qualified Person Endorsement :
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LTA Endorsement :
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Consultant : AECOM

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Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Drawing Title :
VIBRATION ASSESSMENT FOR OPERATIONAL PHASE IN WINDSOR - SPOT 2 (BASE SCENARIO)

Designed	Checked	Approved
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	Drawn EGY	Date MAR 2022

Drawing No. : 12 - 21 | Rev. : - | Sheet : 1 of 1

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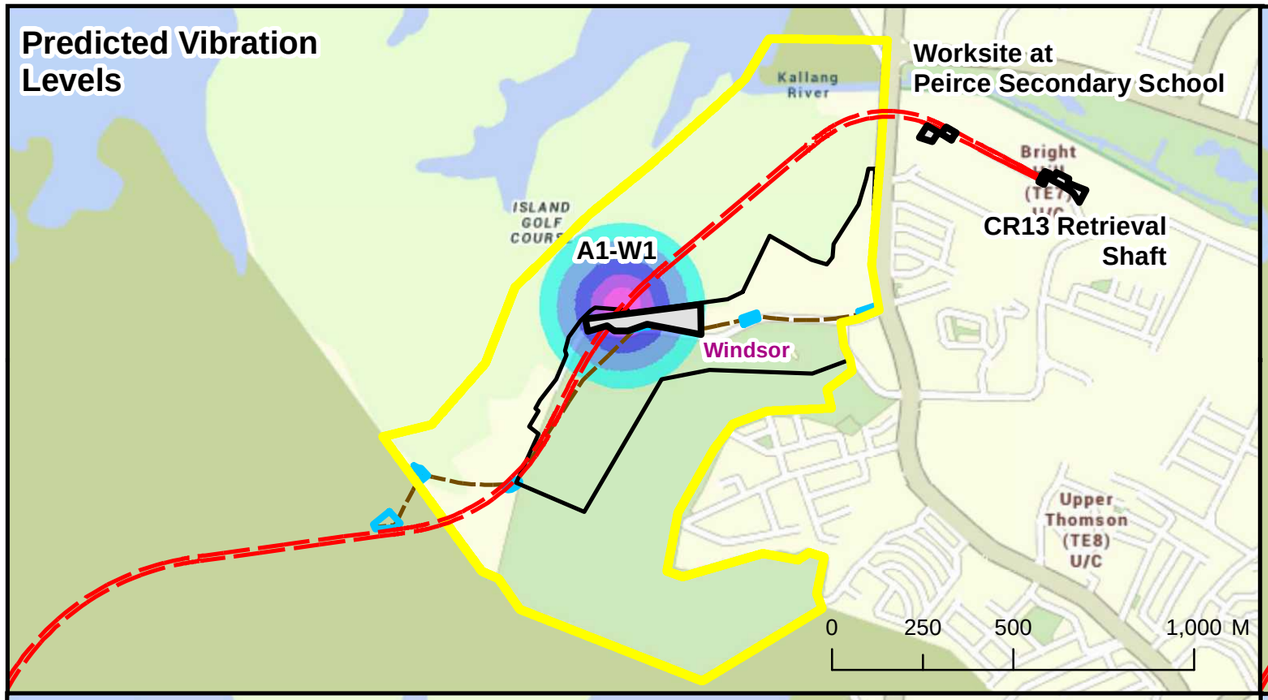
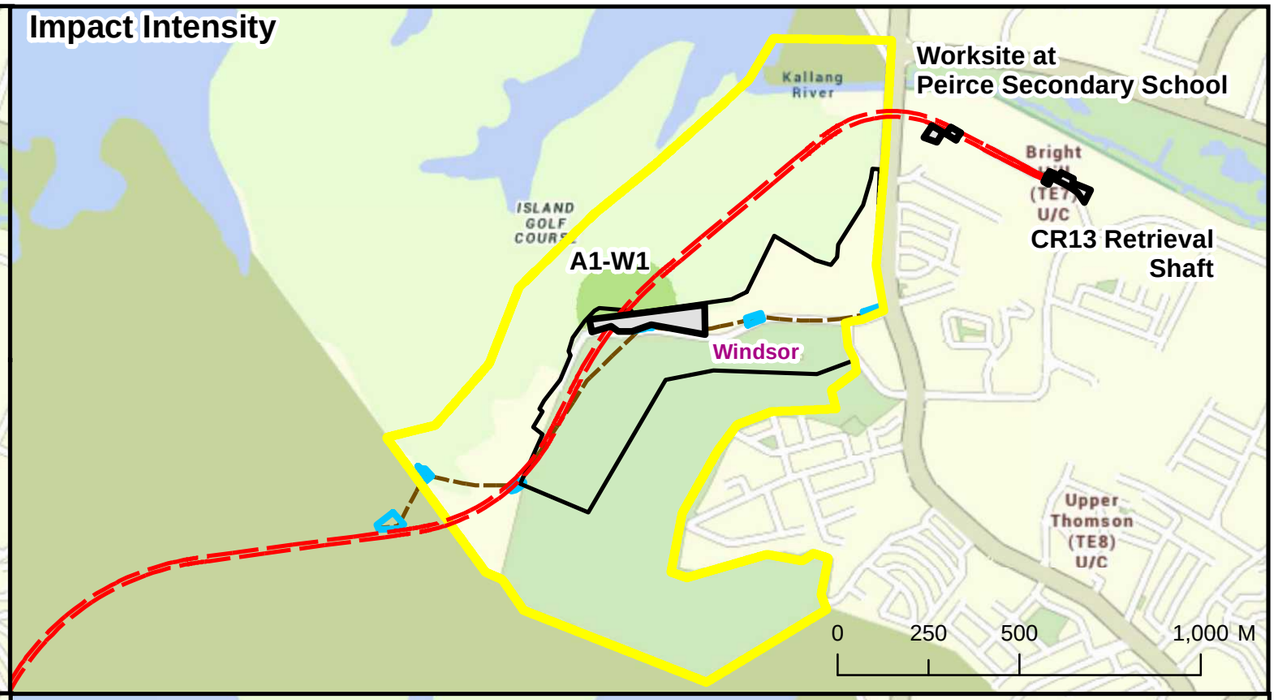
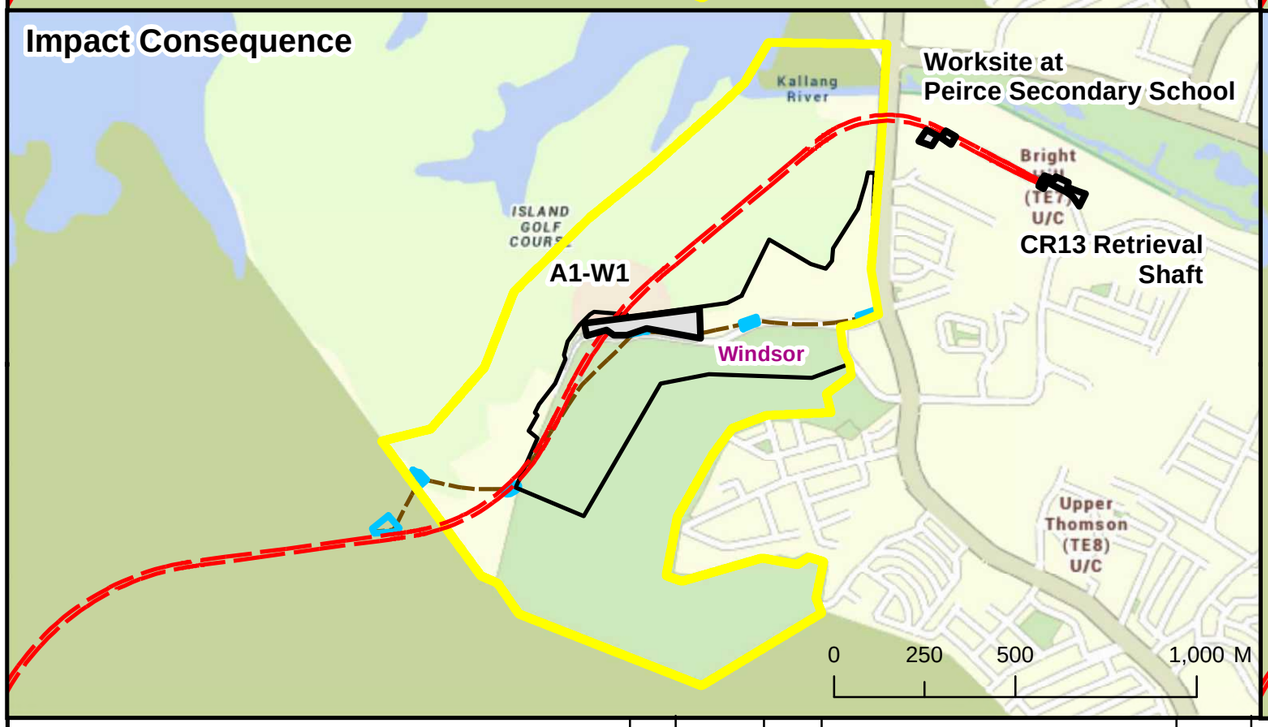
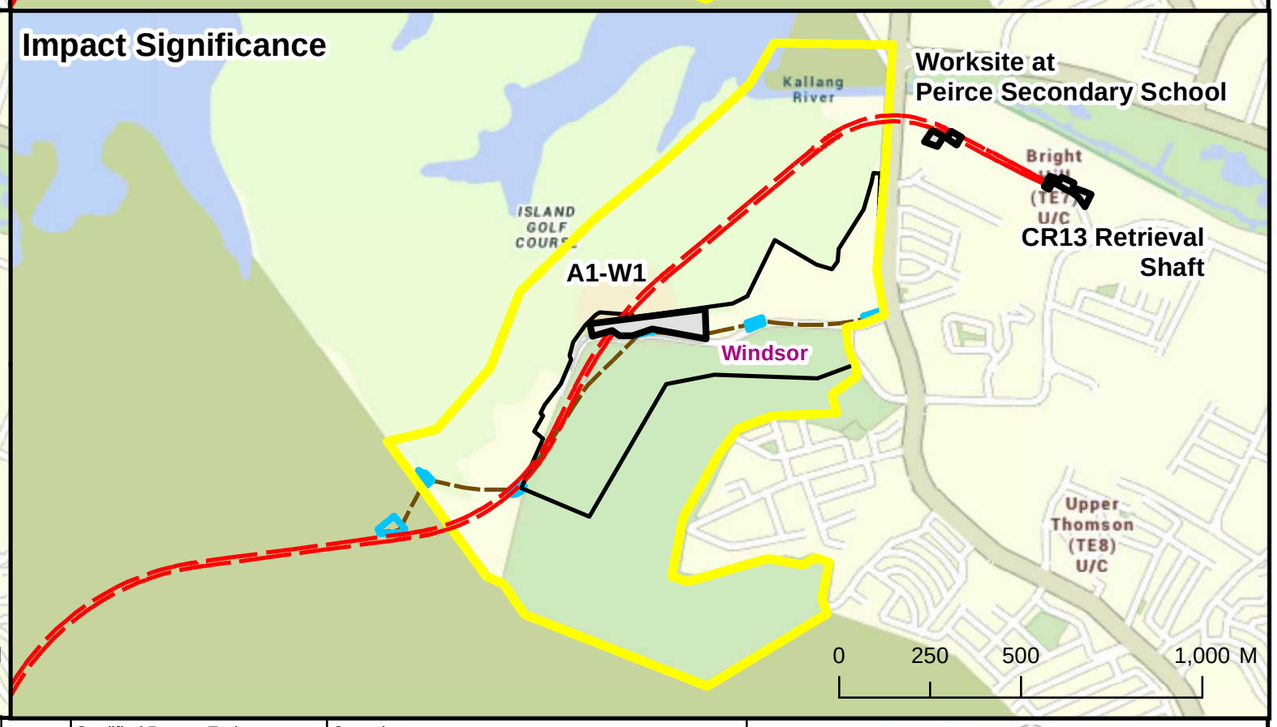
Note: Source of basemap - OneMap









Legend

- Base Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Base)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level PPV (mm/s)	Impact Intensity Value	Impact Consequence Value	Impact Significance Value
0.04 - 0.05	Below Ambient	Below Ambient	Below Ambient
0.05 - 0.07	Negligible	Imperceptible	Negligible
0.07 - 0.09		Very Low	Minor
0.09 - 0.11		Not Assessible	Not Assessible
0.11 - 0.13			

N

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Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Drawing Title :
VIBRATION ASSESSMENT FOR OPERATIONAL PHASE IN WINDSOR - SPOT 3 (BASE SCENARIO)

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Drawing No. : 12 - 22 | Rev. : - | Sheet : 1 of 1

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Note: Source of basemap - OneMap

12.8 Recommended Mitigation Measures

12.8.1 Construction

Based on best practices for building near a nature reserve or an area of high biodiversity value, mitigation measures for construction vibration impacts on sensitive fauna species are recommended.

In the worst case, fauna species (e.g. wild boars) flee to the roads, resulting in road deaths. When rock breaking and excavation occurs, the Contractor must **erect a temporary water barrier on both sides of Island Club Road** (total length of 500 m and approximately 1 m high). An ecologist should be engaged to oversee rock breaking events and test runs during the first seven (7) rock breaking and excavation events. For at least thirty (30) minutes after the event, the ecologist monitors the environment for any faunal behaviours (e.g. charging) that could result in roadkill. Suppose fauna is seen trying to dash onto a road. In that case, the next/following rock breaking event is immediately suspended, and mitigations should be applied to avoid such events in the future. In addition, during rock breaking and excavation events, ecologists shall be present to observe fauna movements. The appointed Contractor should take note to restrict the entry of visitors into the trails of Windsor.

Like the rock breaking and excavation and its impact, it benefits the nocturnal animals if rotary bore piling can be avoided at night. If this **is replaced by secant bored piling** as a required mitigation measure, then night works may be avoided further, resulting in lower fauna's impact due to vibration. Secant bored piling is a method recommended to be explored by Contractors. For safety-critical operations at night, constant monitoring of night-time ensures monitoring of the behavioural changes of the fauna. It is helpful in this Project during and after this phase as well. The Contractor should also use the best available techniques (BAT) and control construction vibration levels to PPV, 8.00 mm/s at vibration sensitive biodiversity areas.

Section 13.11.1 presents mitigation measures.

12.8.2 Operational

Based on the assessment results in Section 12.7.2, the standard trackform of the alignment and a deep tunnel depth is appropriate for the operational alignment and unlikely to cause significant vibration impacts to the sensitive fauna species. General maintenance of railway tracks helps to prolong the effectiveness of the track form concerning vibration levels as the vital vibration source is the rail-wheel interaction of track form with the train wheels. Nevertheless, for precautionary purposes and to further ensure that the impacted fauna does not experience effects that affect their behaviour, monitoring the fauna's behavioural changes is helpful during the Testing and Commissioning Phase.

12.8.3 Summary

A summary of mitigation measures is provided below:

Construction

- Optimise the worksite for the smallest footprint within this area in the vicinity of CCNR
- Schedule rock breaking and excavation activities during the daytime.
- Use best available techniques (BAT) and control rock breaking and excavation vibration levels to PPV, 8.00 mm/s at vibration sensitive biodiversity areas.
- Use of tri-axle trucks to reduce truck trips on the road.
- Erect a temporary barrier on both sides of Island Club Road.
- Substitute rotary bore piling with secant bore piling to avoid working at night
- Prepare a vibration monitoring plan in coordination with the fauna, noise, and light specialist and obtain Authority’s approval.
- If there are justified complaints from the construction works, particularly from the rock breaking and excavation works, piling works, tunnel boring and bulldozer, the operation may need to mitigate vibration levels to the most practical levels.
- 7 vibration (Triaxial with 3G remote communication) monitoring stations are deployed within the study site to correlate noise, light and camera trap sightings with vibration readings generated in the heat/contour map. The duration is 4 blocks of 3 months (total of 12 months) to cover site clearance, rock breaking and excavation, piling and tunnel boring stages.
- 1 vibration (Triaxial with 3G remote communication) monitoring station is deployed at the edge of A1-W1 with noise and light readings. The duration is 4 blocks of 3 months (total of 12 months) to cover site clearance, rock breaking and excavation, piling and tunnel boring stages.

Operational

- The general maintenance of the railway track and reduce wheel defects.

Prepare a vibration monitoring plan in coordination with the fauna, noise, and light specialist and obtain Authority's approval.

12.9 Residual Impacts

12.9.1 Construction Phase

12.9.1.1 A1-W2 Worksite (Mitigated Scenario)

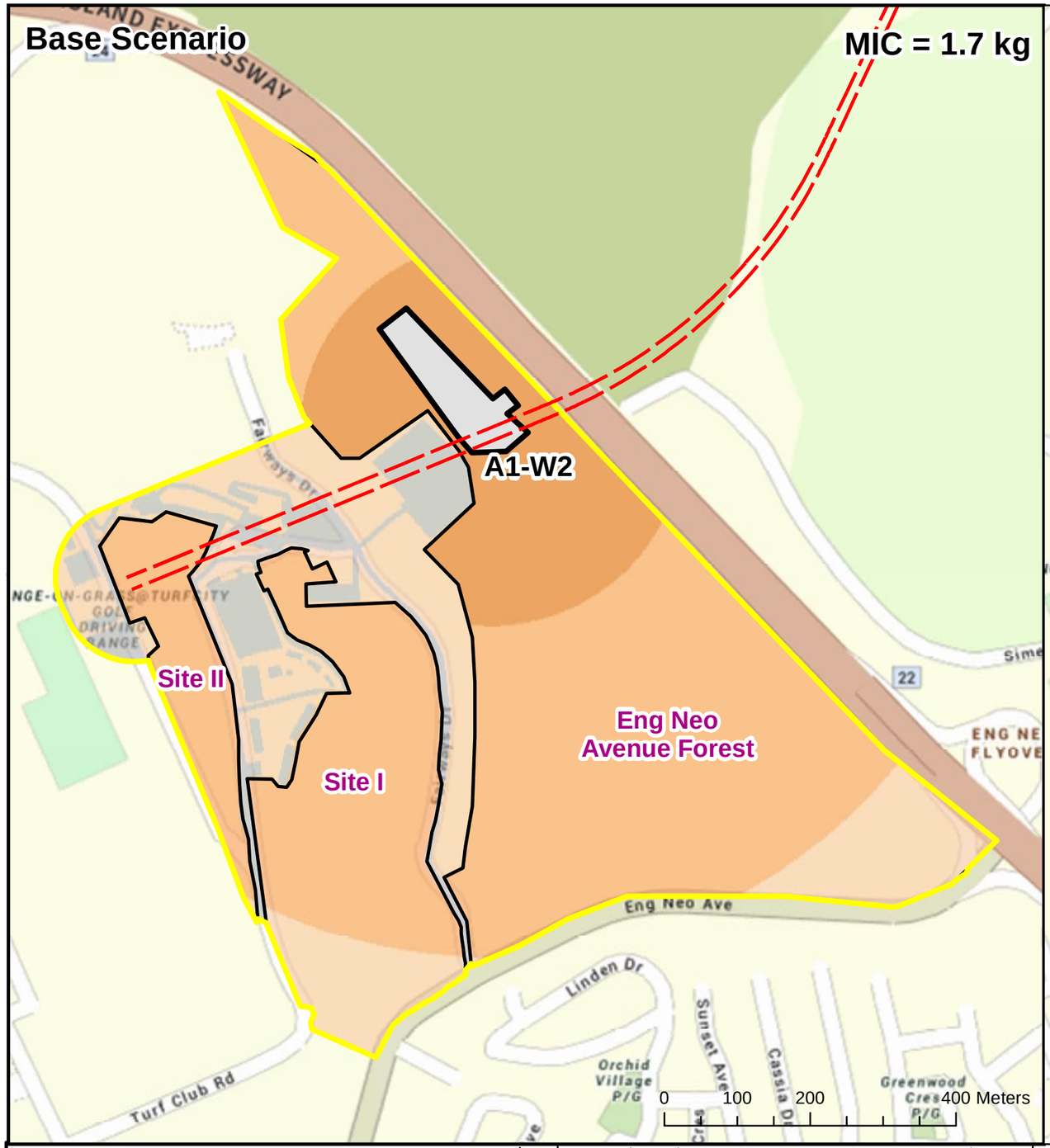
Based on the assessment results in Section 12.7.1, the potential impact significances for base scenario during the construction phase is expected to be **Minor – Major**. After mitigation measures in Section 12.8.1, the impact significance is expected to reduce to **Minor – Moderate**. This includes optimising A1-W2 worksite and relocating outside of Eng Neo Avenue Forest in an urbanised area. Though the **Major** impact significance has been reduced to **Moderate** even after implementing mitigations, it is recommended to implement effective management strategies during the construction phase, see Table 12-33. The maximum PPV for the mitigated scenarios for both worksites can be seen in Table 12-32. The respective figures can be seen from Figure 12-23 to Figure 12-30.

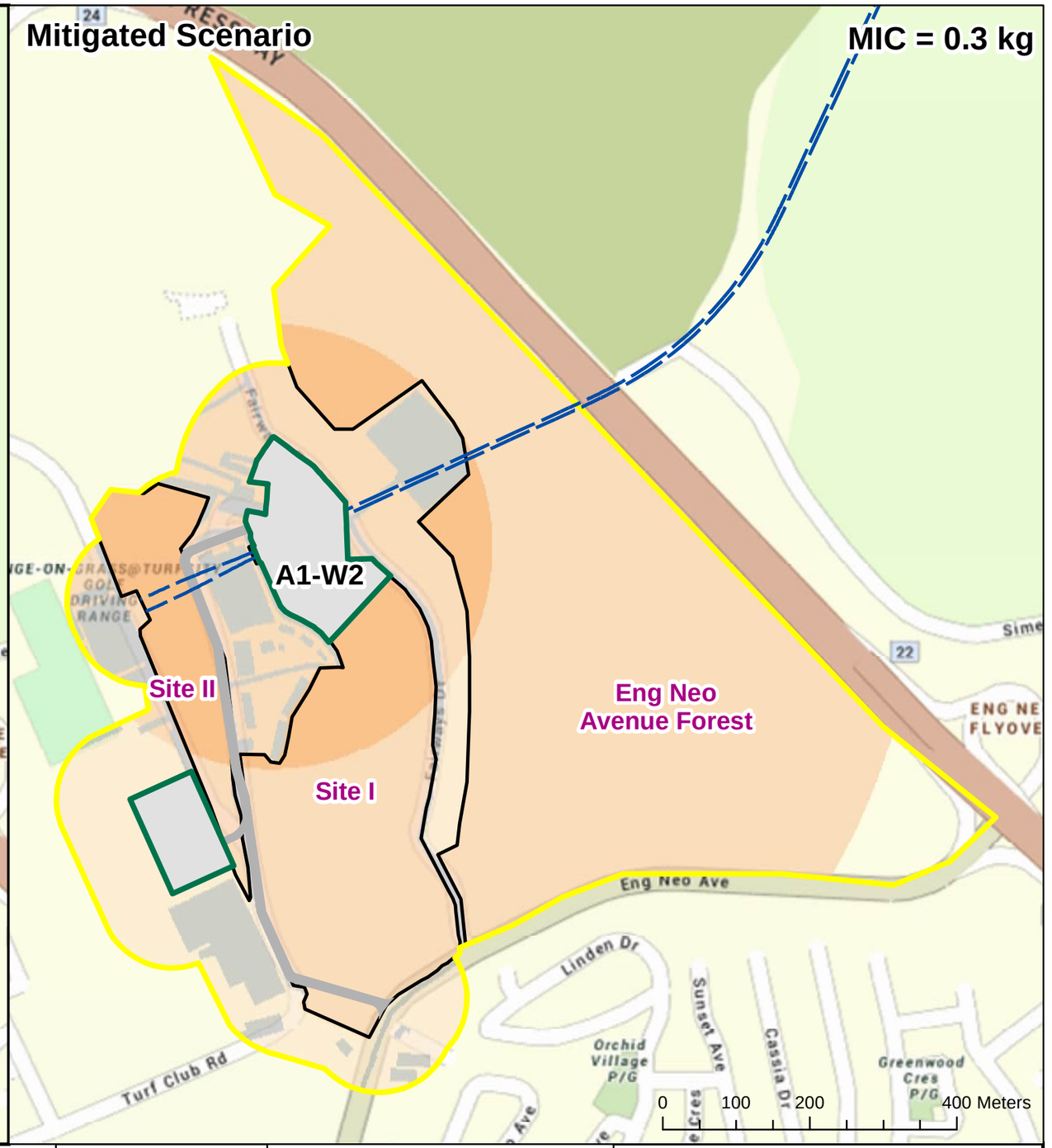
Table 12-32 Summary of Maximum PPV (mm/s) for All Construction Activities at A1-W2 Worksite

Construction Worksite	Construction Activities	Max Predicted PPV, mm/s	
		Biodiversity Study Area - Eng Neo Avenue Forest	**Biodiversity Study Area - Sites I and II**
A1-W2	Rock Breaking and Excavation, BS/ T207	0.17/0.17	0.29/0.33
	Rotary Bore Piling	NA	NA
	Bulldozing	0.09	0.70
	Tunnel Boring (entire tunnel), BS/Esvelt	0.89/0.47	0.31/0.15
	Tunnel Boring Esvelt (at spot)	0.52	0.05
	Low Vibratory Compactor	0.01	1.44
	High Vibratory Compactor	0.07	5.20
	Transition Tunnel Tunnel Boring (entire tunnel) BS/Esvelt	0.18/0.07	1.43/0.62

Table 12-33 Comparison between Base and Mitigated Impact Significances with Mitigation Measures for A1-W2 Worksite

Construction Worksite and Activities	Base Scenario Impact Significance			Mitigation Measure	Mitigated Scenario Impact Significance			Changes in Impact Significance (Increased/Decreased/No Change?)
A1-W2 Worksite	**Eng Neo Avenue Forest**	**Forested Area Adjacent to Fairways Quarters**			**Eng Neo Avenue Forest**	**Forested Area Adjacent to Fairways Quarters**		
		Sites I	**Site II**			**Sites I**	**Site II**	
Rock Breaking and Excavation	Moderate – Major	Moderate	Moderate	1. Optimising the A1-W2 worksite and relocating to an urban area outside Eng Neo Avenue Forest. 2. A temporary water barrier on both sides of Island Club Road can mitigate roadkills due to the impacted fauna trying to dash onto a road during rock breaking and excavation. This measure reduces the impact significance to **Minor – Moderate** at Eng Neo Avenue Forest.	Minor – Moderate	Minor	Minor	Reduces the impact significance to only **Moderate** in Biodiversity Study Areas, with a decrease in impacted area significantly as well.
	Impacted area, ha, BS Method MIC = 1.7 kg				Impacted area, ha, BS Method MIC = 0.3 kg			
	Moderate: 24.5 Major: 9.8	Moderate: 4.1	Moderate: 10		Moderate: 2.7	-	-	
	Impacted area, ha, T207 Method MIC = 2.9 kg				Impacted area, ha, T207 Method MIC = 0.6 kg			
	Moderate: 20.1 Major: 8.2	Moderate: 6.8	Moderate: 3.6		Moderate: 1.6	Moderate: 2.4	Moderate: 3.2	
Rotary Bore Piling	Minor	Negligible	Negligible	1. Optimising the A1-W2 worksite and relocating to an urban area outside Eng Neo Avenue Forest. 2. Using low vibration equipment as the Appointed Contractor needs to monitor vibration generated during construction does not exceed PPV, 3.00 mm/s for the structural integrity of the conservation buildings near the worksite.	Negligible	Negligible	Negligible	No change.
Bulldozer	Minor	Negligible	Negligible		Negligible	Negligible	Negligible	No change.
Low Vibratory Compactor	NA	NA	NA		NA	Minor	Minor	Causes **Minor** impact significance areas in Biodiversity Study Areas
High Vibratory Compactor	NA	NA	NA		NA	Minor	Minor	
Tunnel Boring Machine, Esvelt	Minor – Moderate	Minor	Minor	Mitigation measures are not required as it is reasonable to assess the duration of impacts to be transient during the pass-by of a tunnel boring machine in a day.	Minor – Moderate	Minor – Moderate	Minor – Moderate	Reduced the overall size of **Moderate** impact significance areas in the Biodiversity Study Areas from 24.5 ha to 10.3 ha.
	Impacted area, ha				Impacted area, ha			
	Moderate: 12.3	-	-		Moderate: 8.2	Moderate: 1.4	Moderate: 0.7	
Tunnel Boring Machine at Spot, Esvelt	Minor – Moderate	Minor	Minor		Minor – Moderate	Minor	Minor	**Moderate** impact significance increases by 1.8 ha Most construction activities have either no change or reduced impact significance with the mitigated scenario. Thus, the benefits outweigh the increased impacted area for this construction activity. In addition, the increase in area is not significant, and the impact significance remains below **Major.**
	Impacted area, ha				Impacted area, ha			
	Moderate: 4.6	-	-		Moderate: 6.4	-	-	
Tunnel Boring Machine for Transition Tunnel, Esvelt	NA	NA	NA		Minor	Minor	Minor – Moderate	Causes **Minor – Moderate** impact significance areas in Biodiversity Study Areas
	Impacted Area, ha				Impacted Area, ha			
	NA	NA	NA		-	-	Moderate: 3	
Summary: For all mitigated construction activities with a **Minor** impact significance, despite the increase in vibration levels, fauna species are likely to adapt to the construction activities. They would potentially return to their regular activity and habitat. For all mitigated construction activities that still have an impact significance of **Moderate**, sensitive fauna may be affected in their day-to-day activities (communication/ foraging) for a short period in the zone of impact and may leave the area. Hence EMMP measures shall be applied.								





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite
- Temporary Access Roads
- Study Area
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Negligible
- Minor
- Moderate
- Major
- Not Assessible

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
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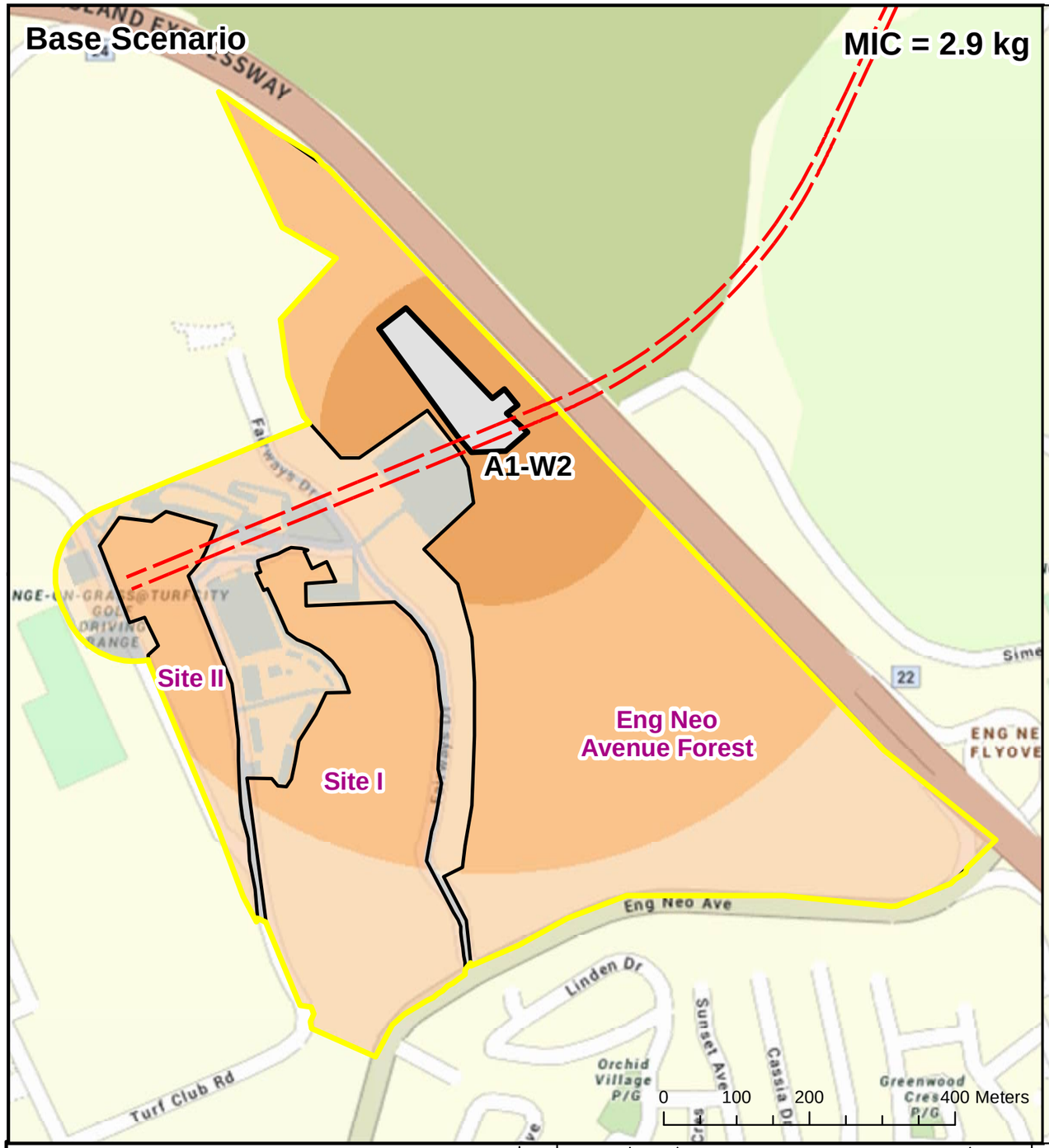
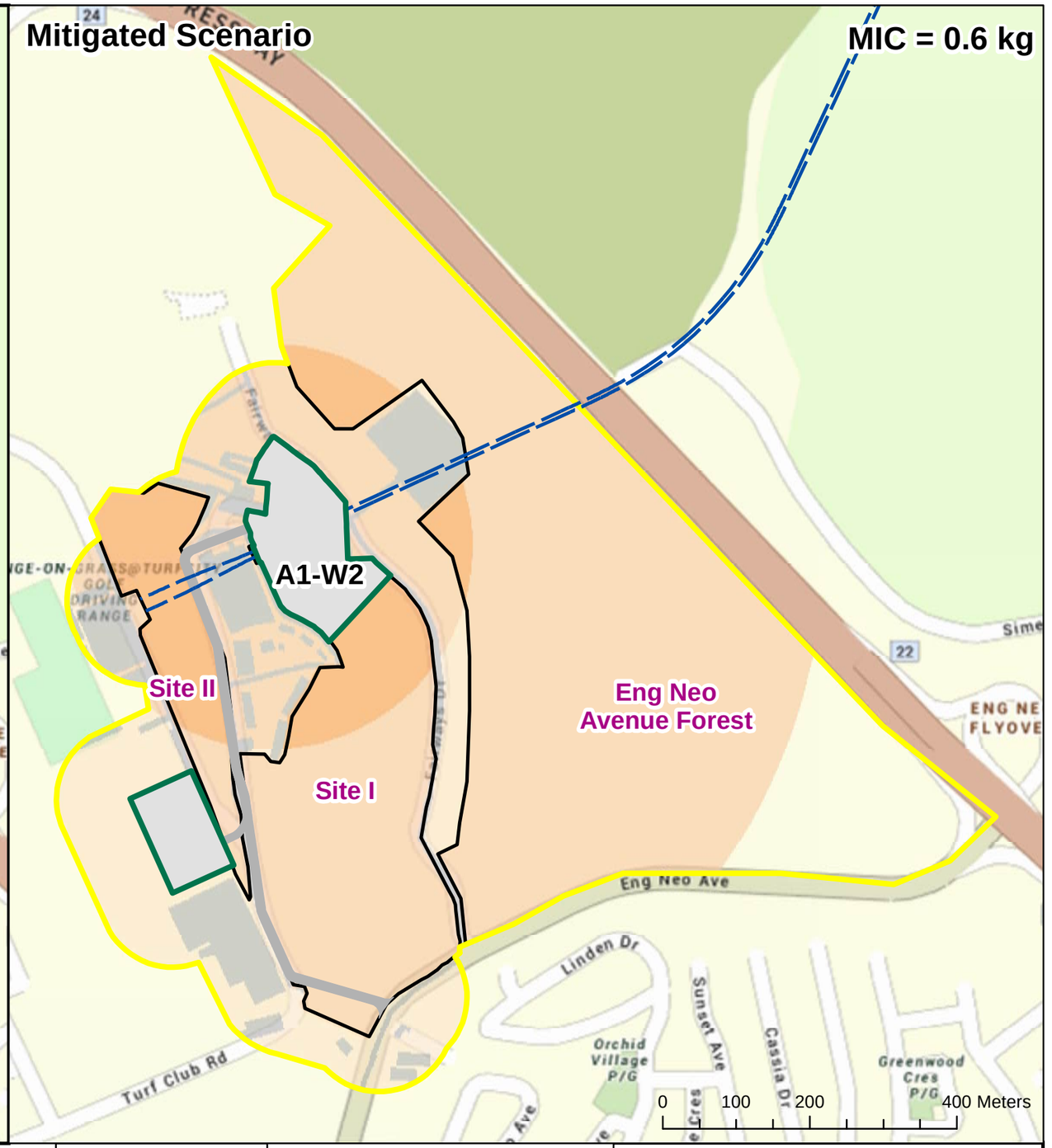
Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Drawing Title :
IMPACT SIGNIFICANCE COMPARISON FOR ROCK BREAKING AND EXCAVATION AT A1-W2 (BS METHOD)

Designed	Checked	Approved	Drawing No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 23	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite
- Temporary Access Roads
- Study Area
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Negligible
- Minor
- Moderate
- Major
- Not Assessible

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
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Project Title :
**CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)**

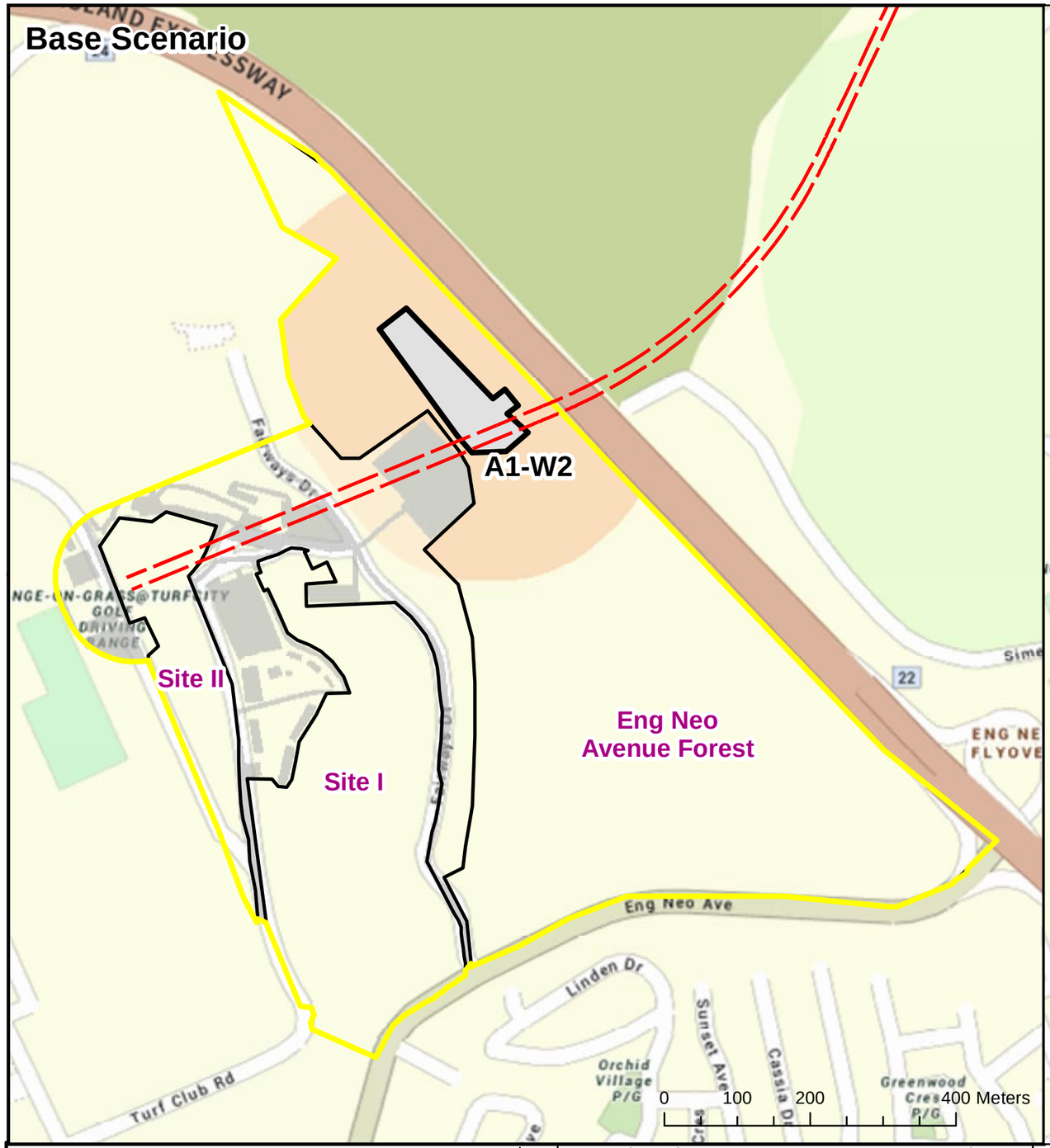
Drawing Title :
**IMPACT SIGNIFICANCE COMPARISON
FOR ROCK BREAKING AND EXCAVATION
AT A1-W2
(T207 METHOD)**

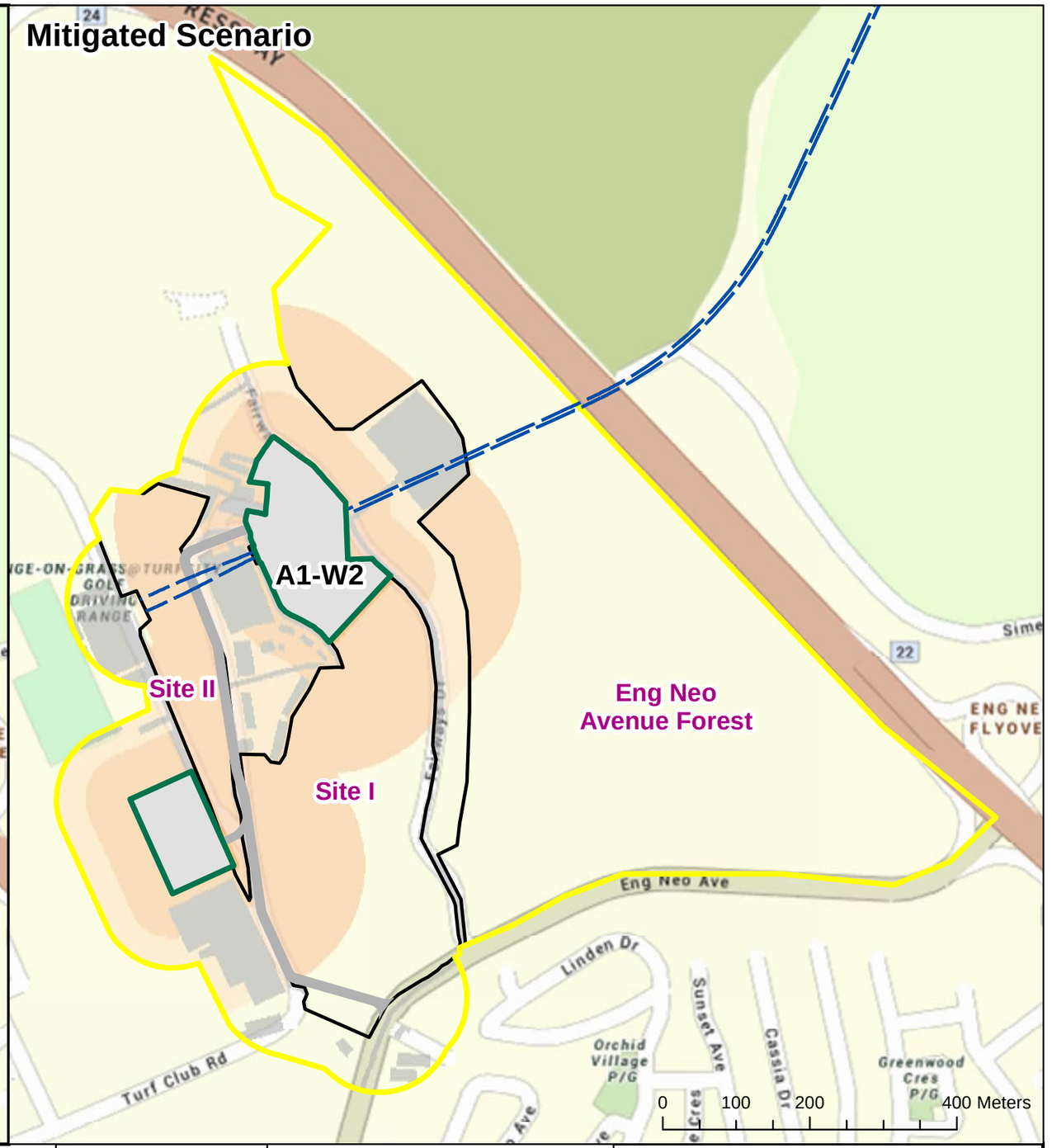
Designed	Checked	Approved
EGY	JAG	JAG
	Drawn: EGY	Date: MAR 2022

Drawing No. : 12 - 24 | Rev. : - | Sheet : 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite
- Temporary Access Roads
- Study Area
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Negligible
- Minor
- Moderate
- Major
- Not Assessible

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant :
AECOM

Land Transport Authority
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Project Title :
**CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)**

Drawing Title :
**IMPACT SIGNIFICANCE COMPARISON
FOR BULLDOZER
AT A1-W2**

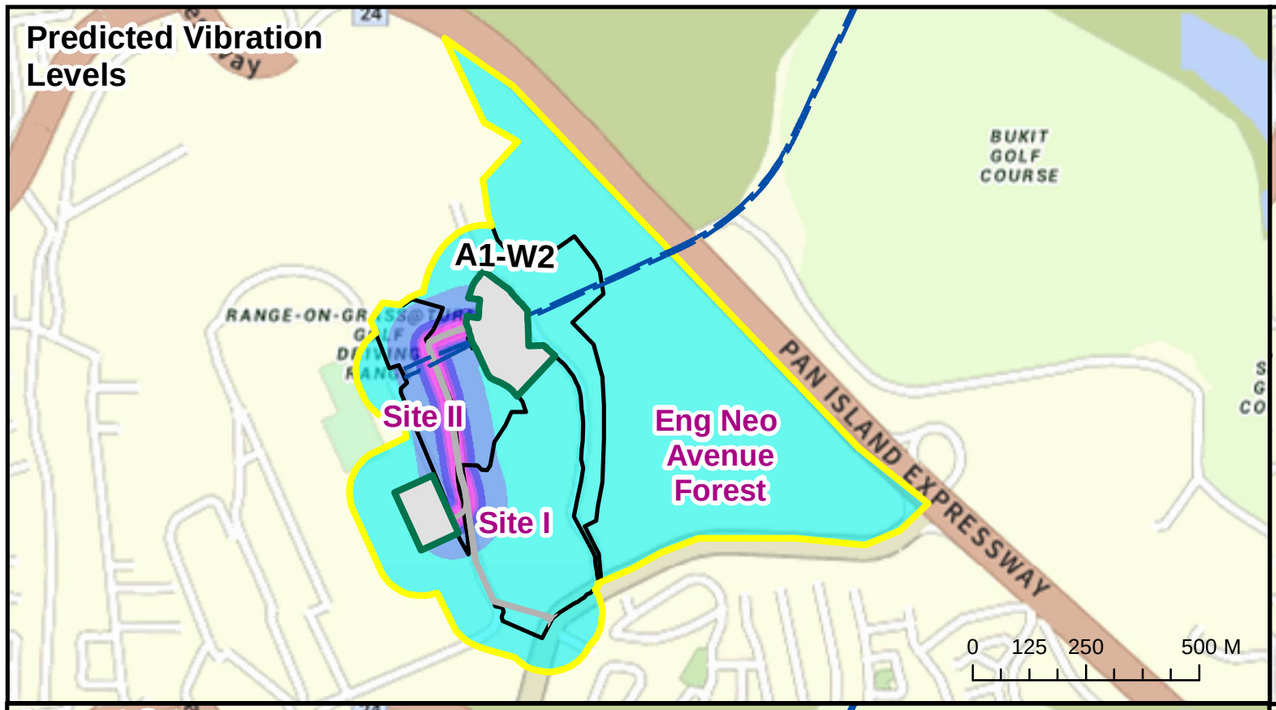
Designed	Checked	Approved
EGY	JAG	JAG
	Drawn EGY	Date MAR 2022

Drawing No. : 12 - 25 | Rev. - | Sheet 1 of 1

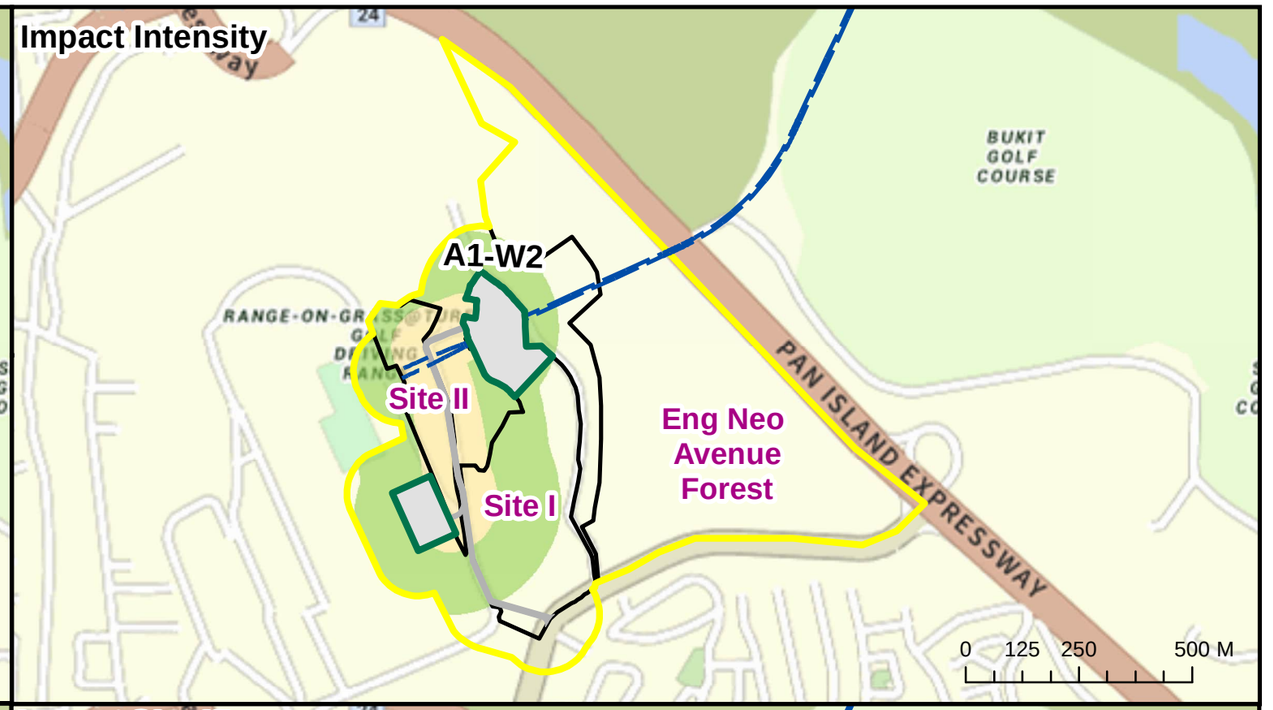
CAD File Name : NA | A3

Note: Source of basemap - OneMap

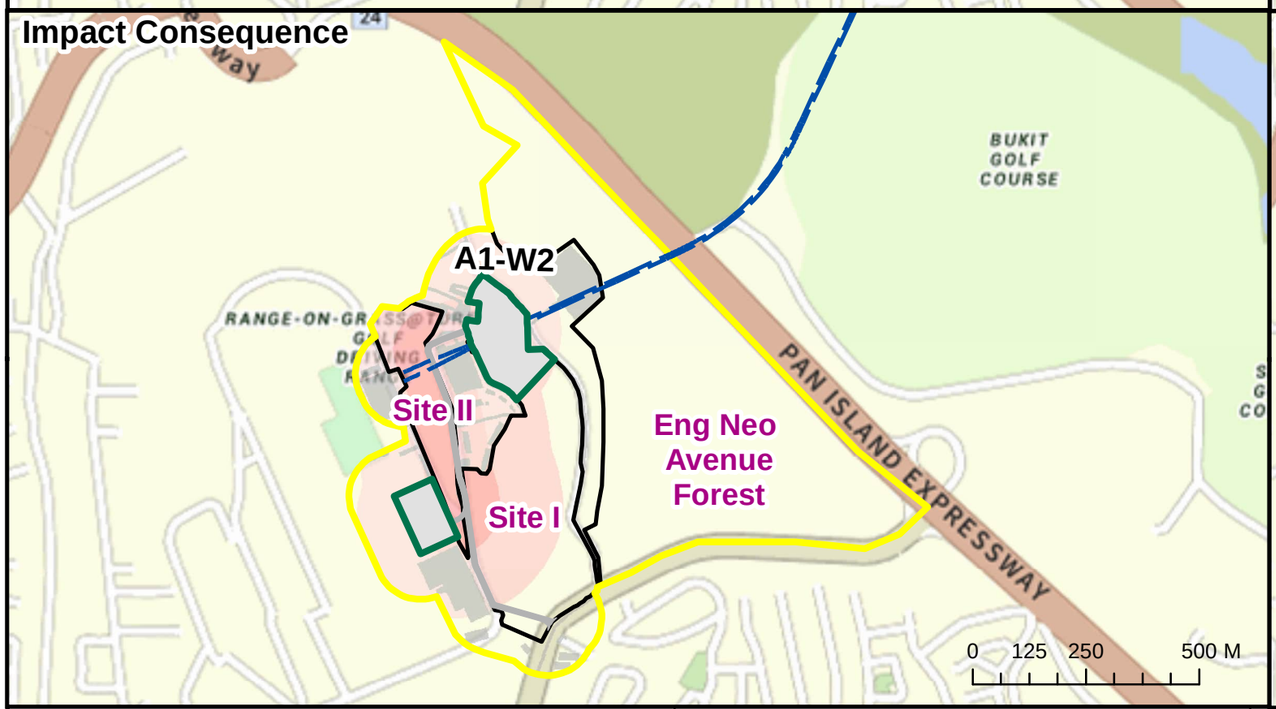
Predicted Vibration Levels



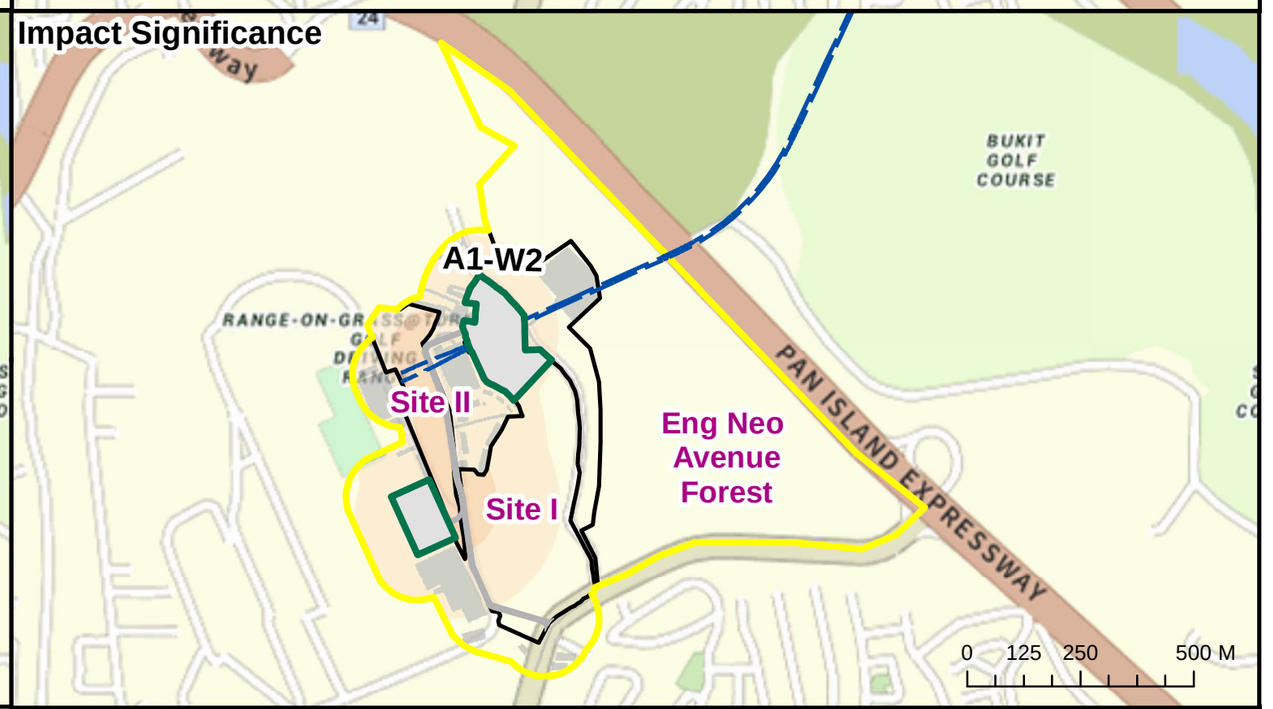
Impact Intensity



Impact Consequence



Impact Significance



Legend

- Mitigated Scenario Construction Worksite
- Proposed CRL Alignment (Mitigated)
- Temporary Access Roads
- Study Area (Mitigated)
- Biodiversity Study Area

Predicted Vibration Level	Impact Intensity	Impact Consequence	Impact Significance
PPV (mm/s)	Below Ambient	Below Ambient	Below Ambient
0 - 0.08	Negligible	Imperceptible	Negligible
0.09 - 0.27	Low	Very Low	Minor
0.28 - 0.61		Low	Not Assessible
0.62 - 1.10		Not Assessible	
1.11 - 1.44			

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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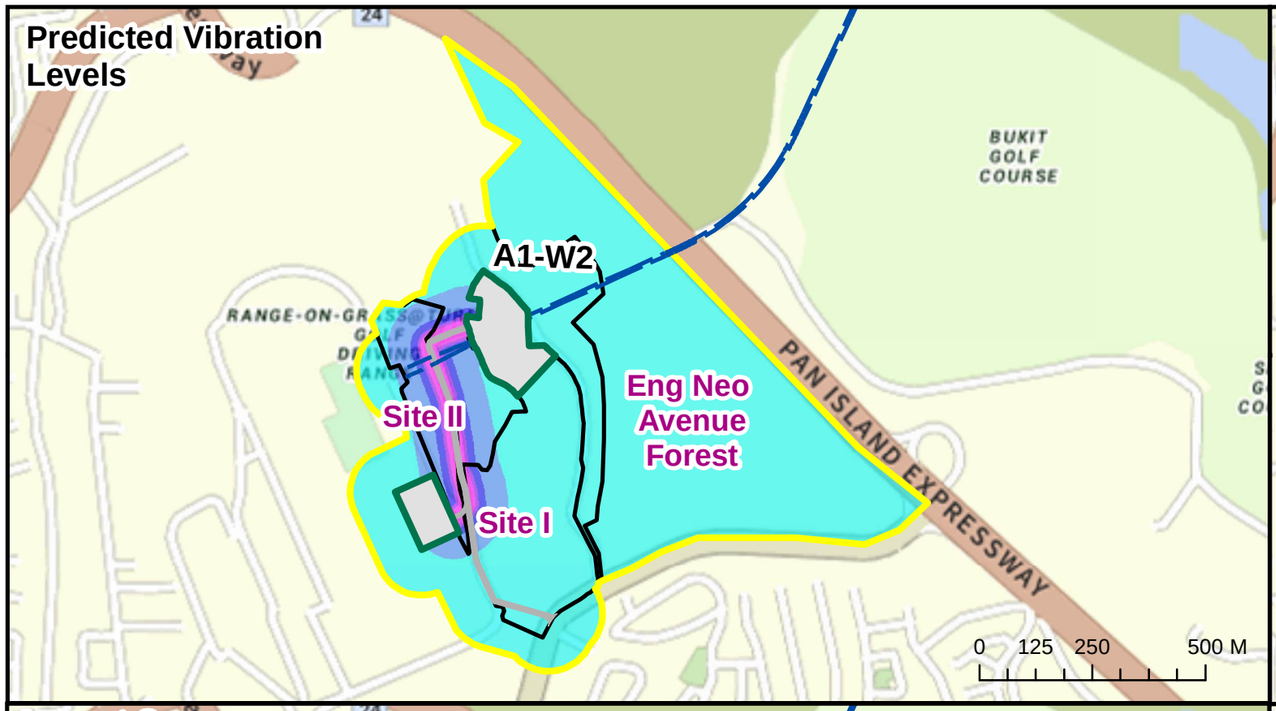
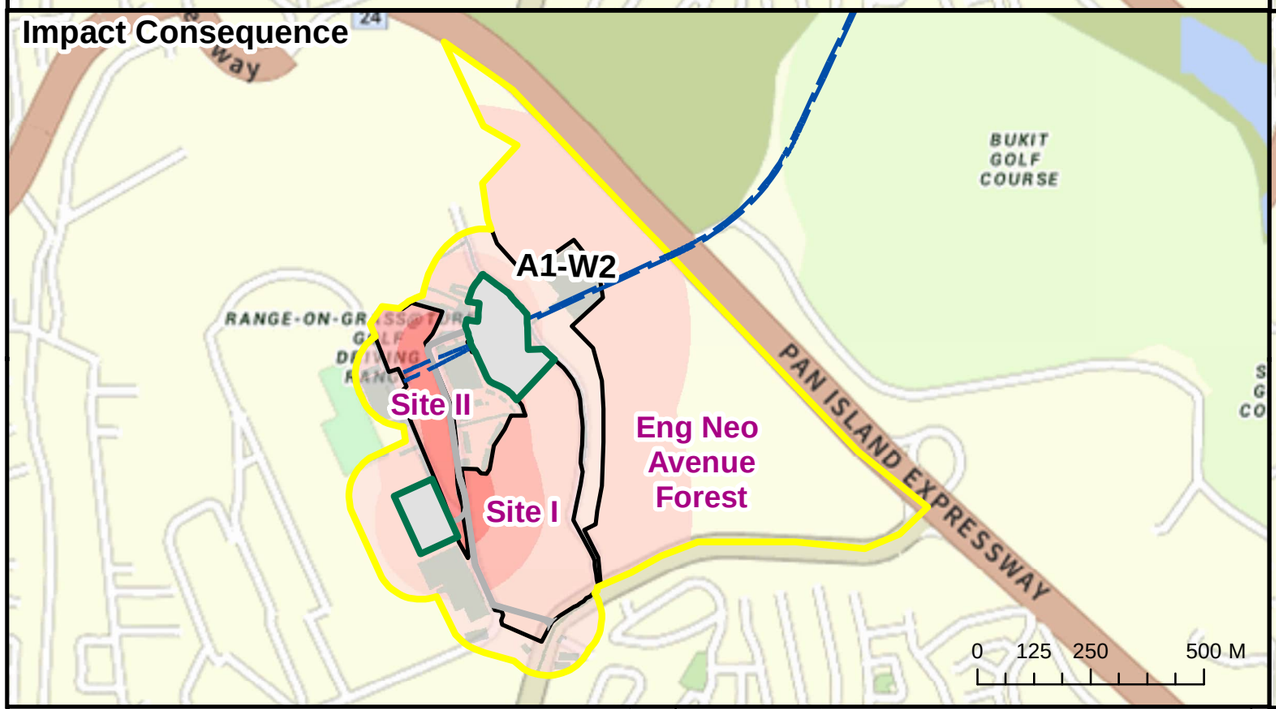
Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

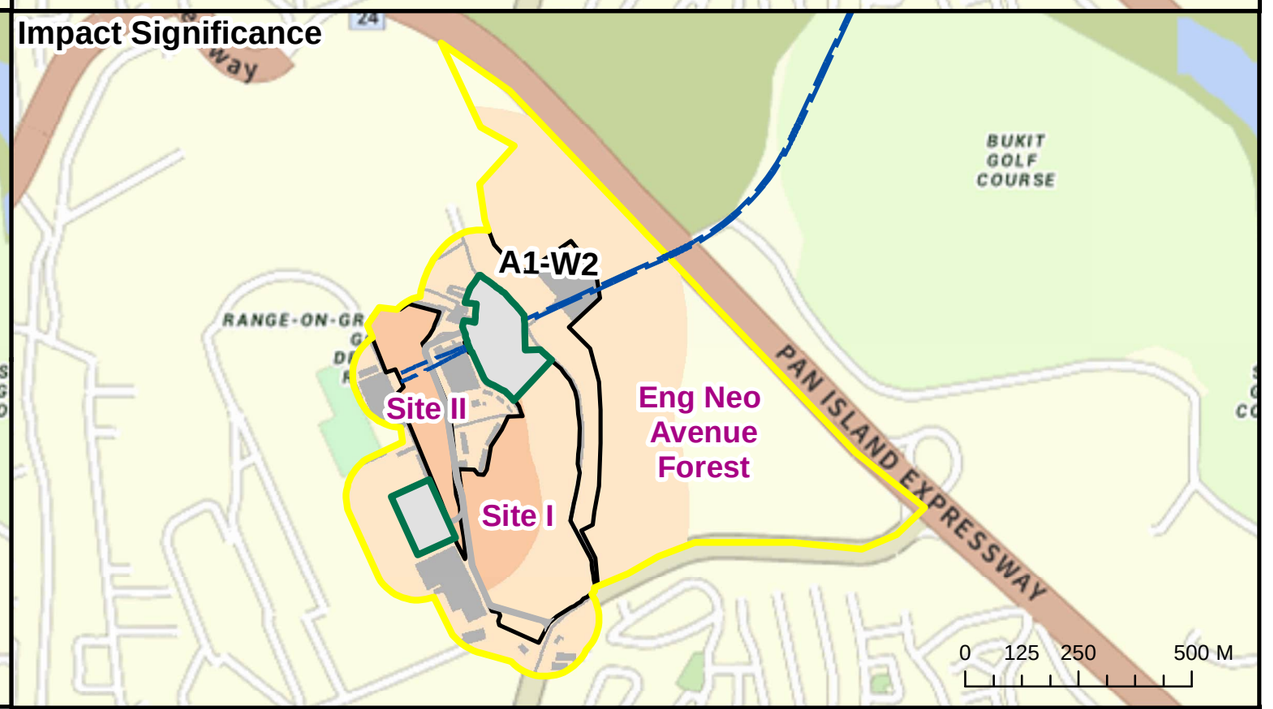
Figure Title :
VIBRATION ASSESSMENT FOR LOW VIBRATORY COMPACTOR AT A1-W2 (MITIGATED SCENARIO)

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 26	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap







Legend

- Mitigated Scenario Construction Worksite
- Proposed CRL Alignment (Mitigated)
- Temporary Access Roads
- Study Area (Mitigated)
- Biodiversity Study Area

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.01 - 0.27	Below Ambient	Below Ambient	Below Ambient
0.28 - 0.97	Negligible	Imperceptible	Negligible
0.98 - 2.19	Low	Very Low	Minor
2.20 - 3.99	Medium	Low	Not Assessible
4.00 - 5.21		Medium	
		Not Assessible	

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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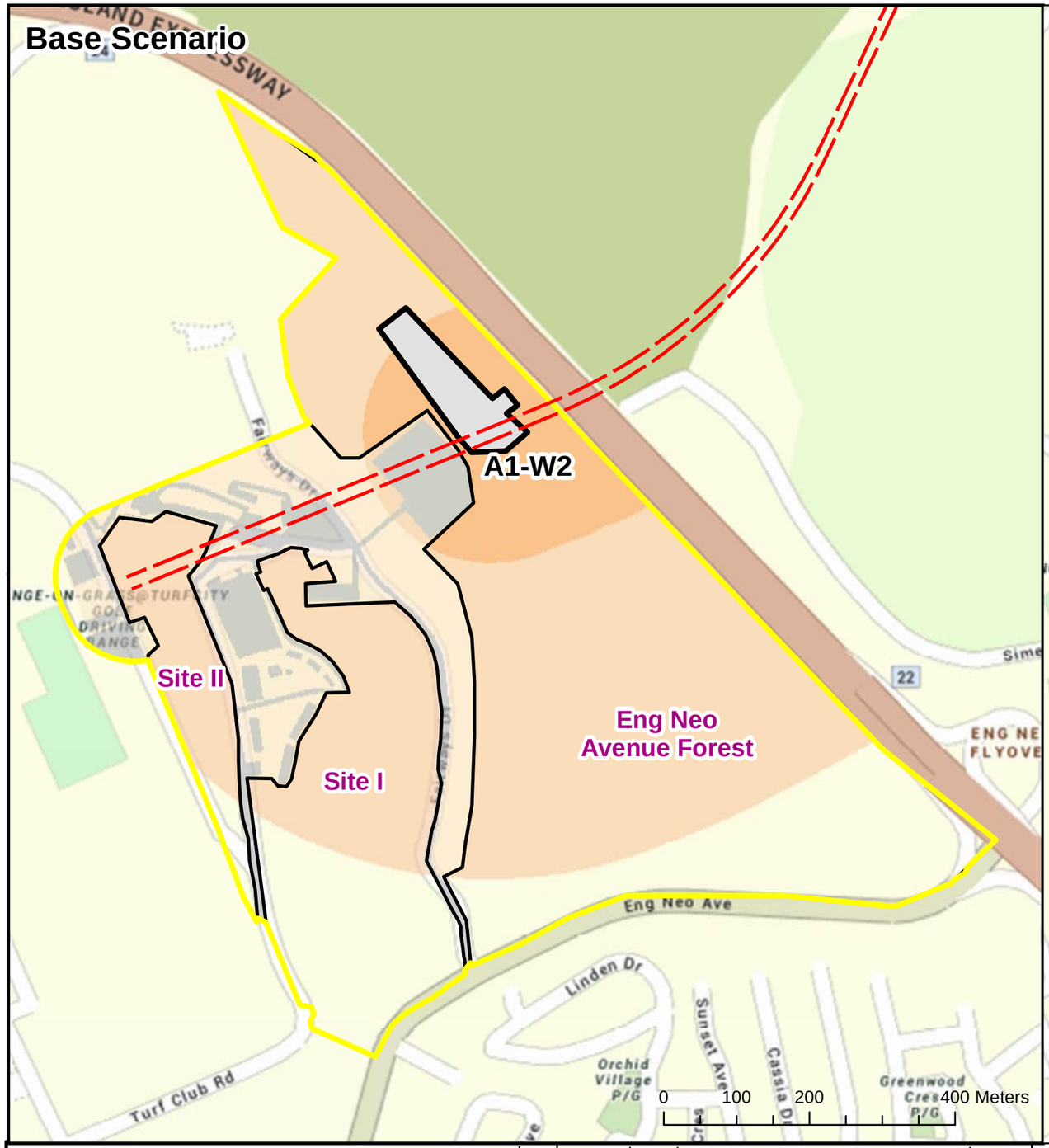
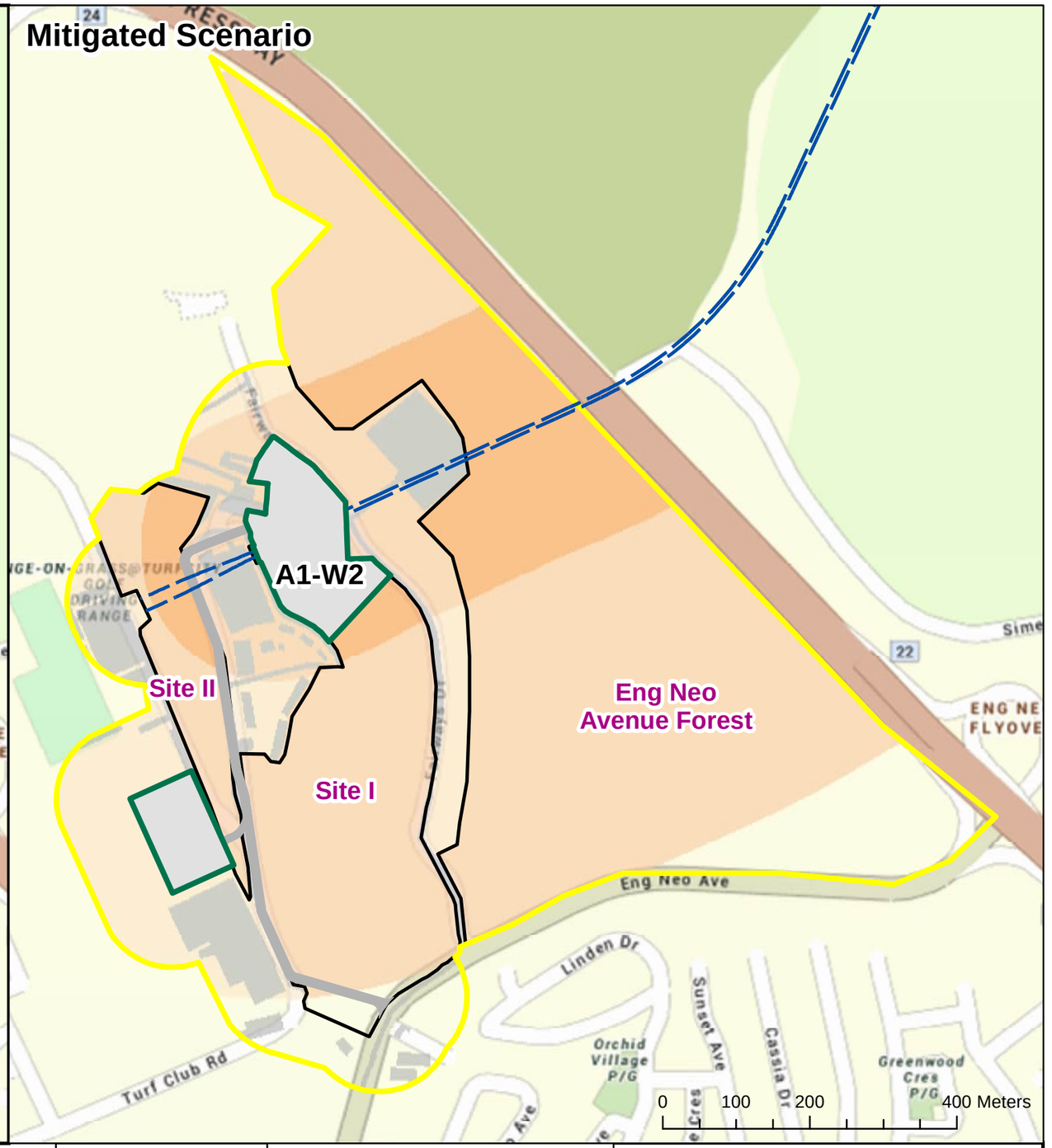
Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
VIBRATION ASSESSMENT FOR HIGH VIBRATORY COMPACTOR AT A1-W2 (MITIGATED SCENARIO)

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG	JAG	12 -27	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite
- Temporary Access Roads
- Study Area
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Negligible
- Minor
- Moderate
- Not Assessible

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant :
AECOM

Land Transport Authority
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Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

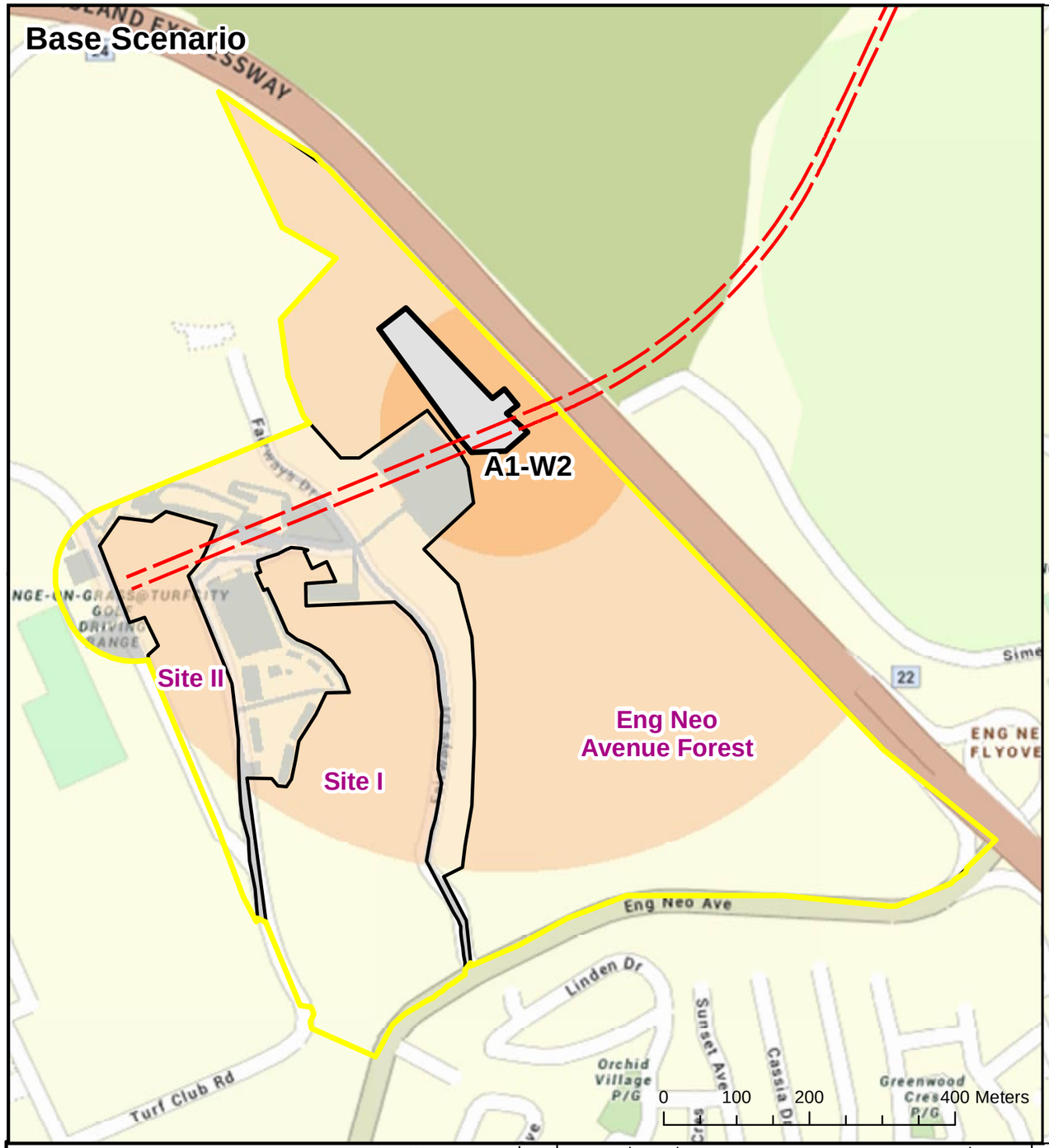
Drawing Title :
HYPOTHETICAL OVERALL IMPACT SIGNIFICANCE COMPARISON FOR TUNNEL BORING AT A1-W2 (ESVELT METHOD)

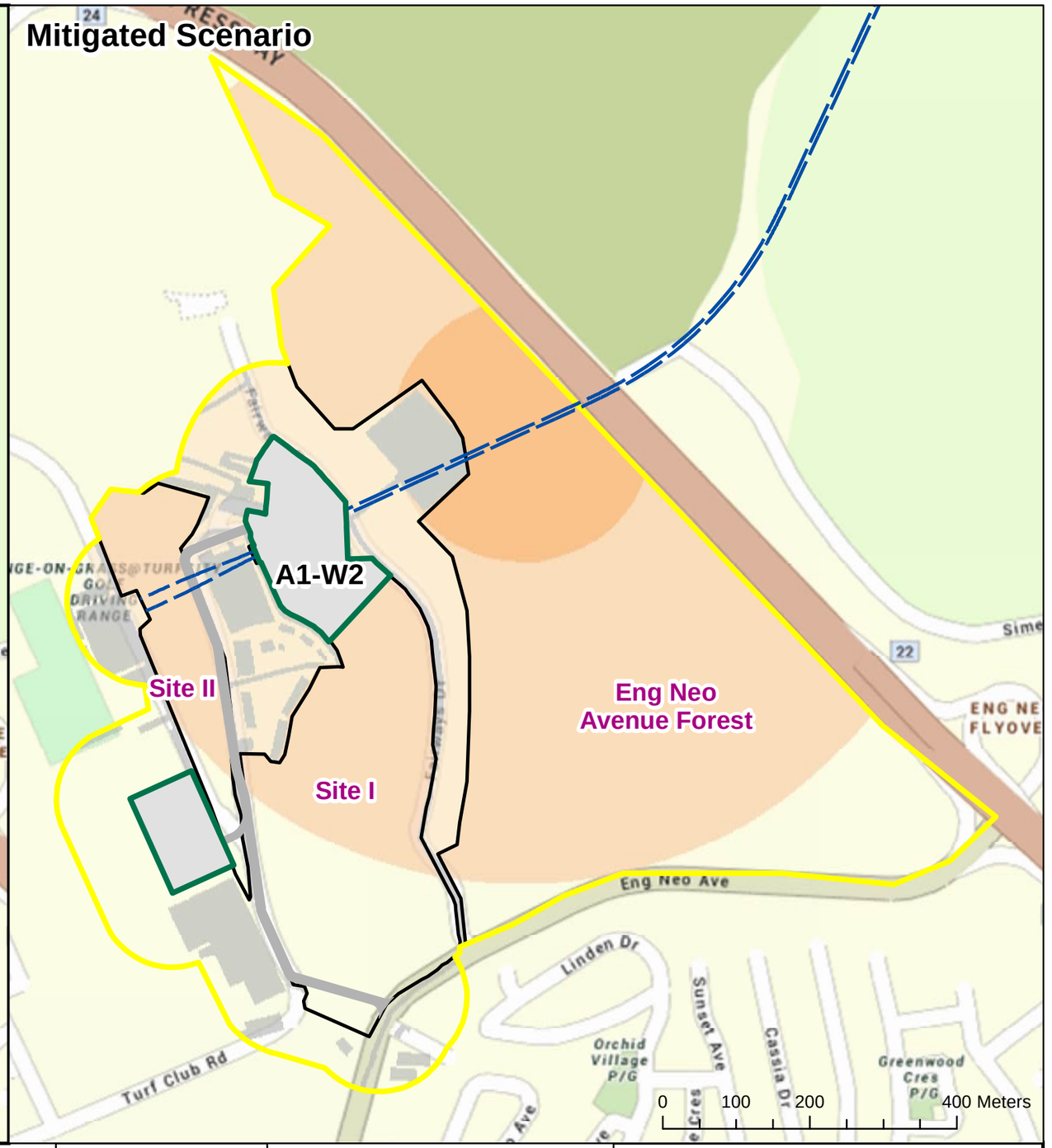
Designed	Checked	Approved
EGY	JAG	JAG
	Drawn: EGY	Date: MAR 2022

Drawing No. : 12 - 28 | Rev. : - | Sheet : 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap





Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite
- Temporary Access Roads
- Study Area
- Biodiversity Study Area

Impact Significance

- Below Ambient
- Negligible
- Minor
- Moderate
- Not Assessible

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

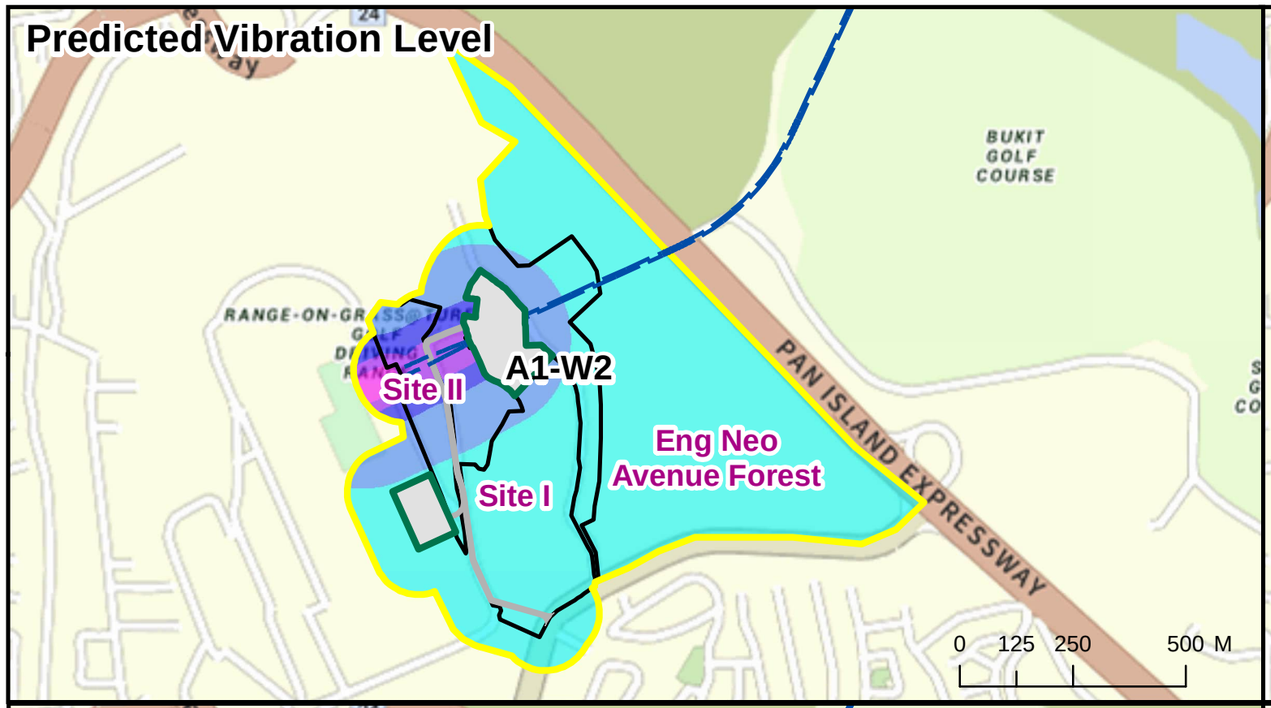
Land Transport Authority — We Keep Your World Moving

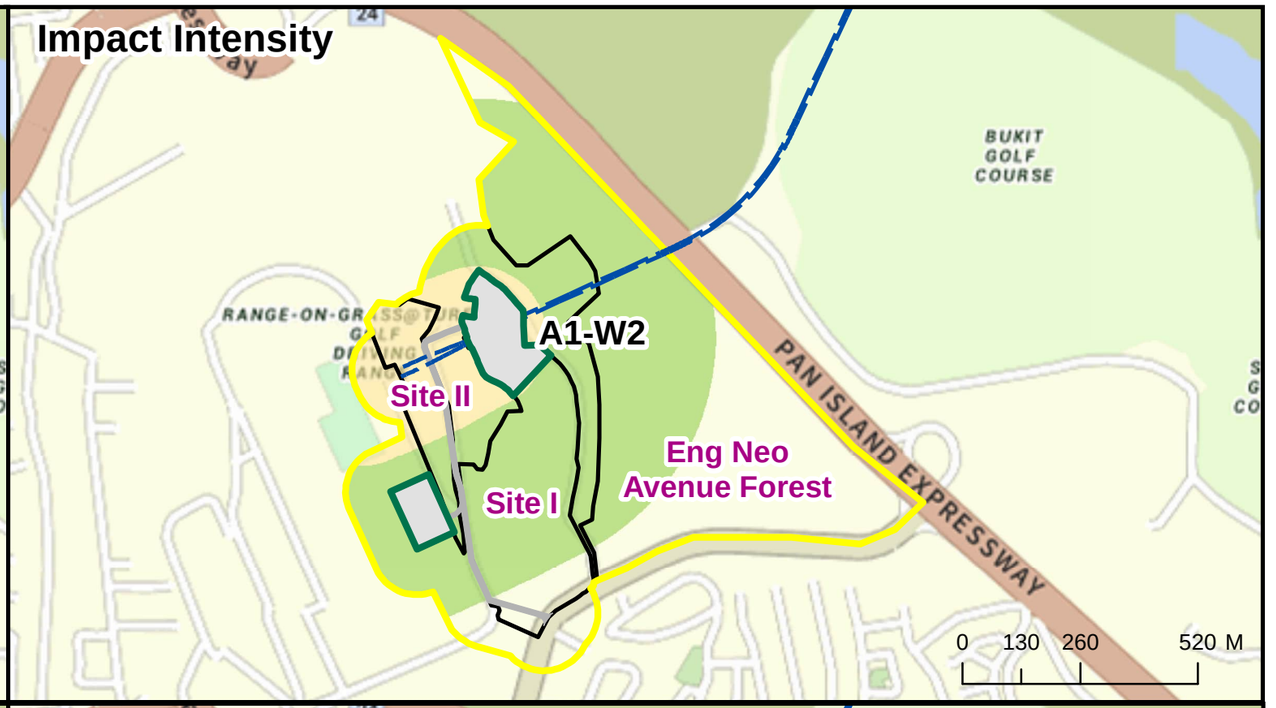
Project Title :
**CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)**

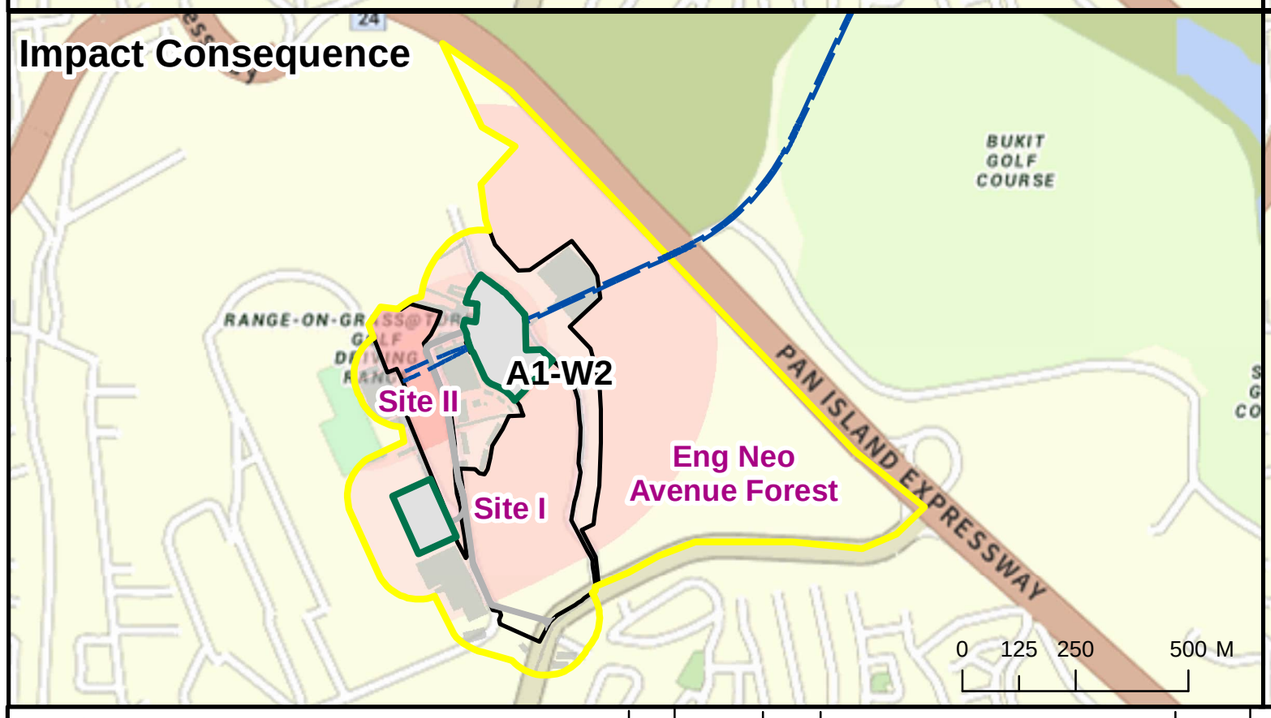
Drawing Title :
IMPACT SIGNIFICANCE COMPARISON FOR SPOT TUNNEL BORING MACHINE AT A1-W2 (ESVELT METHOD)

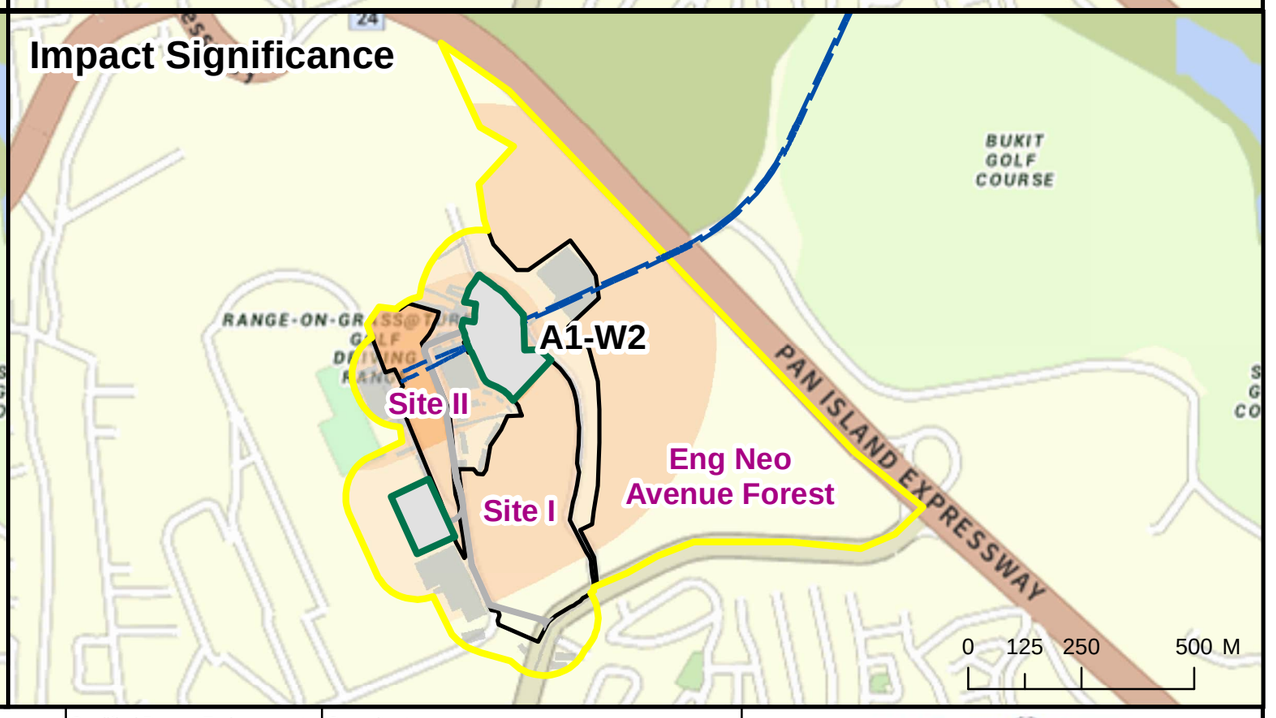
Designed	Checked	Approved	Drawing No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 29	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap









Legend

- Mitigated Scenario Construction Worksite
- Proposed CRL Alignment (Mitigated)
- Temporary Access Roads
- Study Area (Mitigated)
- Biodiversity Study Area

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.01 - 0.07	Below Ambient	Below Ambient	Below Ambient
0.08 - 0.20	Negligible	Imperceptible	Negligible
0.21 - 0.41	Low	Very Low	Minor
0.42 - 0.71		Low	Moderate
0.72 - 0.99		Not Assessible	Not Assessible

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Drawing Title :
VIBRATION ASSESSMENT FOR TUNNEL BORING MACHINE AT TRANSITION TUNNEL, ESVELT METHOD (MITIGATED SCENARIO)

Designed	Checked	Approved	Drawing No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 30	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

12.9.1.2 A1-W1 Worksite (Mitigated Scenario)

Based on the assessment results in Section 12.7.1, the potential impact significance for the base scenario during the construction phase is expected to be **Minor – Major.** After mitigation measures in Section 12.8.1, the impact significance is expected to reduce, resulting in **Minor – Moderate** impacts. Mitigation measure includes optimising the A1-W2 worksite and relocating outside of Eng Neo Avenue Forest in an urbanised area. Though the **Major** impact significance has been reduced to **Moderate** even after implementing mitigations, it is recommended to implement effective management strategies during the construction phase, Table 12-35.

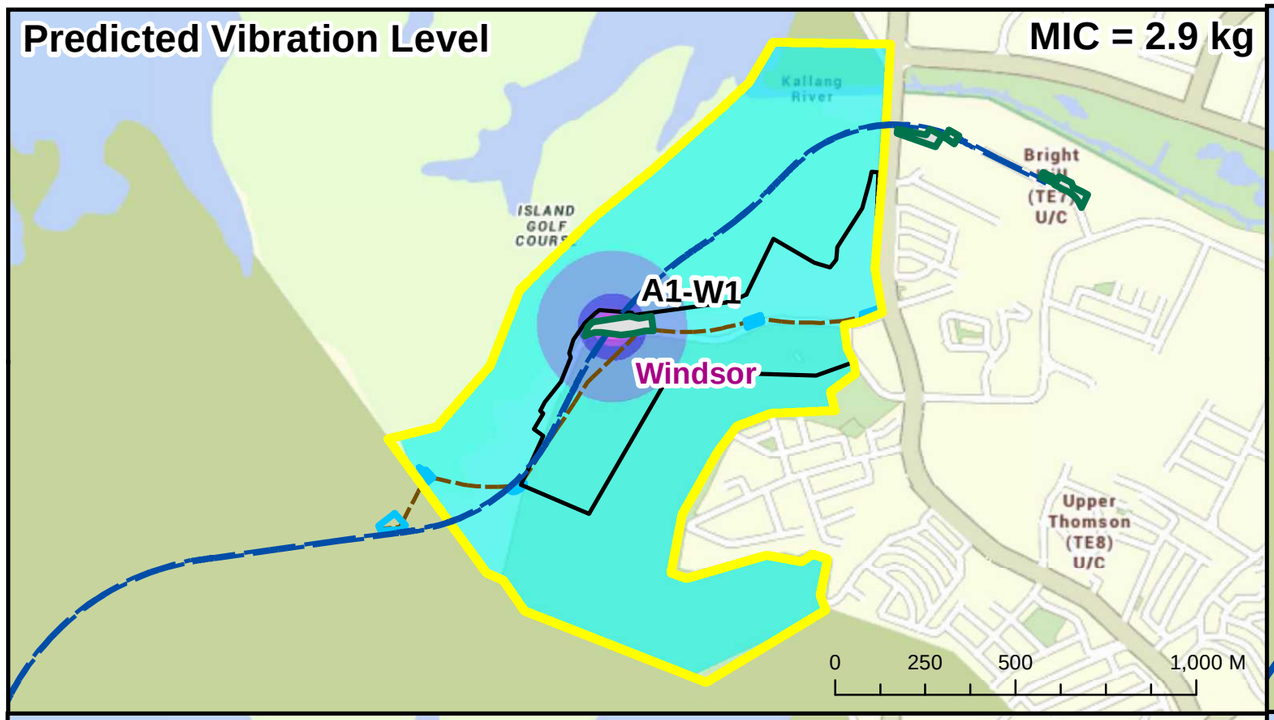
The maximum vibration level for the mitigated scenarios for both worksites can be seen in Table 12-34. The respective figures can be seen in Figure 12-31 to Figure 12-37.

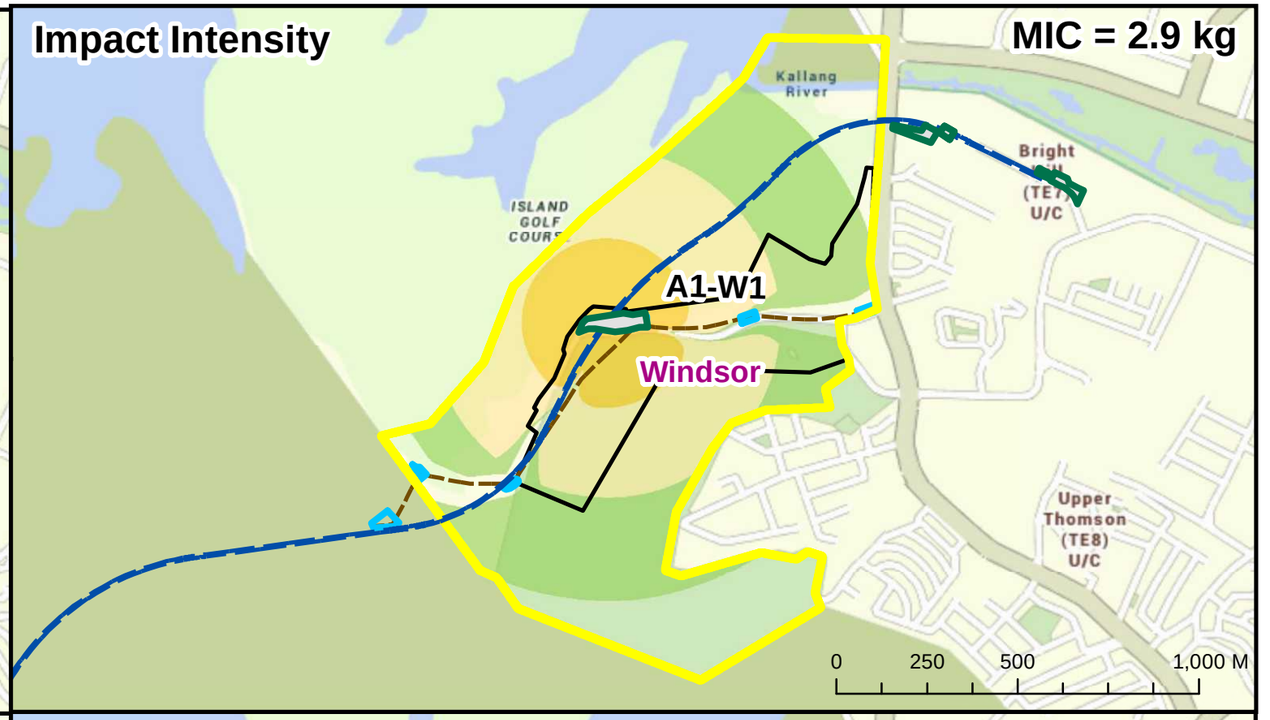
Table 12-34 Summary of Maximum PPV (mm/s) for All Construction Activities at A1-W1 Worksite

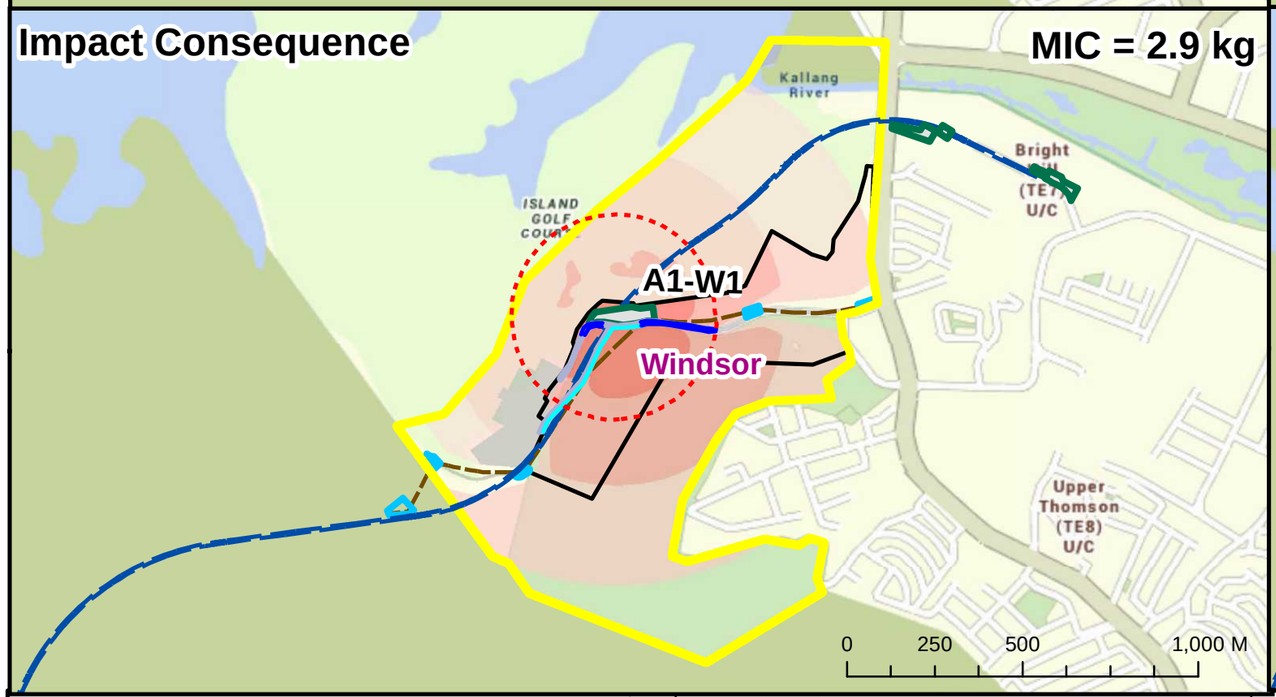
Construction Worksite	Construction Activities	Max Predicted PPV, mm/s
		Biodiversity Study Area - Windsor
A1-W1	Rock Breaking and Excavation, BS/ T207	9.36/10.80
	Rotary Bore Piling	0.30
	Bulldozing	1.02
	Tunnel Boring (entire tunnel) , BS/ Esvelt	0.51/0.45
	Tunnel Boring (at spot 1)	0.07
	Tunnel Boring (at spot 2)	0.45
	Tunnel Boring (at spot 3)	0.23

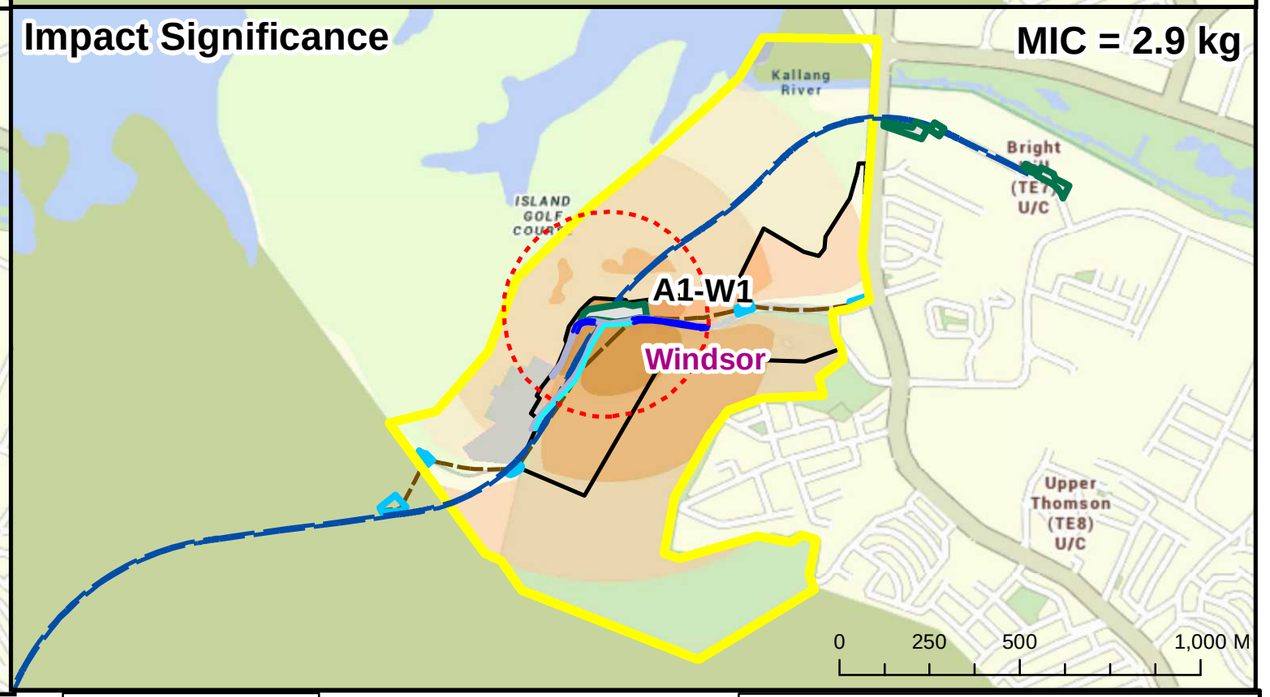
Table 12-35 Comparison between Base and Mitigated Impact Significances with Mitigation Measures for A1-W1 Worksite

Construction Worksite and Activities	Base Scenario Impact Significance	Mitigation Measure	Mitigated Scenario Impact Significance	Changes in Impact Significance (Increased/Decreased/No Change?)
A1-W1 Worksite	**Windsor**		**Windsor**	
Rock Breaking and Excavation, T207	Moderate – Major Impacted area, ha: Moderate: 9.9 Major: 5.7	1. Optimising the A1-W2 worksite and relocating to an urban area outside Eng Neo Avenue Forest. 2. A temporary water barrier on both sides of Island Club Road can mitigate roadkills due to the impacted fauna trying to dash onto a road during rock breaking and excavation. This measure reduces the impact significance, resulting in Minor – Moderate at Eng Neo Avenue Forest.	Minor – Moderate Impacted area, ha: Moderate: 15.6	Reduces the size of **Moderat**e and **Major** impact significance areas within Biodiversity Study Areas. Since the impact significance is still Moderate, EMMP measures should be applied.
Rotary Bore Piling	Minor	Mitigation measures are not required.	Minor	No change.
Bulldozer	Minor		Minor	No change.
Tunnel Boring Machine Full Tunnel	Minor – Moderate Impacted area, ha: Moderate: 7	Mitigation measures are not required as it is reasonable to assess the duration of impacts to be transient during the pass-by of a tunnel boring machine in a day.	Minor – Moderate Impacted area, ha: Moderate: 7	No change. Since the impact significance is still Moderate, EMMP measures should be applied.
Tunnel Boring Machine at Spot 1	Minor – Moderate Impacted area, ha: Moderate: 7		Minor – Moderate Impacted area, ha: Moderate: 7	
Tunnel Boring Machine at Spot 2	Minor – Moderate Impacted area, ha: Moderate: 2.2		Minor – Moderate Impacted area, ha: Moderate: 2.2	
Tunnel Boring Machine at Spot 3	Minor – Moderate Impacted area, ha: Moderate: 0.3		Minor – Moderate Impacted area, ha: Moderate: 0.3	
For all mitigated construction activities that have an impact significance of **Minor**, despite the increase in vibration levels, fauna species are likely to adapt to the construction activities and would potentially return to their normal activity and habitat. For all mitigated construction activities that still have an impact significance of **Moderate**, sensitive fauna may be affected in terms of their day-to-day activities (communication/ foraging) for a short period in the zone of impact and may leave the area. Hence EMMP measures should be applied.				









Legend

- Mitigated Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Mitigated)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)
- Impact Buffer 50m
- Water Barrier
- Water Barrier
- Existing Fence
- Road

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.03 - 0.59	Below Ambient	Below Ambient	Below Ambient
0.59 - 2.30	Negligible	Imperceptible	Negligible
2.30 - 5.77	Low	Very Low	Minor
5.77 - 11.37	Medium	Low	Moderate
11.37 - 18.11		Medium	Major
		Not Assessible	Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Designed	Checked	Approved
EGY	JAG	JAG
	Drawn: EGY	Date: MAR 2022

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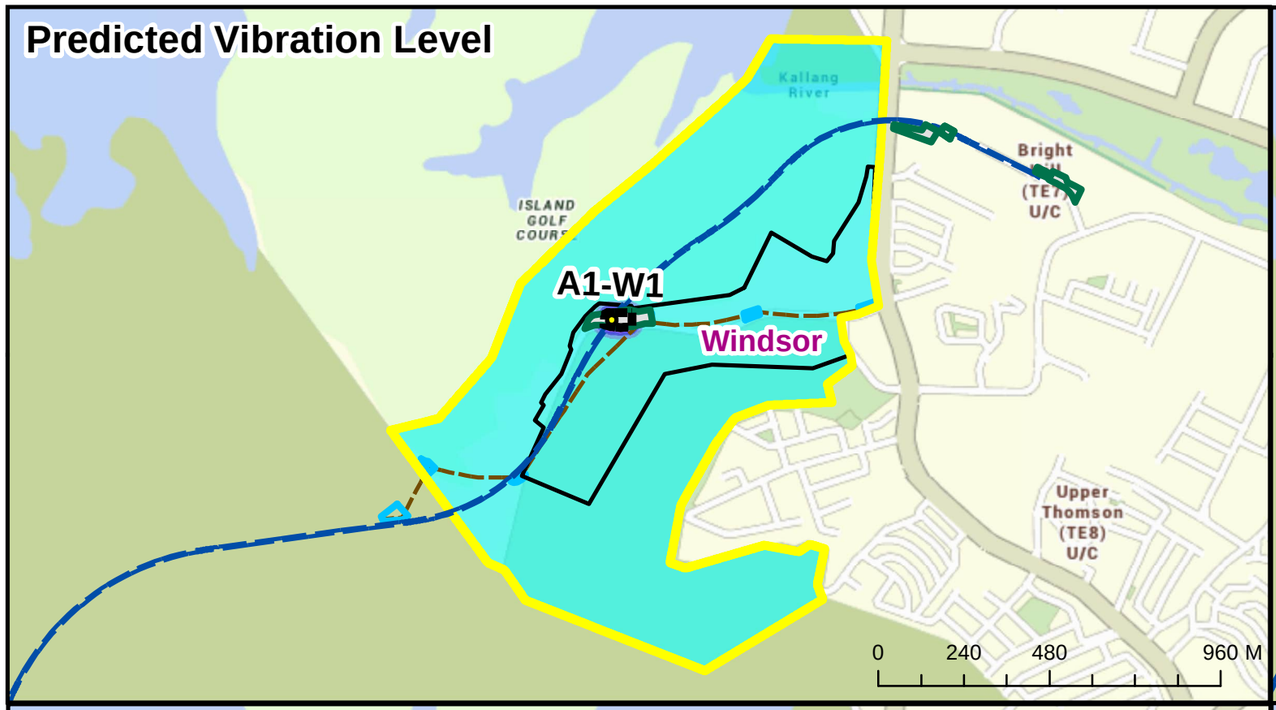
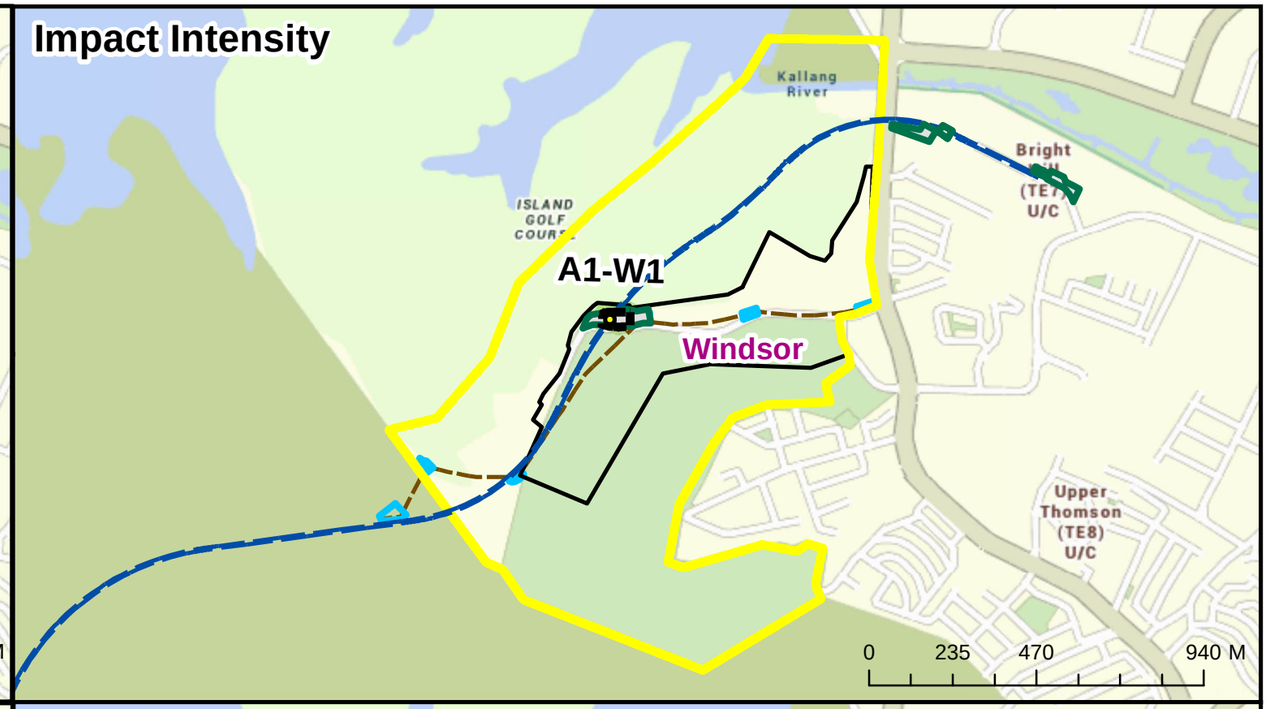
Figure Title :
VIBRATION ASSESSMENT FOR ROCK BREAKING AND EXCAVATION WORKS USING T207 METHOD AT A1-W1 (2.9 KG) (MITIGATED SCENARIO)

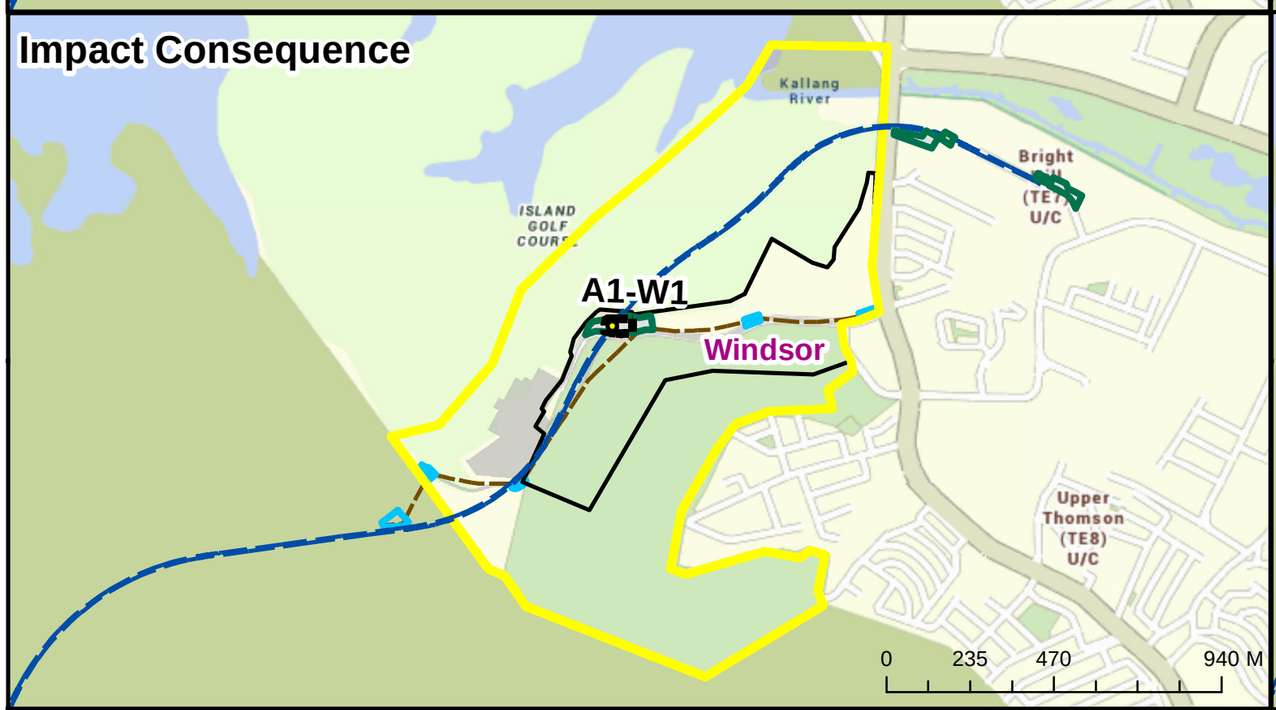
Figure No. :	Rev.	Sheet
12 - 31	-	1 of 1

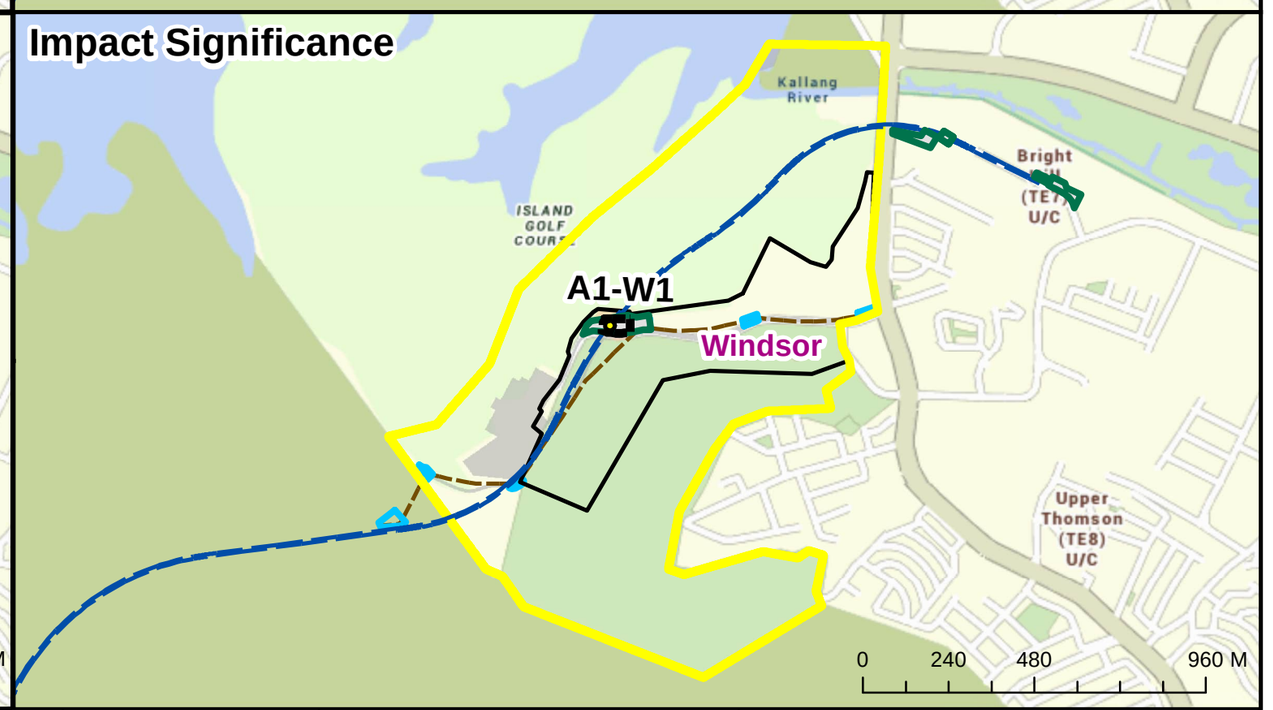
CAD File Name : NA — A3

Note: Source of basemap - OneMap









Legend

- Facility Building (Above-ground)
- Facility Building (Underground)
- Mitigated Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Mitigated)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.00 - 0.07	Below Ambient	Below Ambient	Below Ambient
0.07 - 0.15	Negligible	Imperceptible	Negligible
0.15 - 0.50	Low	Very Low	Minor
0.50 - 2.49	Medium	Low	Not Assessible
2.49 - 4.99		Not Assessible	

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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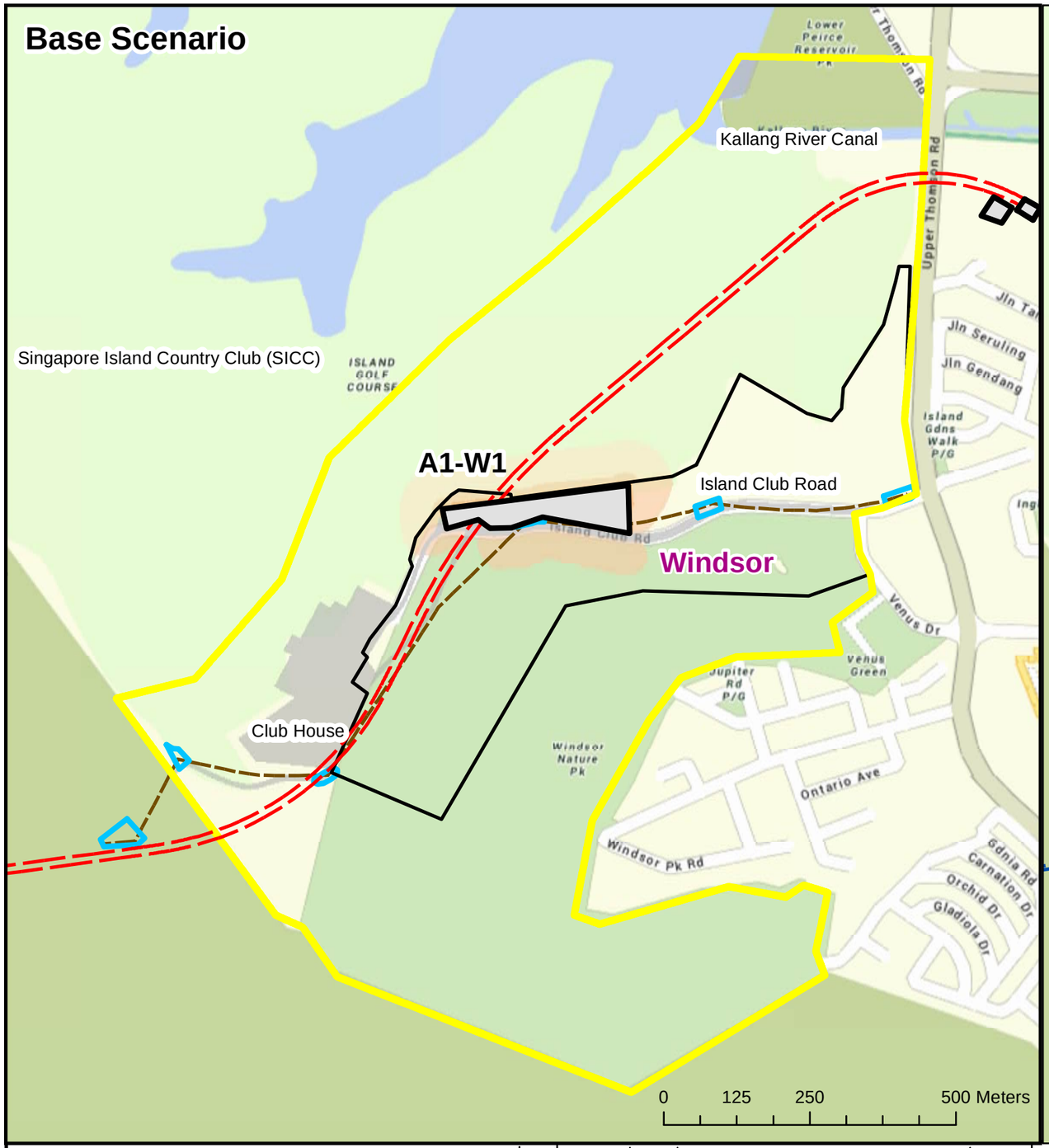
Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Figure Title :
VIBRATION ASSESSMENT FOR ROTARY BORE PILING AT A1-W1 (MITIGATED SCENARIO)

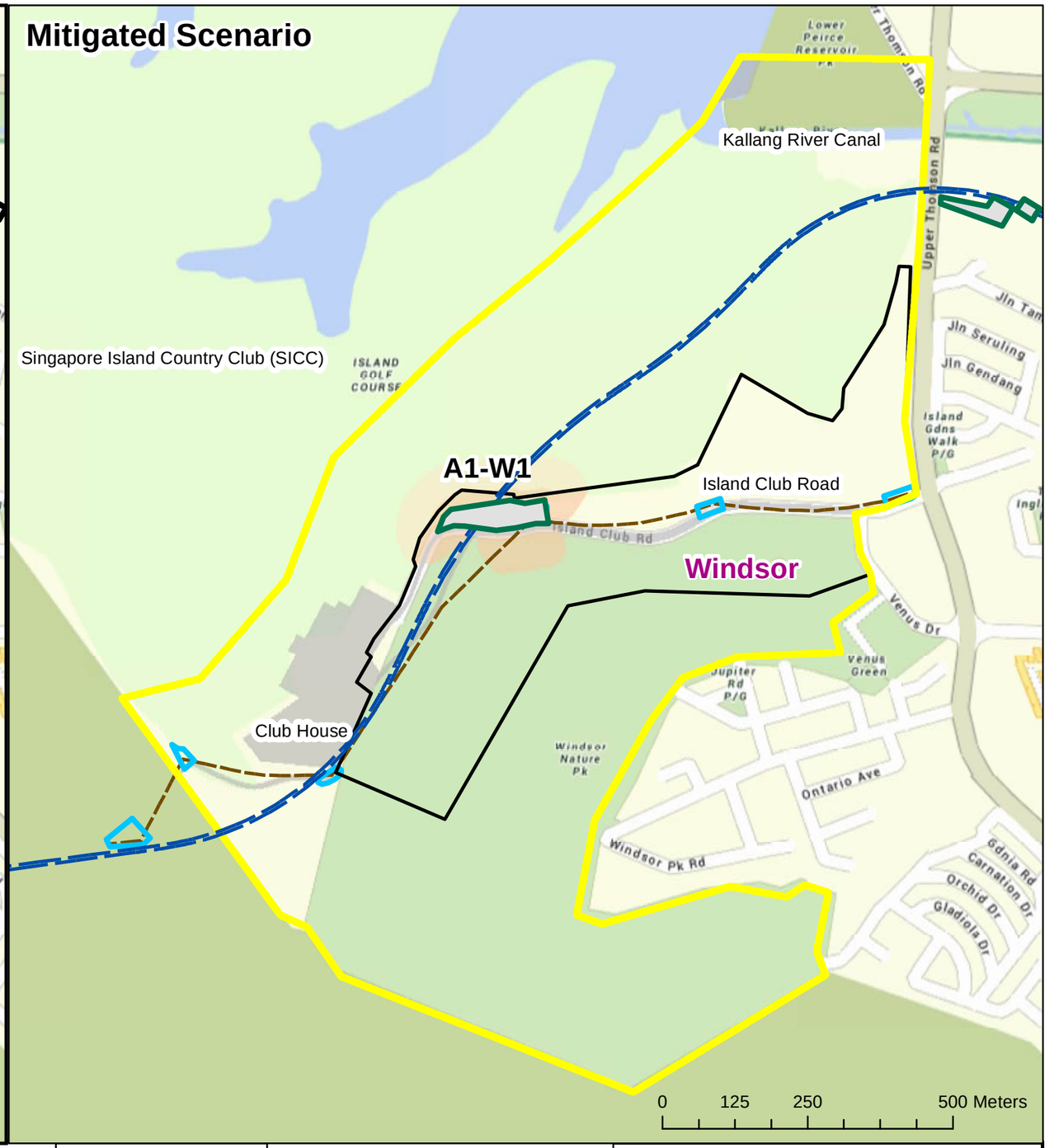
Designed	Checked	Approved	Figure No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 32	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

Base Scenario



Mitigated Scenario



Legend

- Proposed CRL Alignment (Base)
- Proposed CRL Alignment (Mitigated)
- Base Scenario Construction Worksite Footprint
- Mitigated Scenario Construction Worksite Footprint
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Impact Significance

- Below Ambient
- Negligible
- Minor
- Moderate
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
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LTA Endorsement :
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Consultant : AECOM

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Project Title :

CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)

Drawing Title :

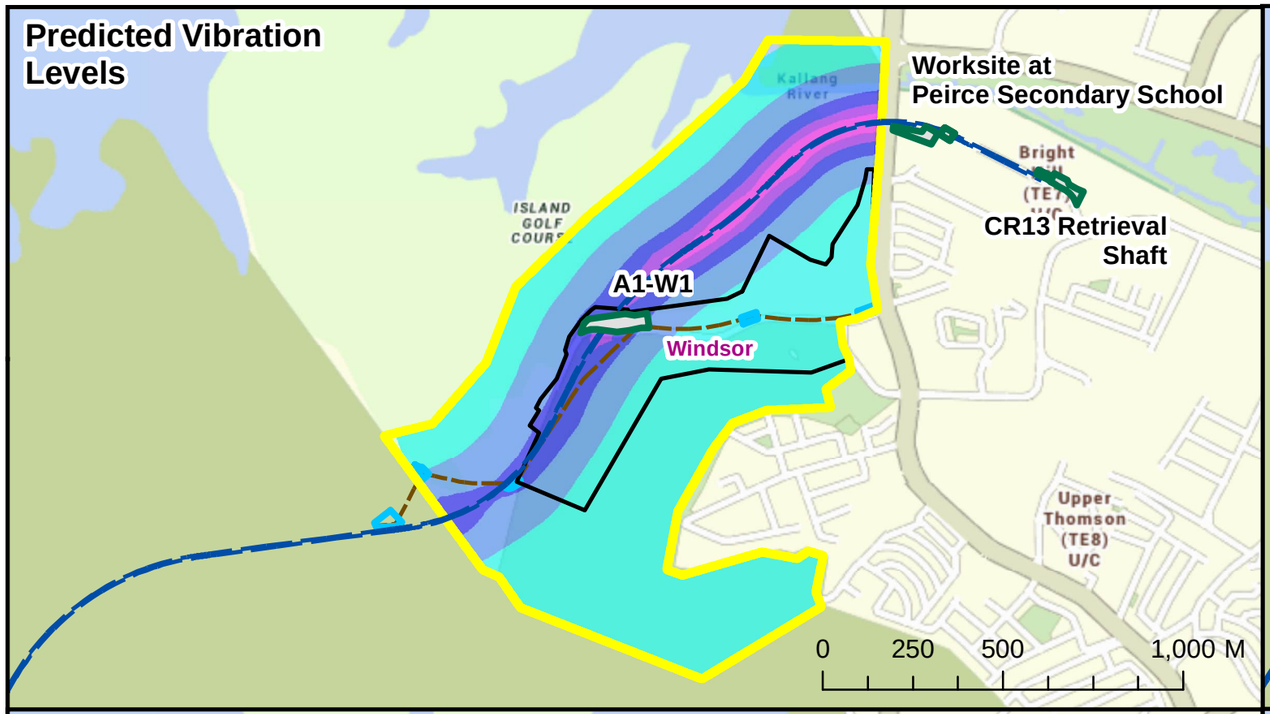
IMPACT SIGNIFICANCE COMPARISON FOR BULLDOZER AT A1-W1

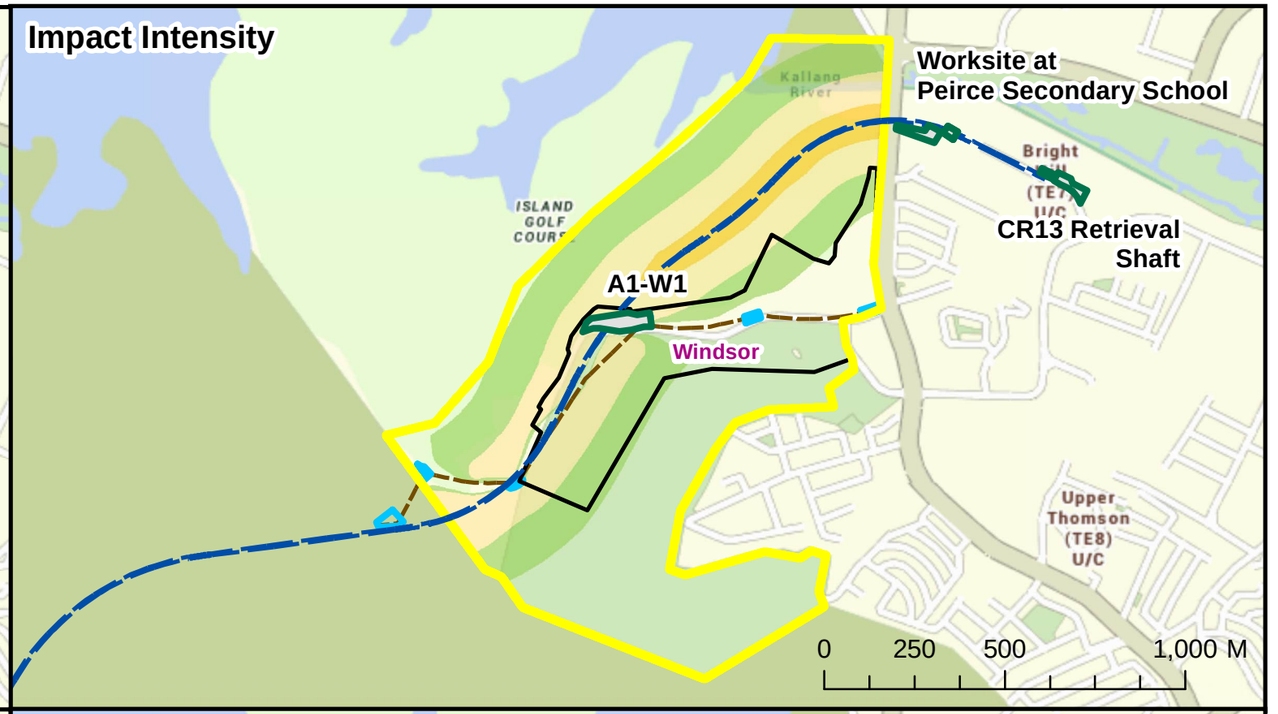
Designed	Checked	Approved
EGY	JAG	JAG
	Drawn: EGY	Date: MAR 2022

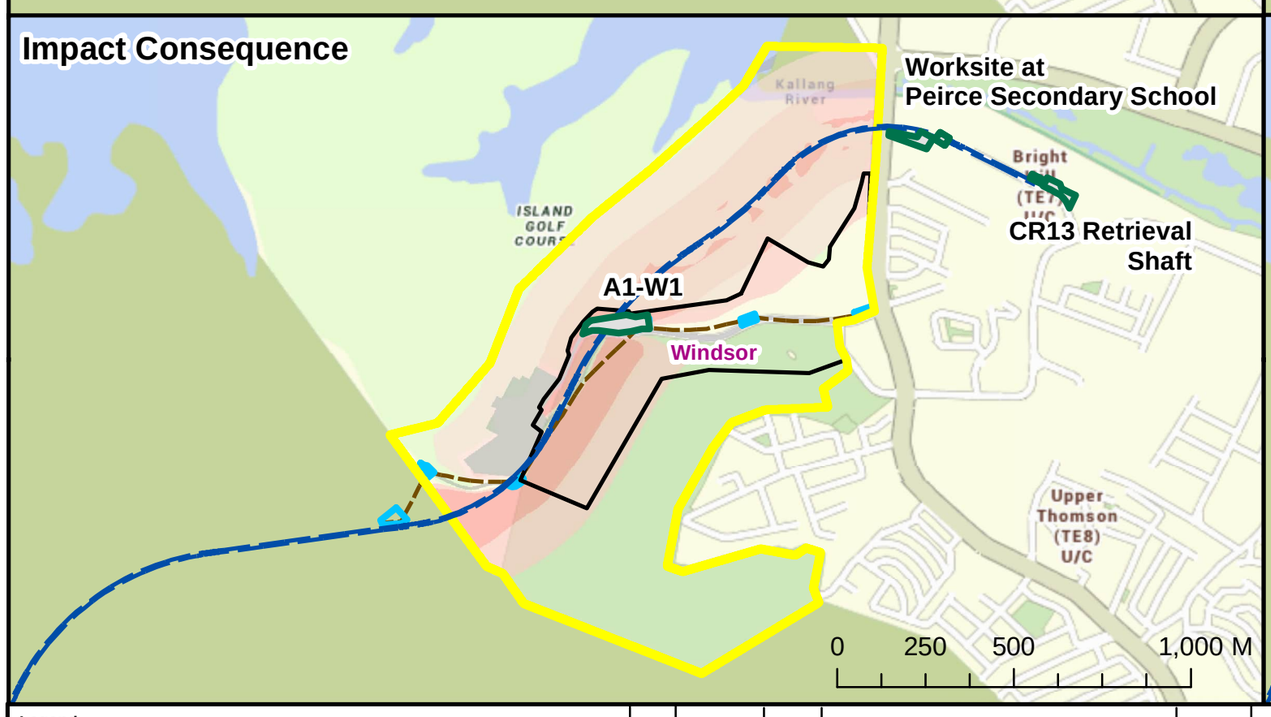
Drawing No. : 12 - 33 | Rev. : - | Sheet : 1 of 1

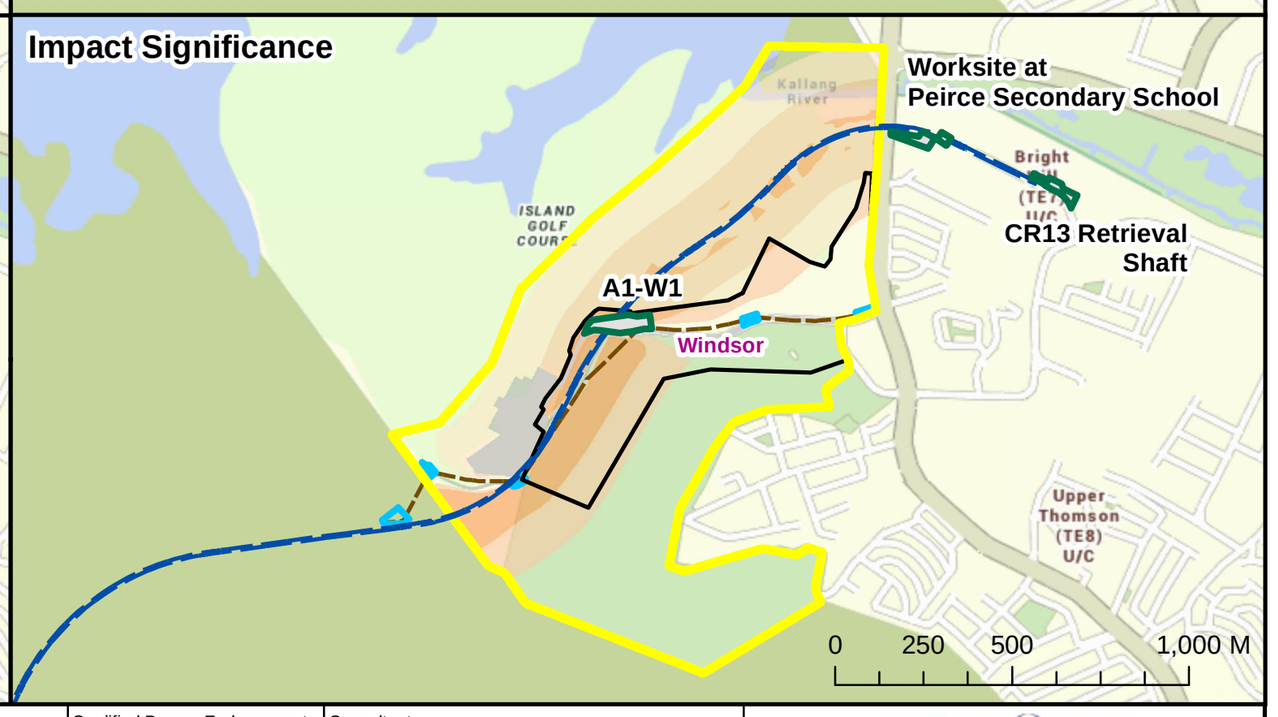
CAD File Name : NA | A3

Note: Source of basemap - OneMap









Legend

- Mitigated Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Mitigated)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.01 - 0.11	Below Ambient	Below Ambient	Below Ambient
0.11 - 0.25	Negligible	Imperceptible	Negligible
0.25 - 0.46	Low	Very Low	Minor
0.46 - 0.78	Medium	Low	Moderate
0.78 - 1.58		Not Assessible	Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant :
AECOM

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Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

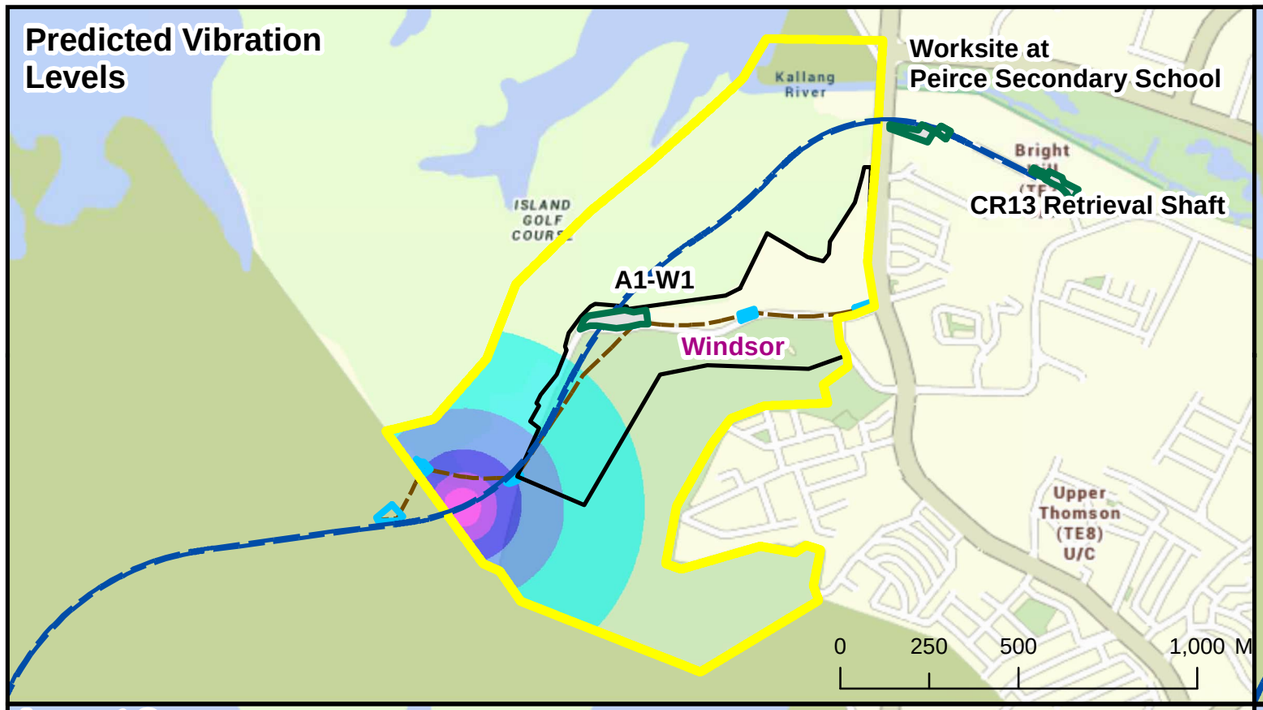
Drawing Title :
HYPOTHETICAL OVERALL VIBRATION ASSESSMENT FOR TUNNEL BORING IN WINDSOR USING ESVELT PREDICTIONS (MITIGATED SCENARIO)

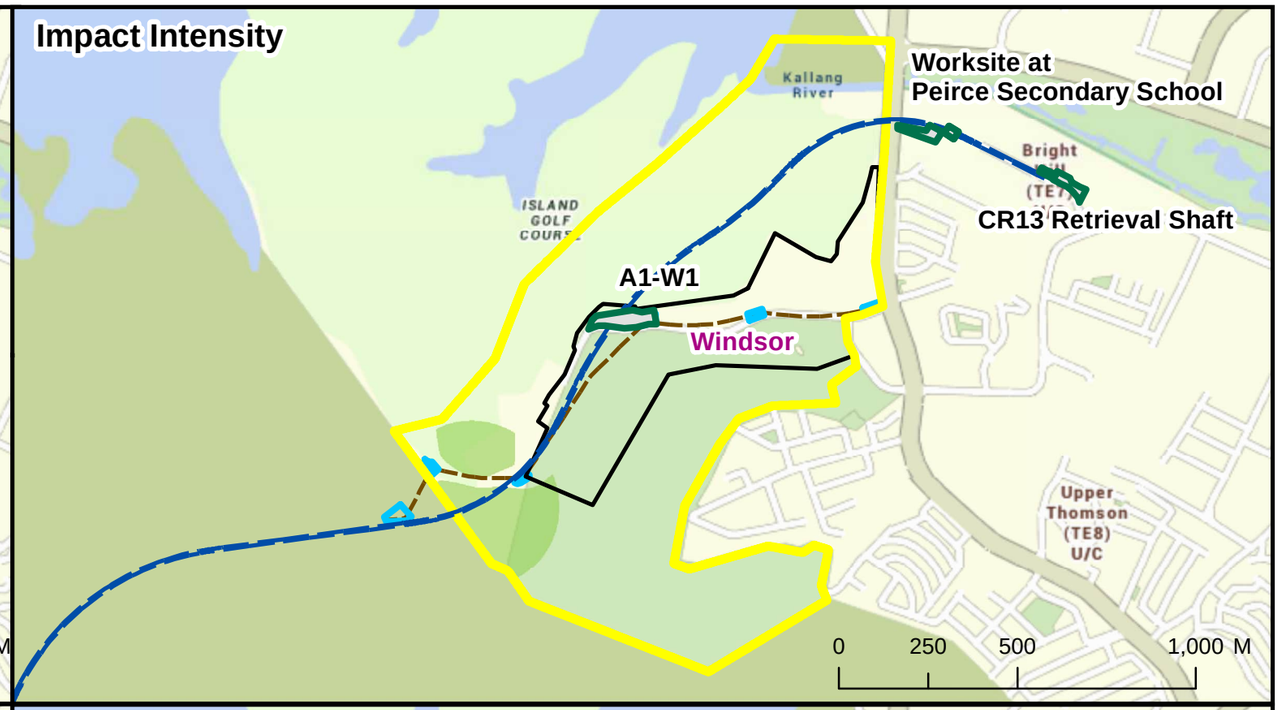
Designed	Checked	Approved
EGY	JAG	JAG
	Drawn EGY	Date MAR 2022

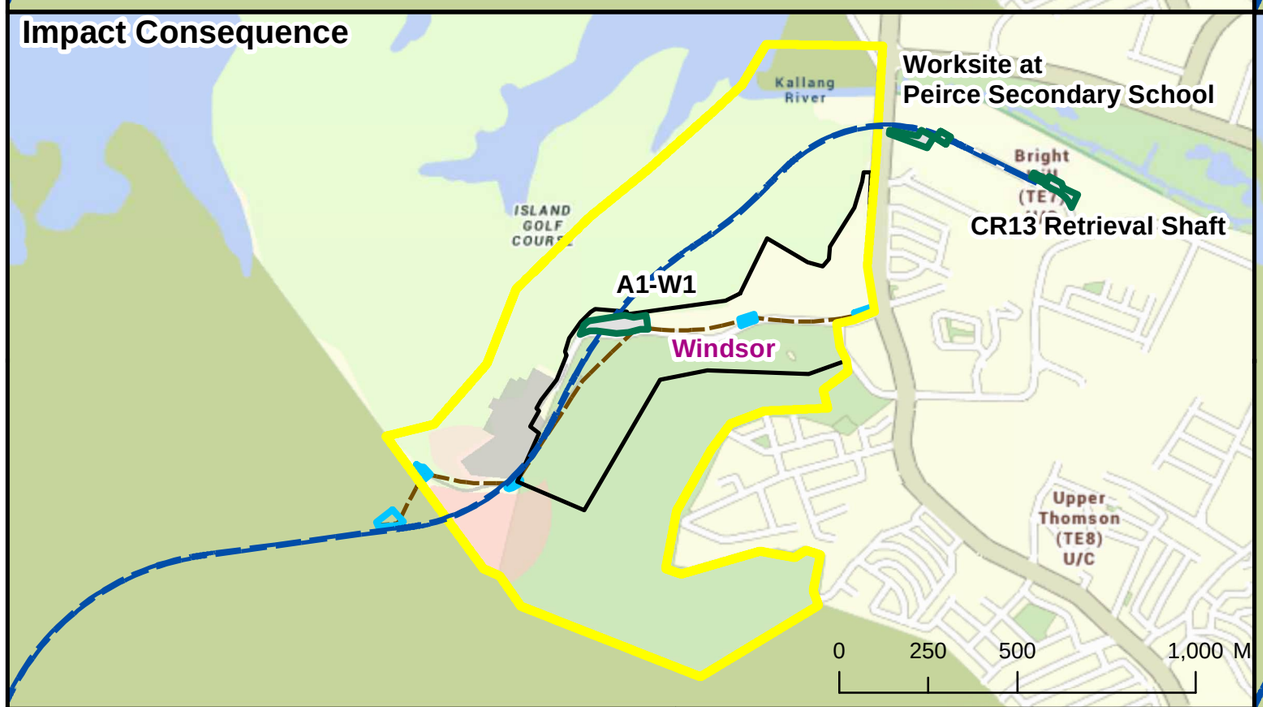
Drawing No. : 12 - 34 | Rev. - | Sheet 1 of 1

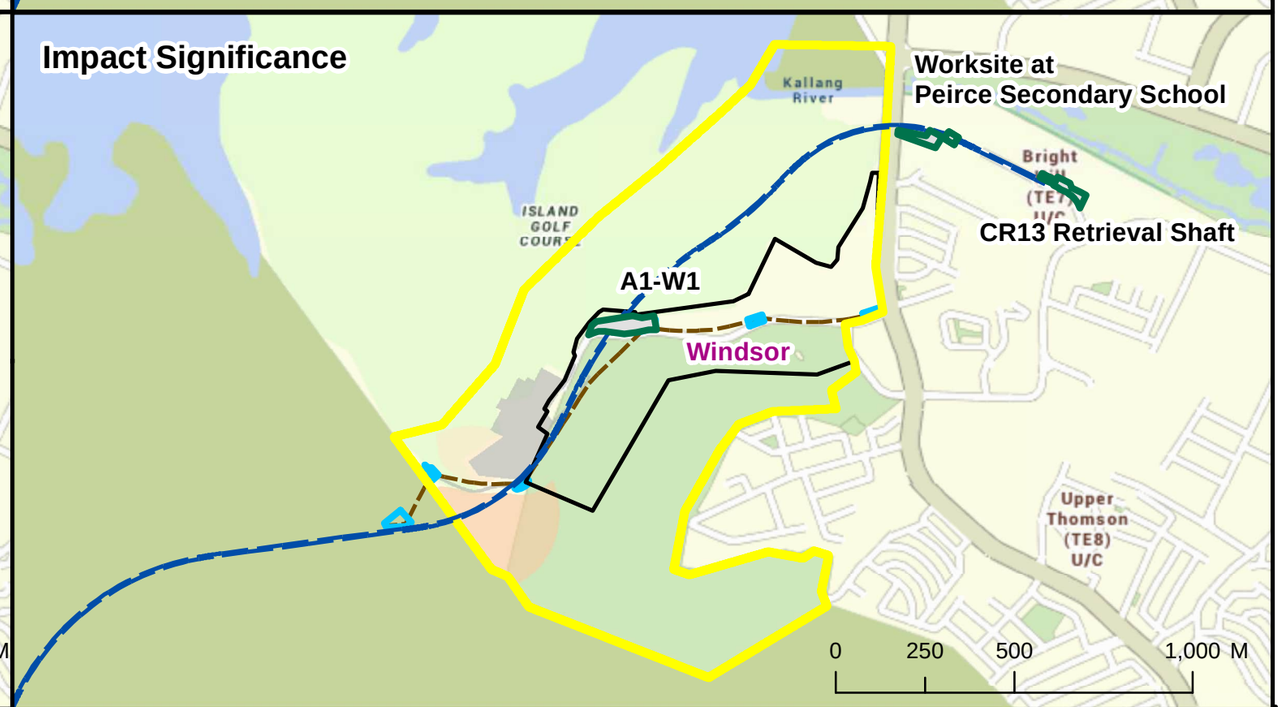
CAD File Name : NA | A3

Note: Source of basemap - OneMap









Legend

- Mitigated Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Mitigated)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.02 - 0.05	Below Ambient	Below Ambient	Below Ambient
0.05 - 0.11	Negligible	Imperceptible	Negligible
0.11 - 0.20	Low	Very Low	Minor
0.20 - 0.32		Low	Moderate
0.32 - 0.51		Not Assessible	Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement : NA

LTA Endorsement : NA

Consultant : AECOM

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Project Title :

CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Drawing Title :

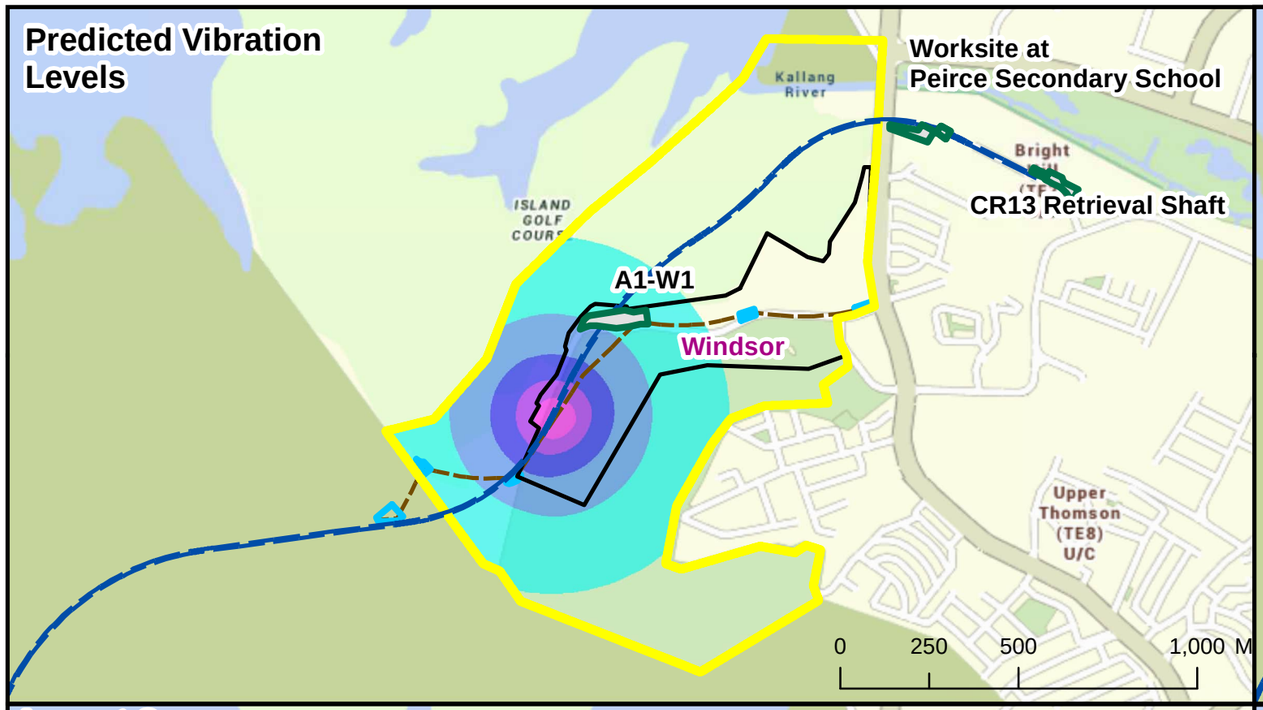
VIBRATION ASSESSMENT FOR TUNNEL BORING AT WINDSOR USING ESVELT METHOD - SPOT 1 (MITIGATED SCENARIO)

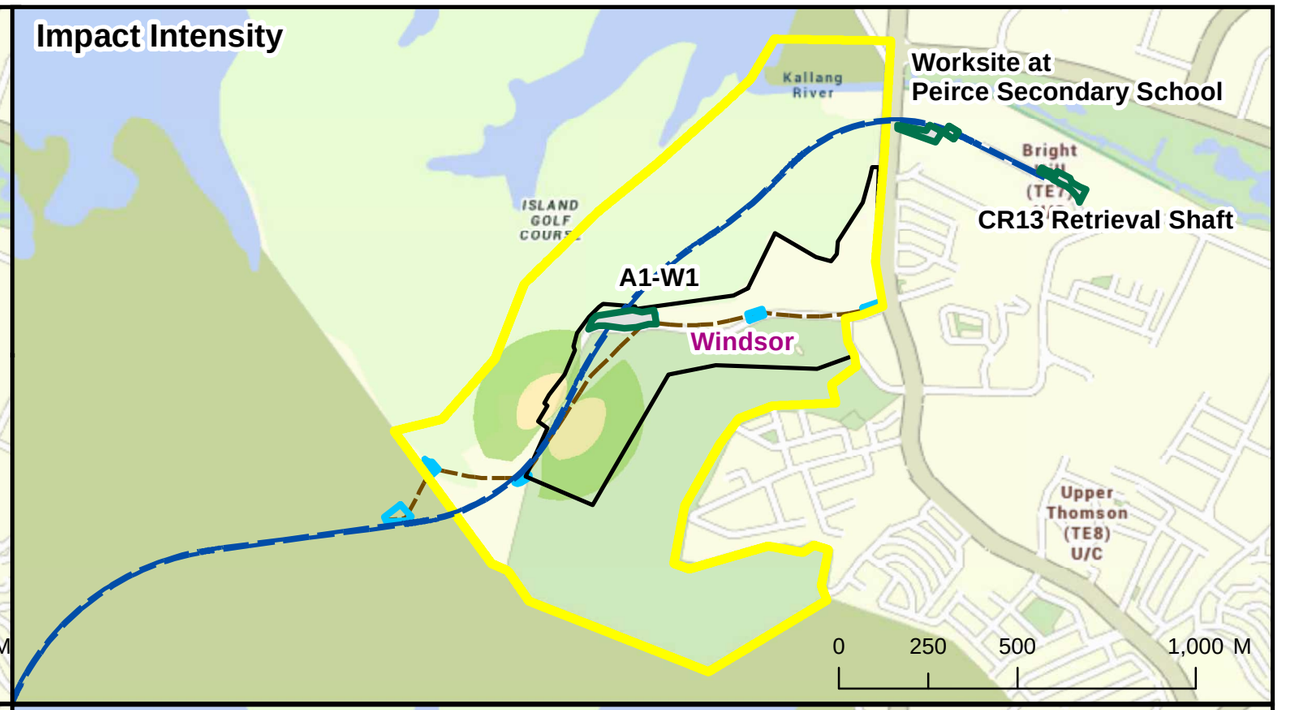
Designed	Checked	Approved
EGY	JAG	JAG
	Drawn EGY	Date MAR 2022

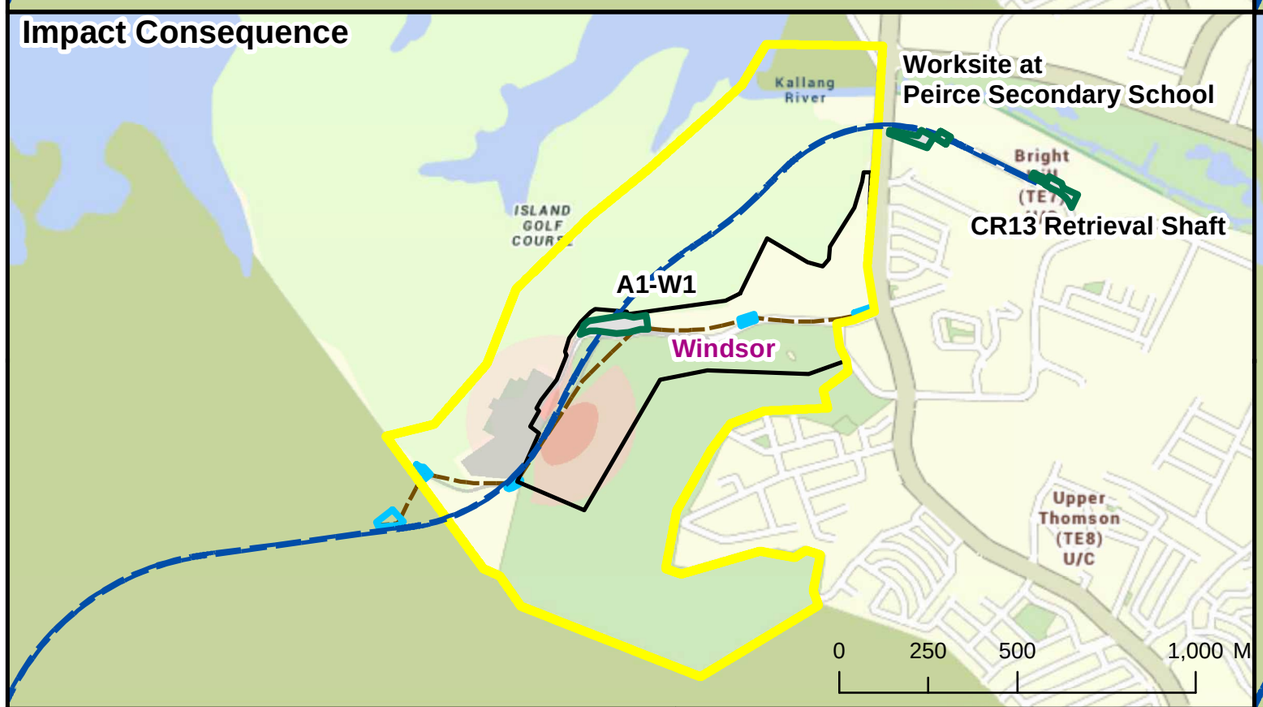
Drawing No. : 12 - 35 | Rev. - | Sheet 1 of 1

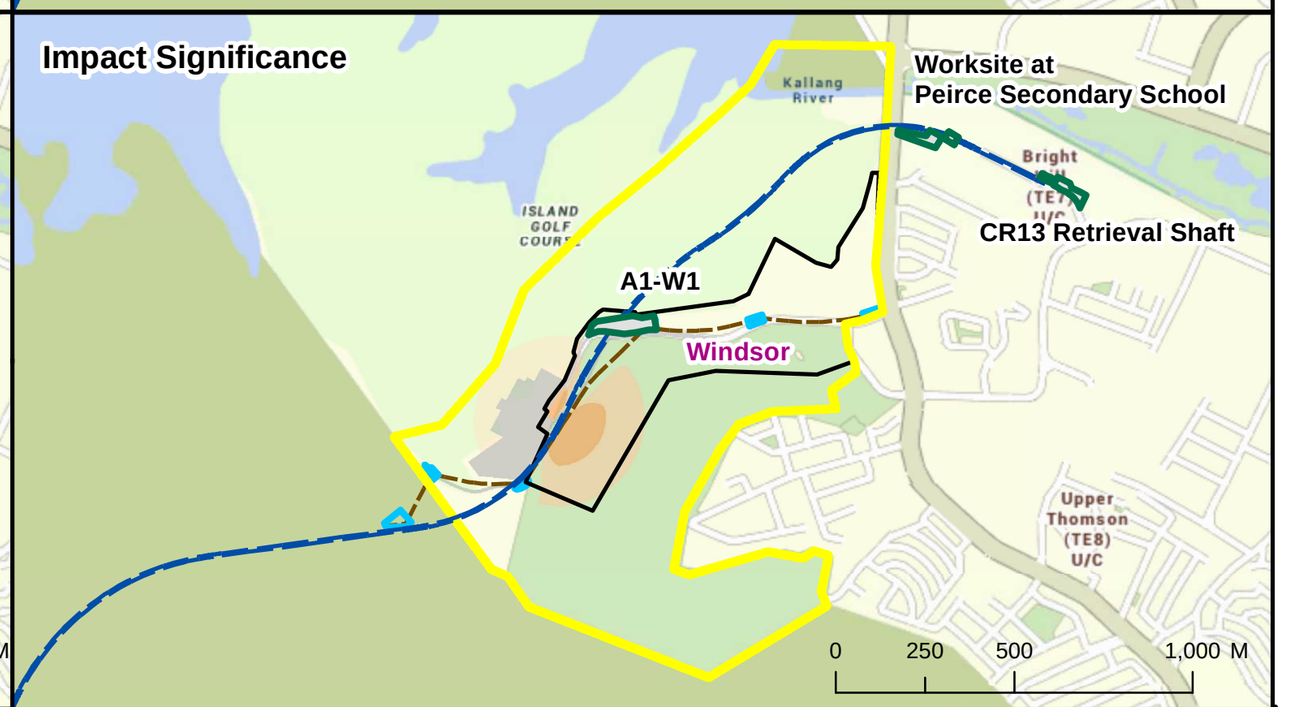
CAD File Name : NA | A3

Note: Source of basemap - OneMap









Legend

- Mitigated Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Mitigated)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.02 - 0.05	Below Ambient	Below Ambient	Below Ambient
0.05 - 0.11	Negligible	Imperceptible	Negligible
0.11 - 0.20	Low	Very Low	Minor
0.20 - 0.32		Low	Moderate
0.32 - 0.51		Not Assessible	Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant :
AECOM

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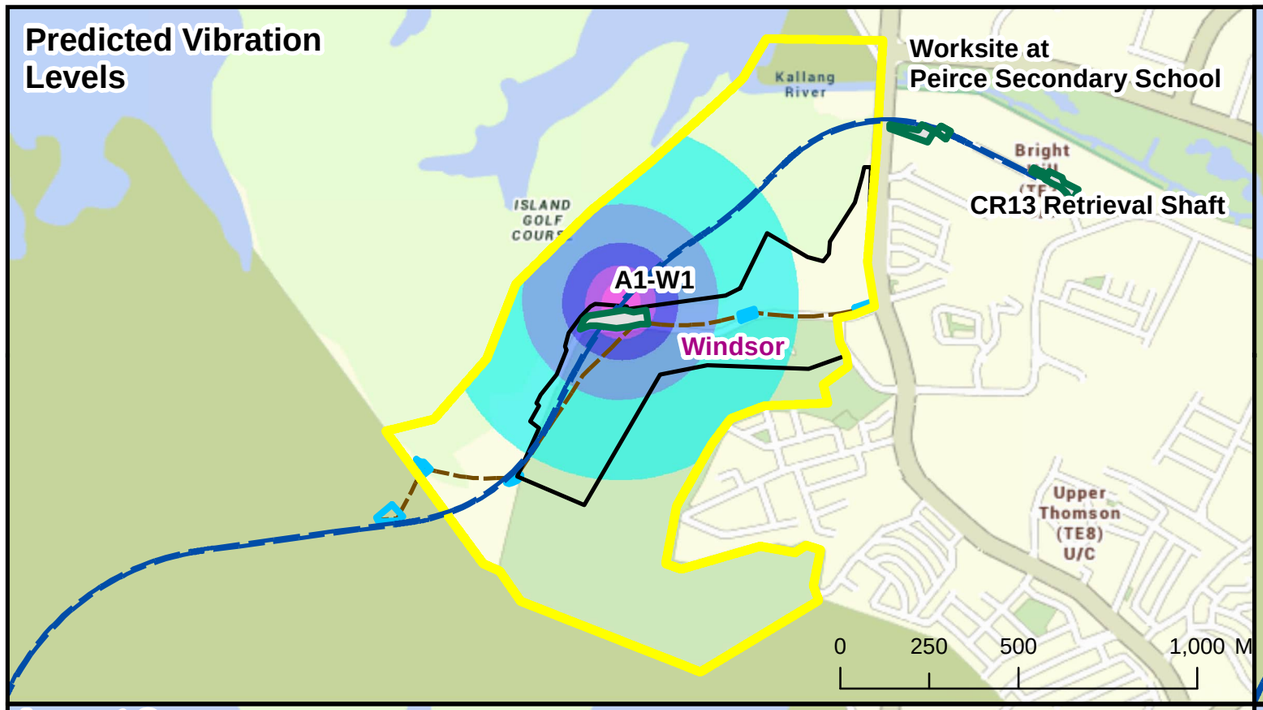
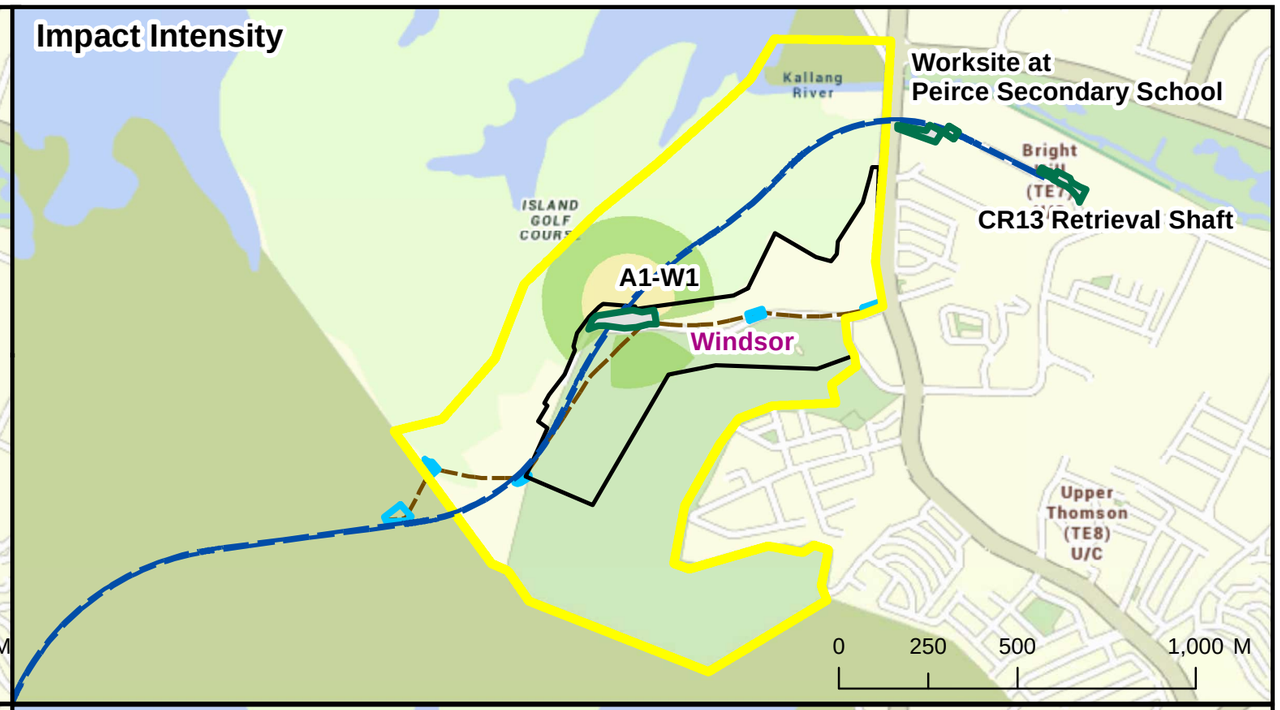
Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

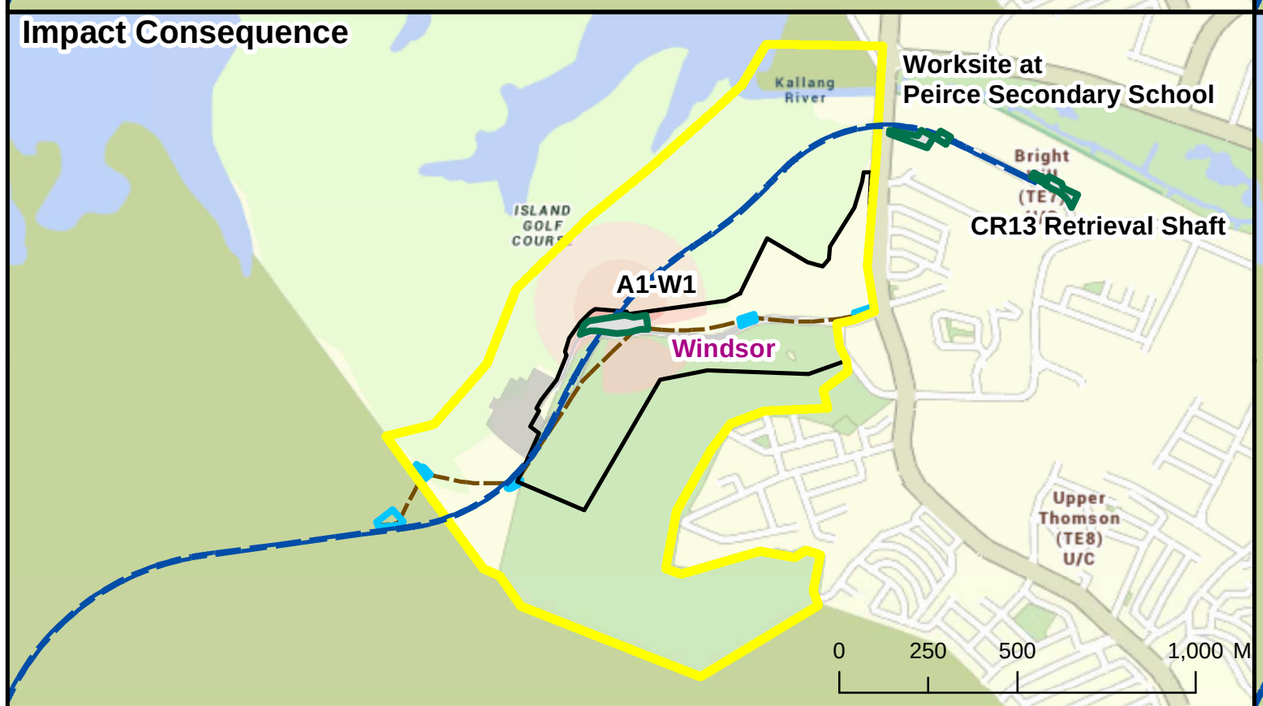
Drawing Title :
VIBRATION ASSESSMENT FOR TUNNEL BORING AT WINDSOR USING ESVELT METHOD - SPOT 2 (MITIGATED SCENARIO)

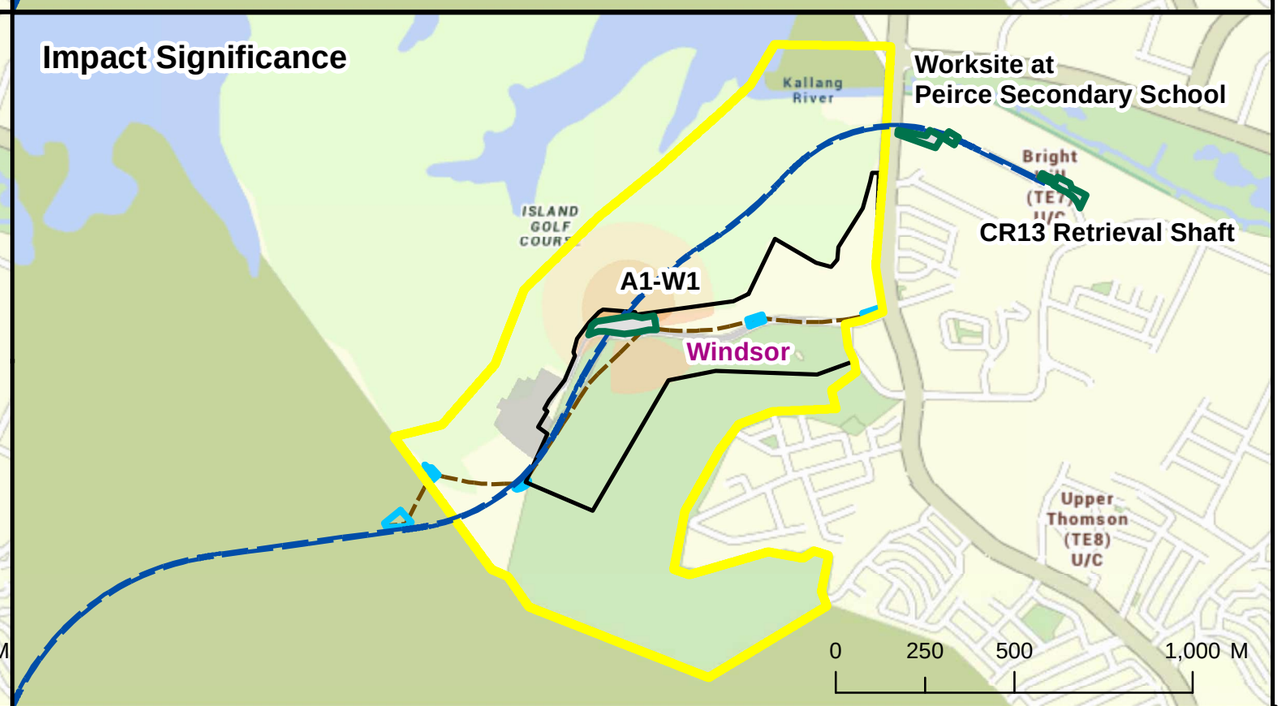
Designed	Checked	Approved	Drawing No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 36	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap









Legend

- Mitigated Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Mitigated)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.02 - 0.05	Below Ambient	Below Ambient	Below Ambient
0.05 - 0.11	Negligible	Imperceptible	Negligible
0.11 - 0.20	Low	Very Low	Minor
0.20 - 0.32		Low	Moderate
0.32 - 0.51		Not Assessible	Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant :
AECOM

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Project Title :
**CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)**

Drawing Title :
VIBRATION ASSESSMENT FOR TUNNEL BORING AT WINDSOR USING ESVELT METHOD - SPOT 3 (MITIGATED SCENARIO)

Designed	Checked	Approved
EGY	JAG	JAG
	Drawn: EGY	Date: MAR 2022

Drawing No. : 12 - 37
Rev. : -
Sheet : 1 of 1
CAD File Name : NA
A3

Note: Source of basemap - OneMap

12.9.2 Operational Phase

Based on the assessment results in Section 12.7.2, the potential impact significance for the base scenario during the operational phase is expected to be **Minor**. Nevertheless, for precautionary purposes, monitoring the behaviour of fauna by an ecologist is recommended during the Testing and Commissioning Phase. Regular track maintenance is also encouraged to ensure that the operational trains do not generate excessive vibration.

The maximum vibration levels for Eng Neo Avenue Forest, Sites I and II and Windsor are summarised in Table 12-36. The respective figures can be seen in Figure 12-38 to Figure 12-43. The detailed impact assessment results of these vibration sources are in Appendix CC.

Table 12-36 Results of Operational Impact Assessment at Eng Neo Avenue Forest and Windsor

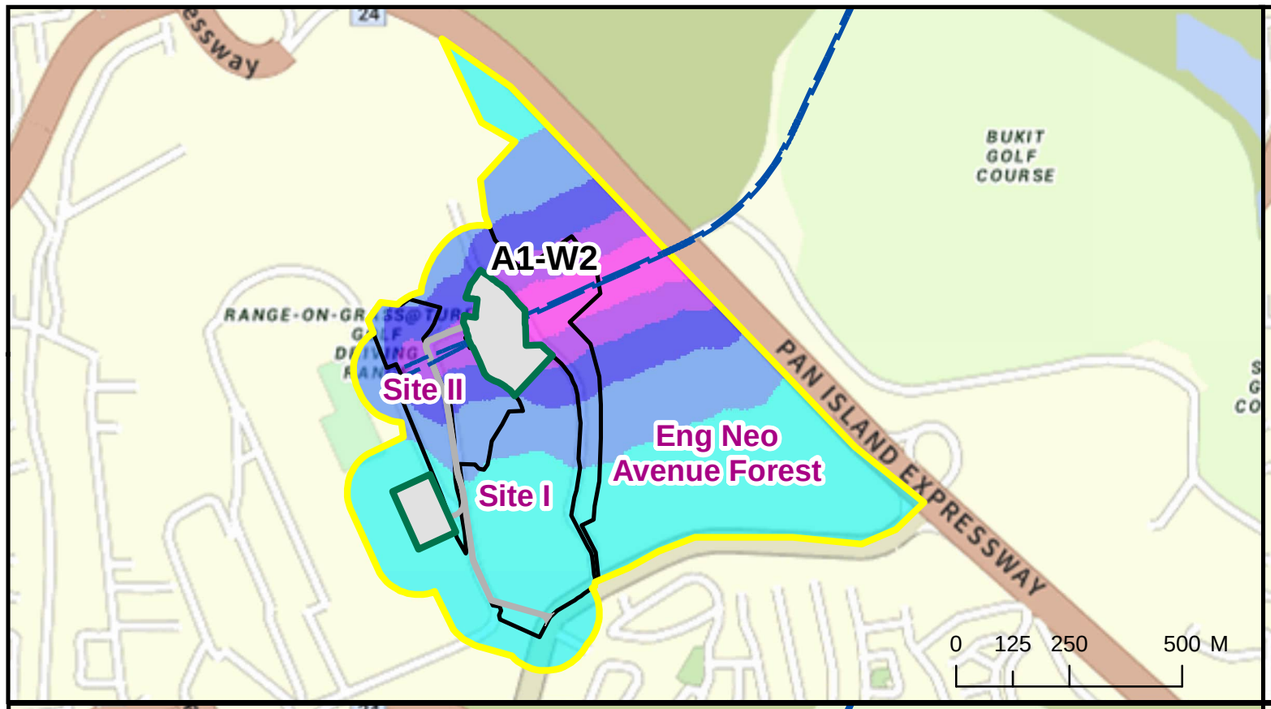
Operational Vibration Impact Assessment	Max PPV, mm/s Outside Worksite and Within Biodiversity Study Area (Eng Neo Avenue Forest),	Max PPV Outside Worksite and Within Biodiversity Study Area (Sites I and II), mm/s	Vibration Threshold for Damage/Collapse of the Burrow, PPV, mm/s	Evaluation Outcome
Train Mitigated Scenario Cumulative	0.08	0.05	8	Unlikely to cause damage/collapse to the burrow
Train Mitigated Scenario Spot	0.09	0.02	8	
Operational Vibration Impact Assessment	**Max PPV, mm/s Outside Worksite and within Biodiversity Study Area (Windsor),**	**Vibration Threshold for Damage/Collapse of the Burrow, PPV, mm/s**		**Evaluation Outcome**
Train Mitigated Scenario Cumulative	0.09	8		Unlikely to cause damage/collapse to the burrow
Train Mitigated Scenario Spot 1	0.06	8		
Train Mitigated Scenario Spot 2	0.13	8		
Train Mitigated Scenario Spot 3	0.09	8		

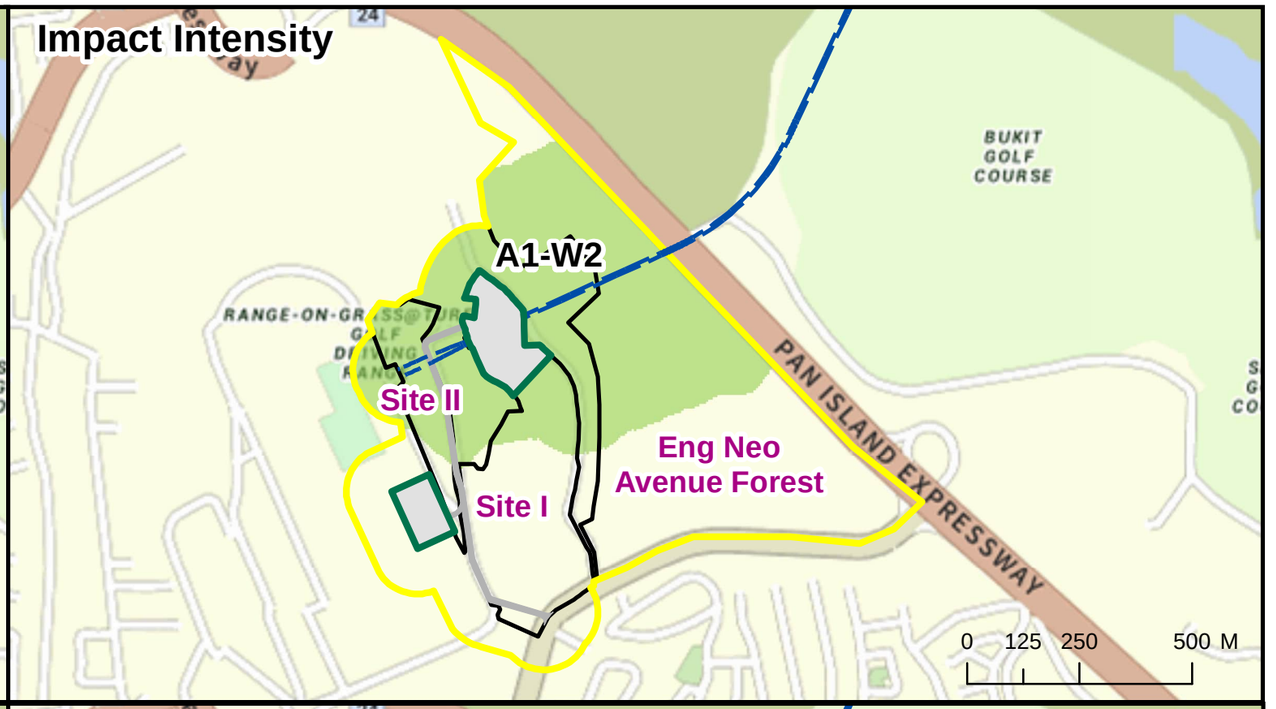
Table 12-37 Comparison between Base and Mitigated Impact Significances for Operational Activities at Biodiversity Study Areas

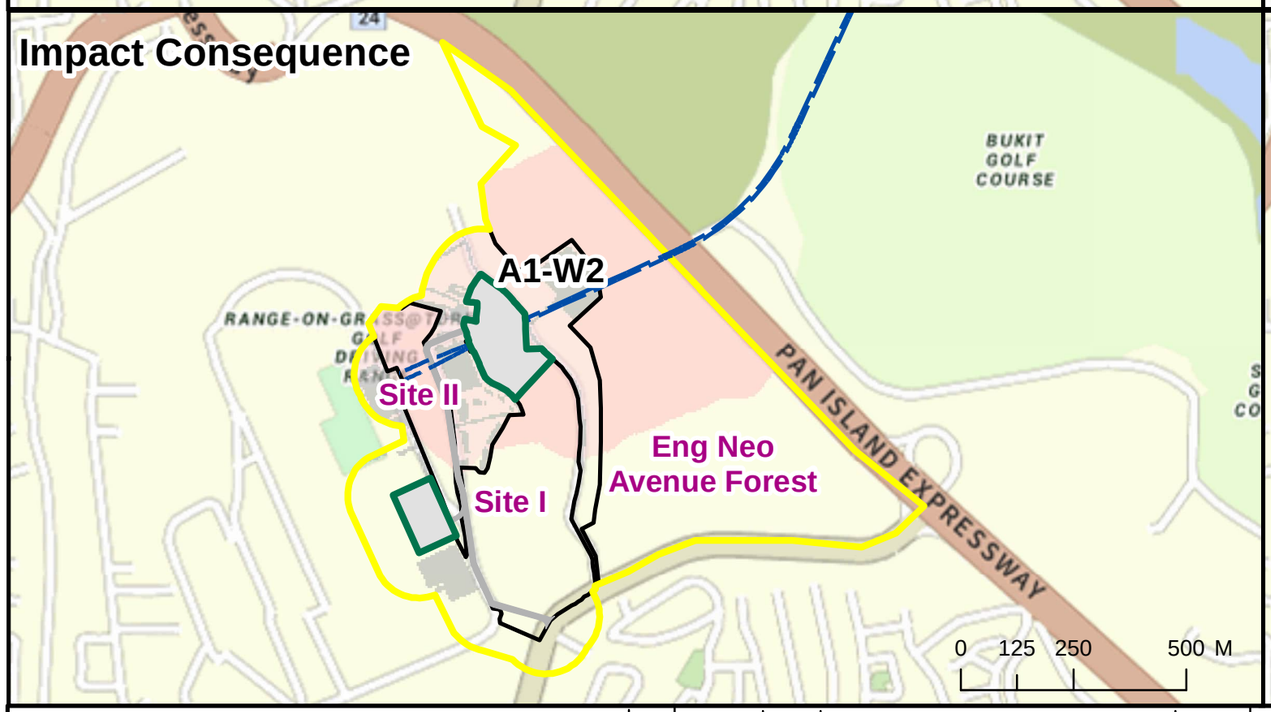
Operational Train	Base Scenario Impact Significance				Mitigation Measure	Mitigated Scenario Impact Significance				Changes in Impact Significance (Increased/Decreased/No Change?)
	Eng Neo Avenue Forest	Forested Area Adjacent To Fairways Quarters		Windsor		Eng Neo Avenue Forest	Forested Area Adjacent To Fairways Quarters		Windsor	No change in area with **Minor** impact significance.
		Site I	Site II				Site I	Site II		
Full Alignment Analysis	NA	NA	NA	Minor	Track mitigation measures are not required.	Minor	Minor	Minor	Minor	
Spot Analysis	NA	NA	NA	Minor		Minor	Minor	Not Impacted	Minor	

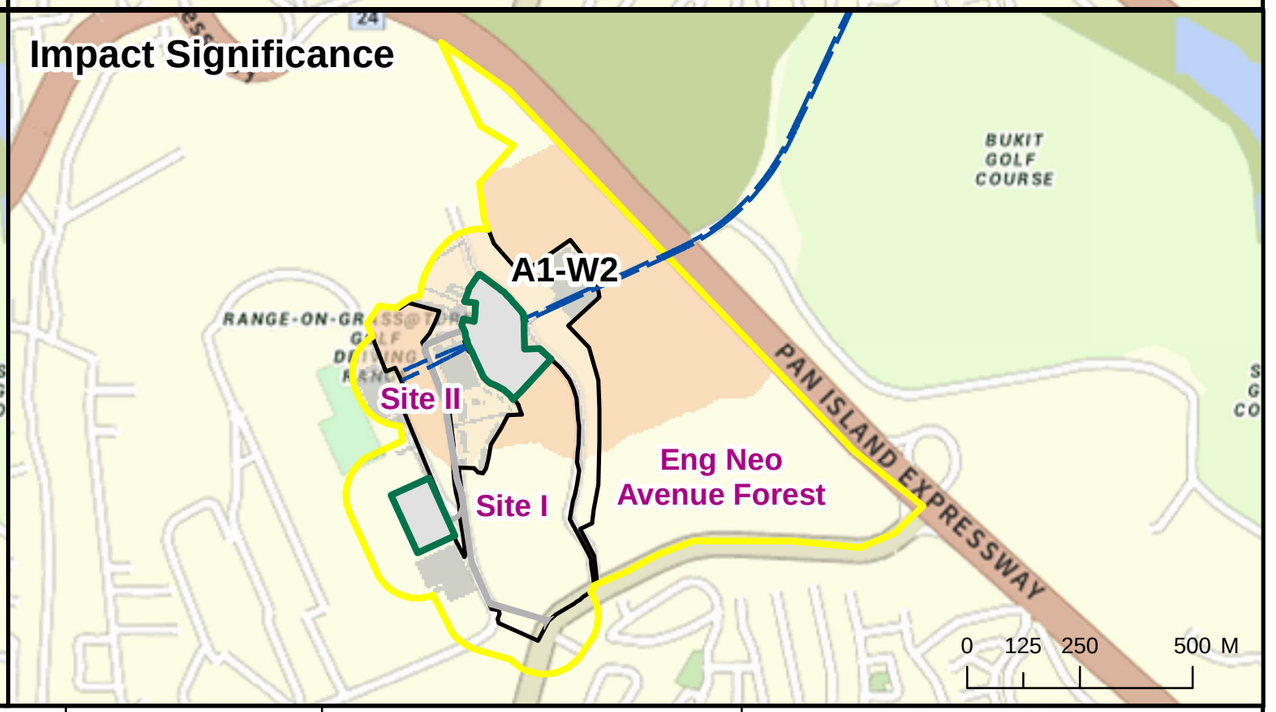
Summary:

For all mitigated construction activities with a **Minor** impact significance, despite the increase in vibration levels, fauna species are likely to adapt to the construction activities. They would potentially return to their regular activity and habitat.









Legend

- Proposed CRL Alignment (Mitigated)
- Temporary Access Roads
- Study Area (Mitigated)
- Biodiversity Study Area

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0 - 0.02	Below Ambient	Below Ambient	Below Ambient
0.03 - 0.03	Negligible	Imperceptible	Negligible
0.04 - 0.05		Very Low	Minor
0.06 - 0.07		Not Assessible	Not Assessible
0.08 - 0.10			

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

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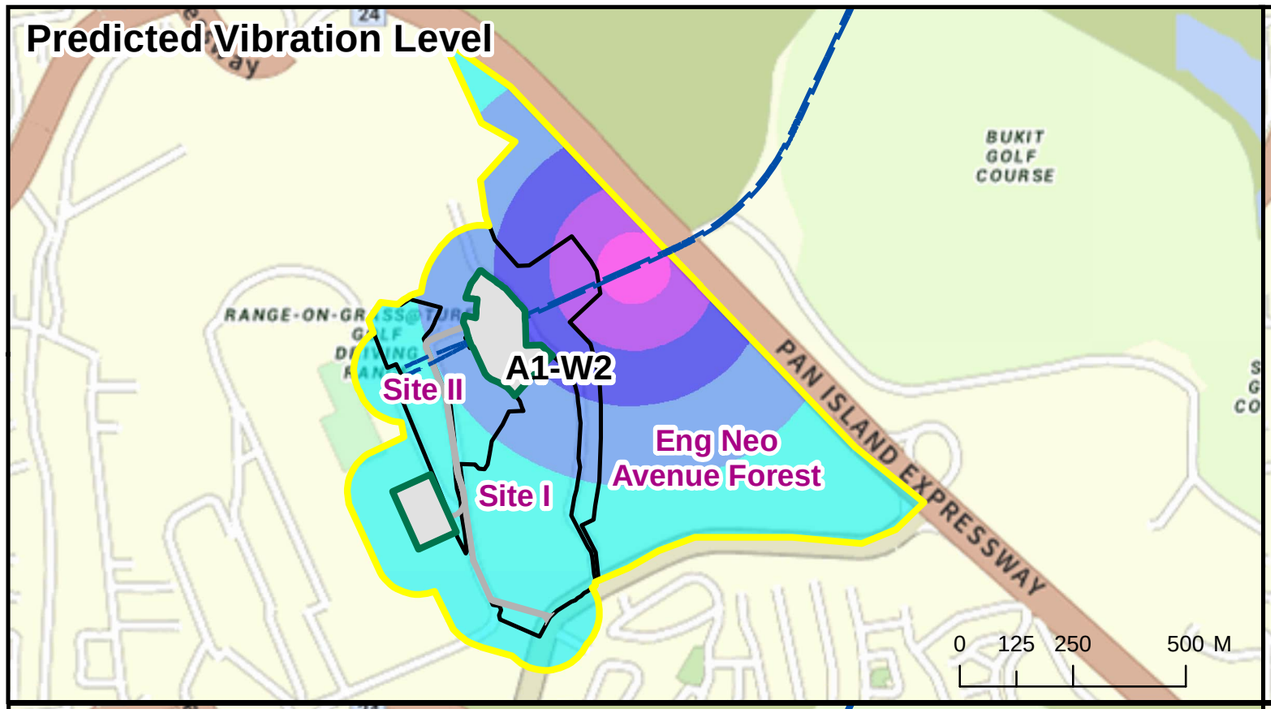
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)**

Drawing Title :
**VIBRATION ASSESSMENT
FOR OPERATIONAL PHASE
IN ENG NEO AVENUE FOREST
(MITIGATED SCENARIO)**

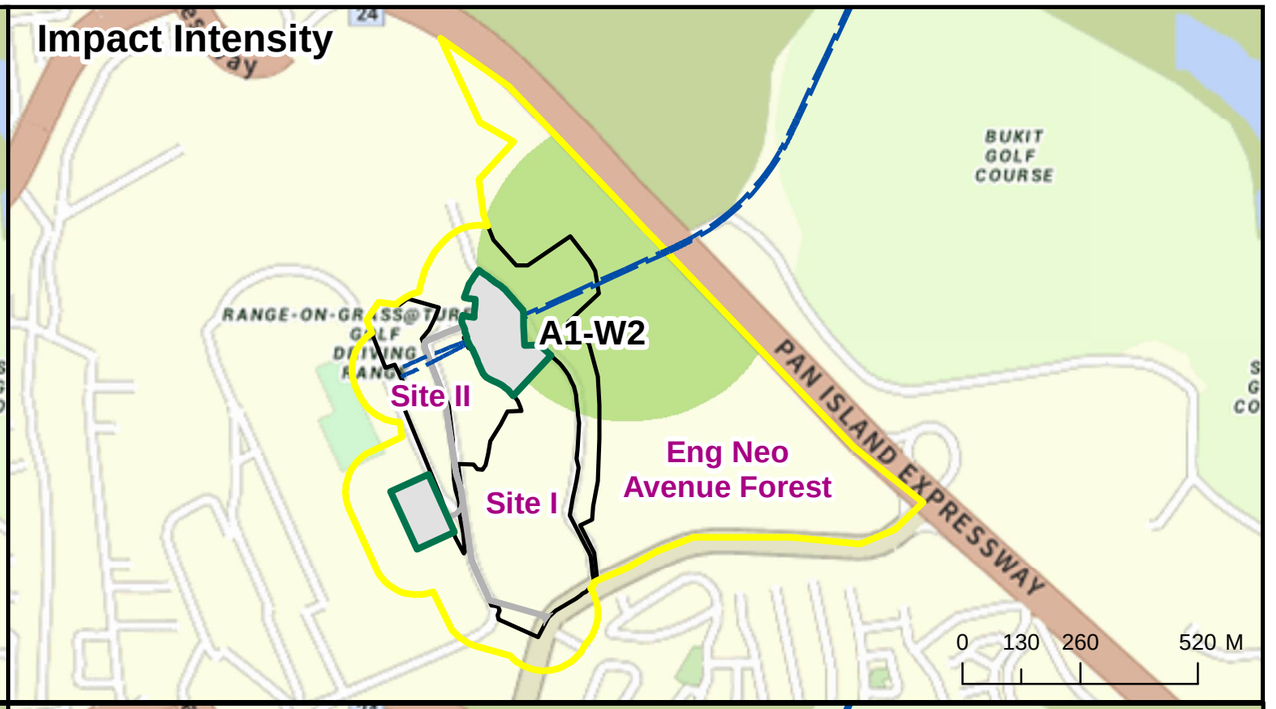
Designed	Checked	Approved	Drawing No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 38	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap

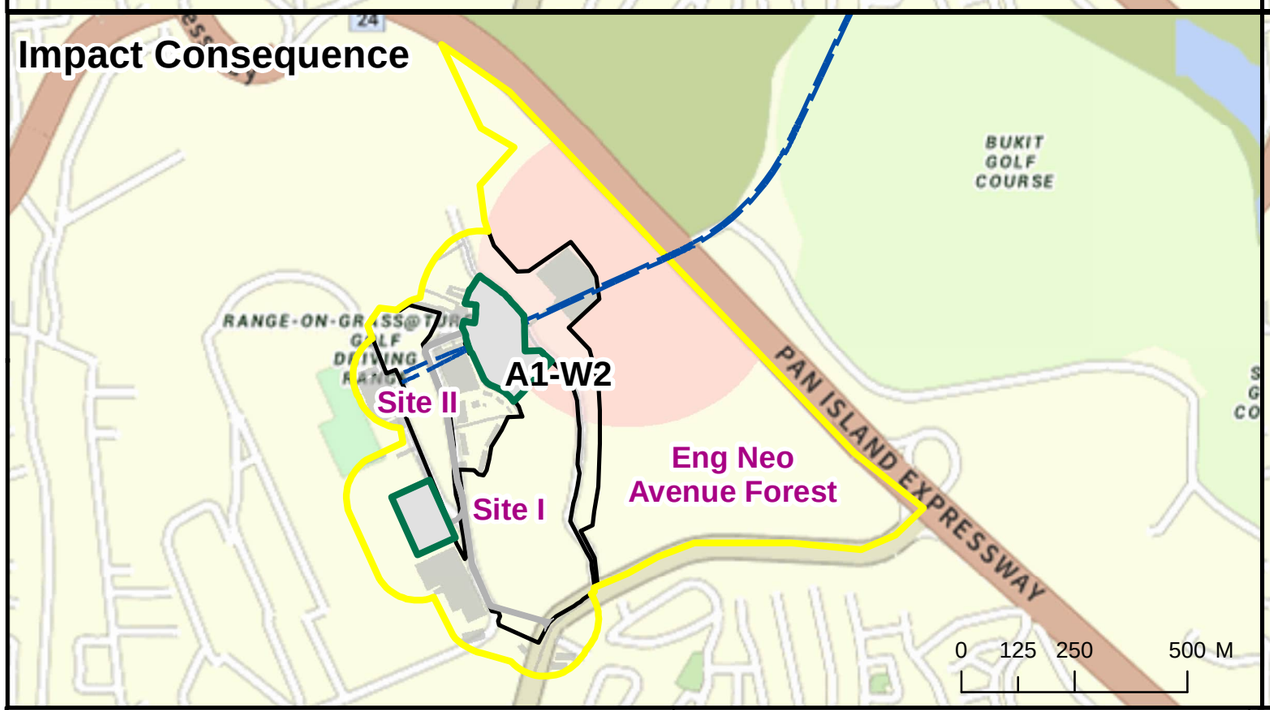
Predicted Vibration Level



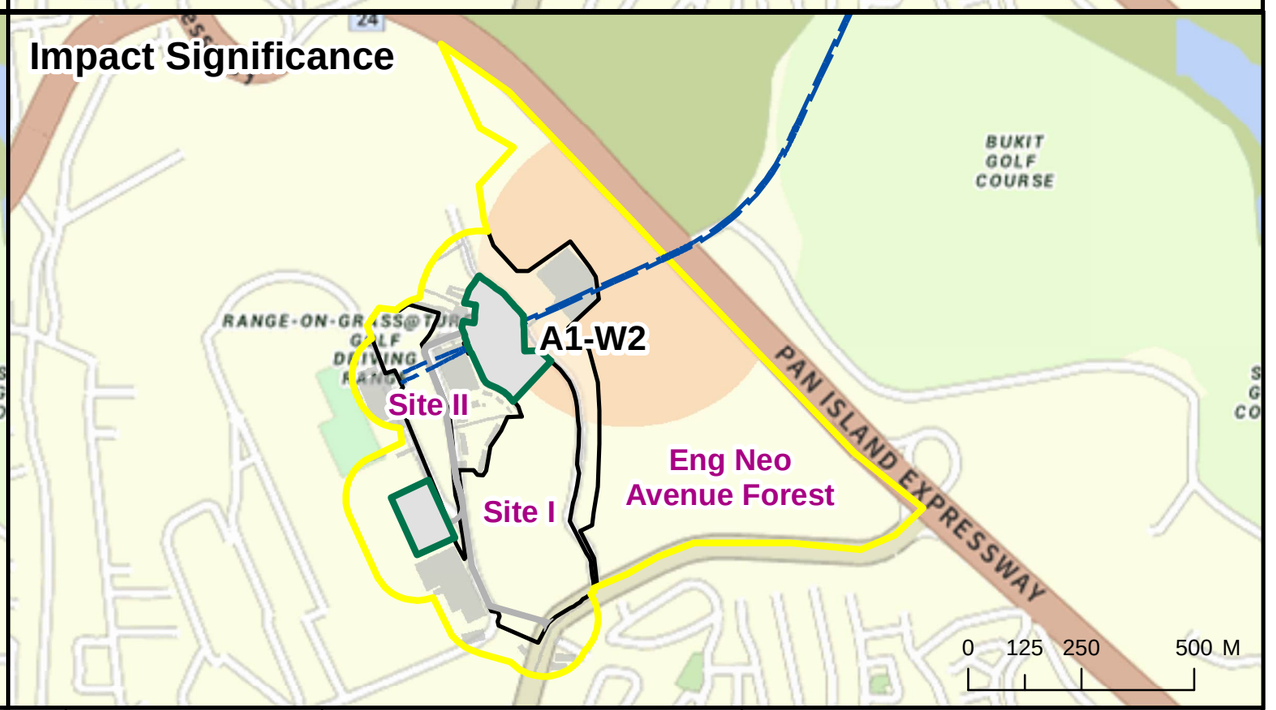
Impact Intensity



Impact Consequence



Impact Significance



Legend

- Proposed CRL Alignment (Mitigated)
- Temporary Access Roads
- Study Area (Mitigated)
- Biodiversity Study Area

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0 - 0.01	Below Ambient	Below Ambient	Below Ambient
0.02 - 0.02	Negligible	Imperceptible	Negligible
0.03 - 0.04		Very Low	Minor
0.05 - 0.06		Not Assessible	Not Assessible
0.07 - 0.10			

Note:
Sites I & II: Forested area adjacent to Fairways Quarters

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
**CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)**

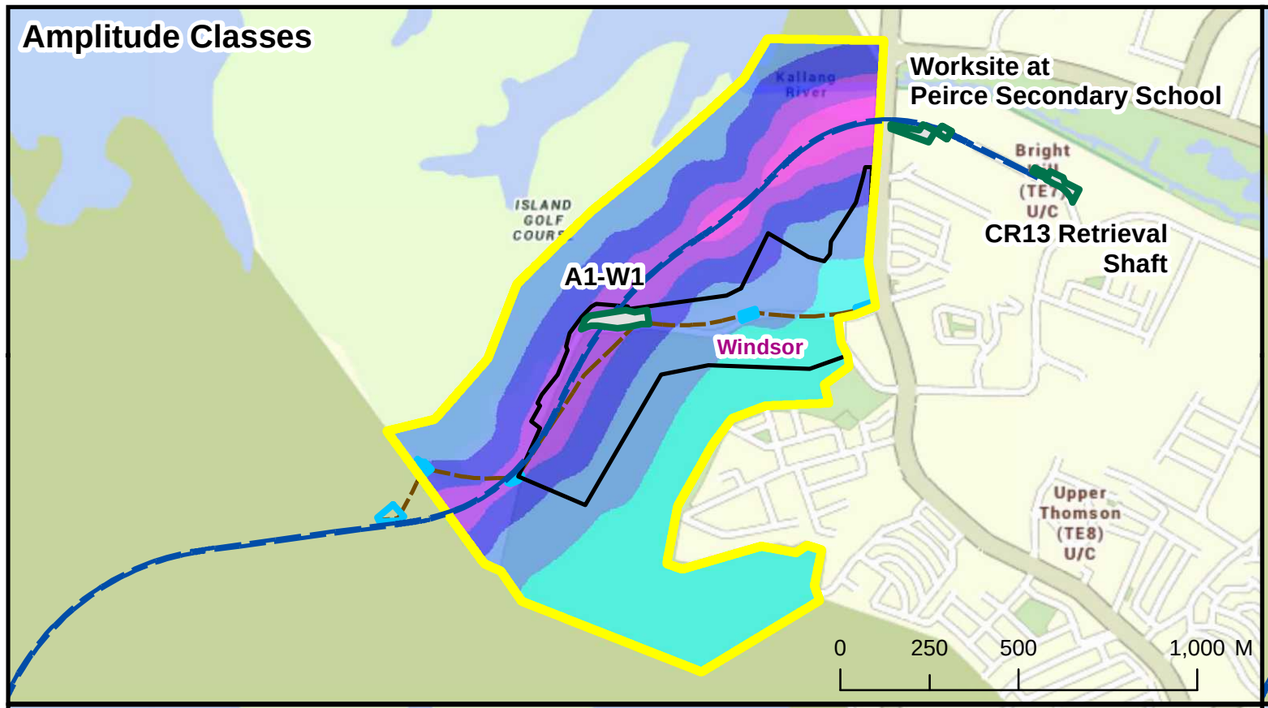
Drawing Title :
**VIBRATION ASSESSMENT
FOR OPERATIONAL PHASE
IN ENG NEO AVENUE FOREST - SPOT
(MITIGATED SCENARIO)**

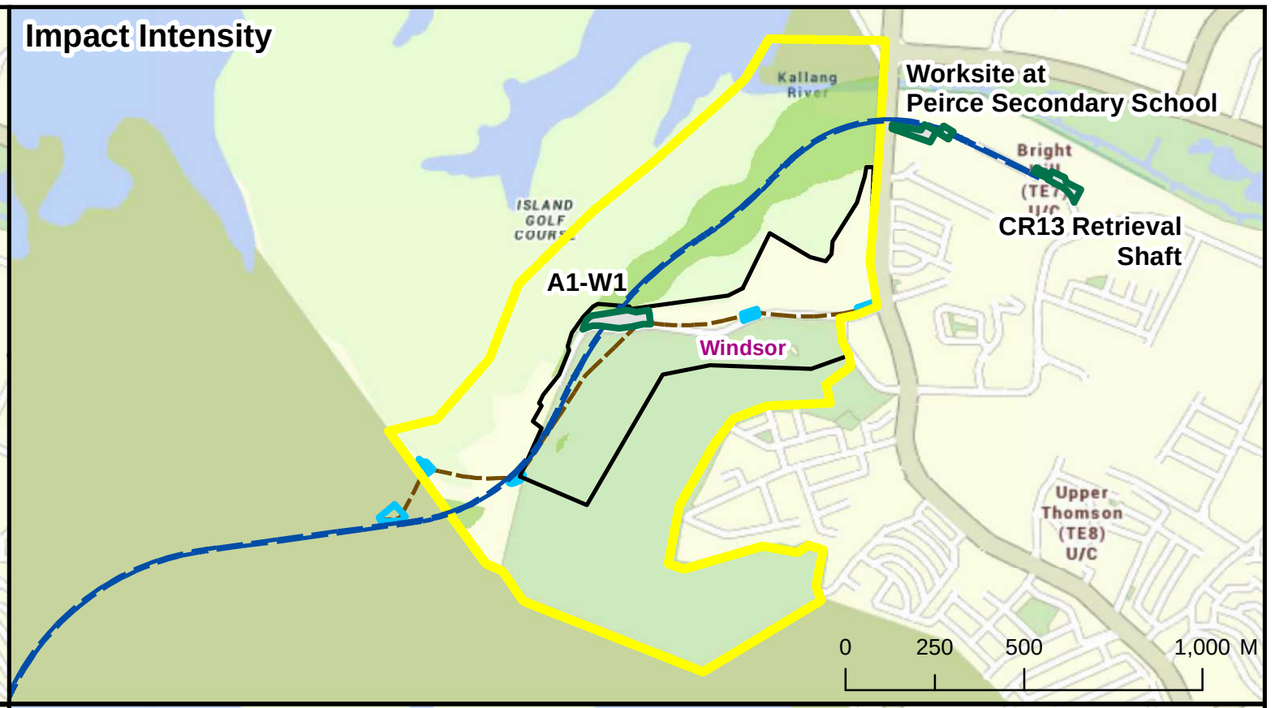
Designed	Checked	Approved
EGY	JAG	JAG
	Drawn: EGY	Date: MAR 2022

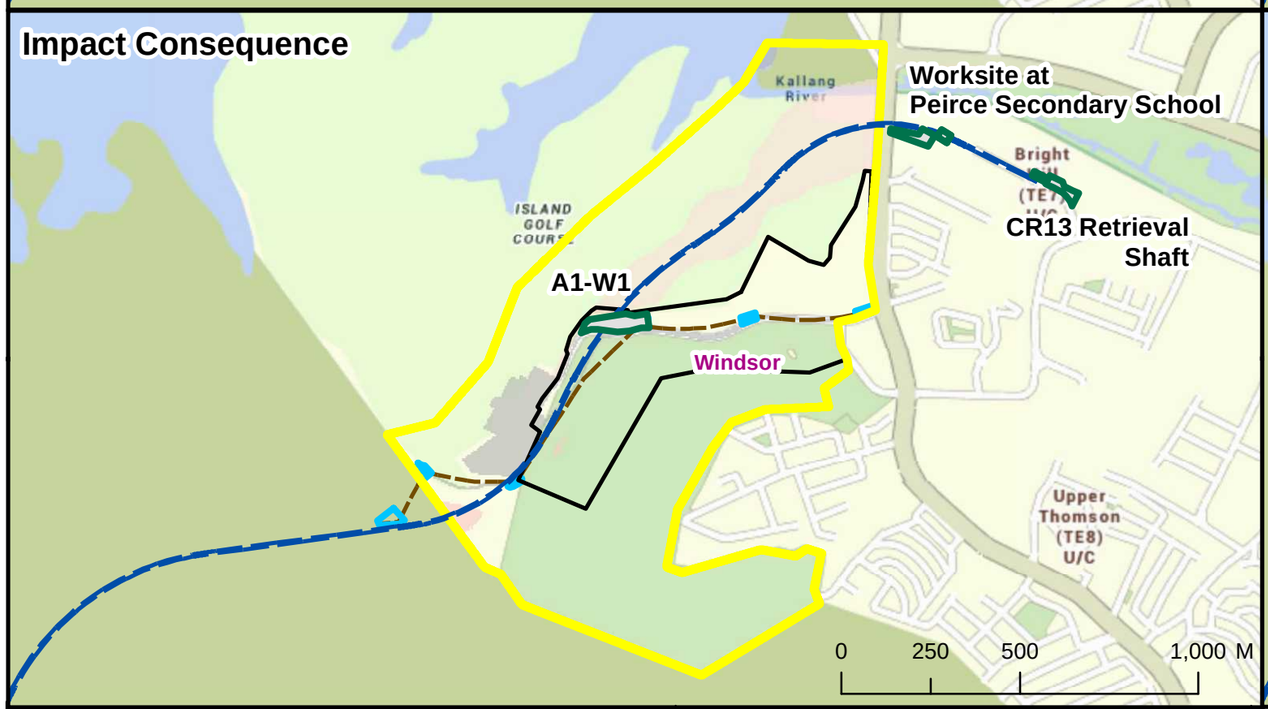
Drawing No. : 12 - 39 | Rev. : - | Sheet : 1 of 1

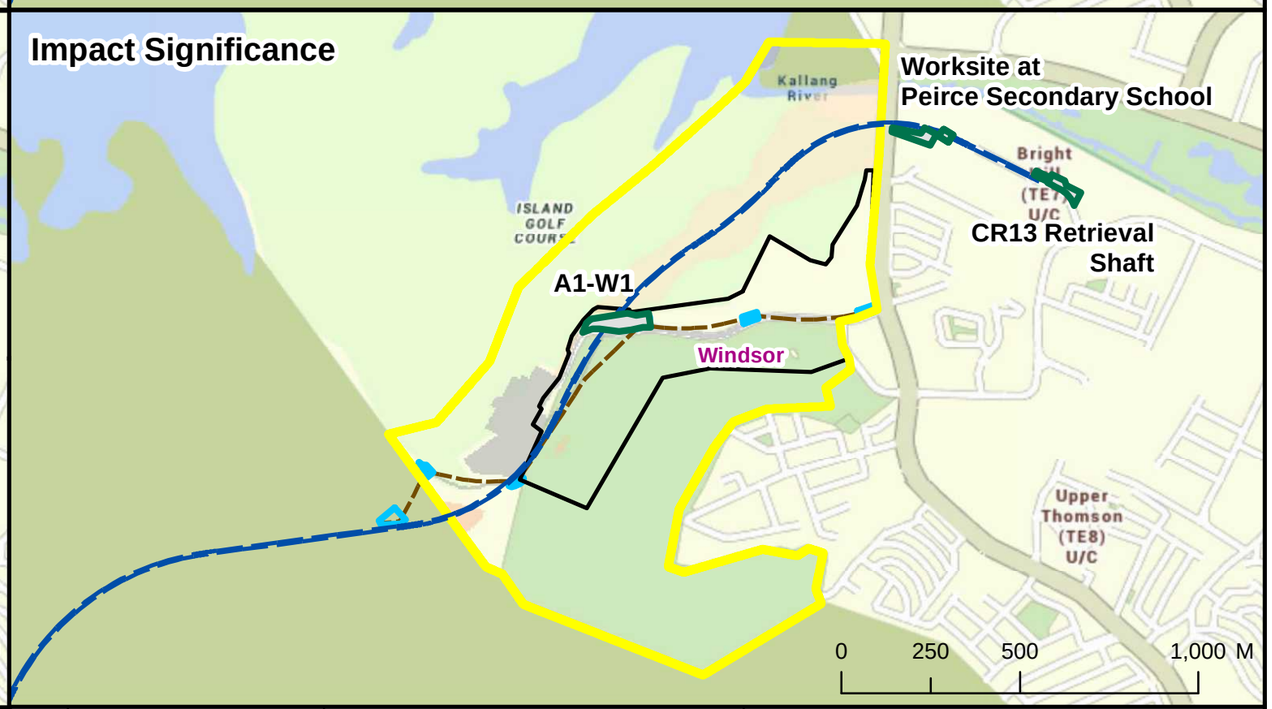
CAD File Name : NA | A3

Note: Source of basemap - OneMap









Legend

- Mitigated Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Mitigated)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level PPV (mm/s)	Impact Intensity	Impact Consequence	Impact Significance
0.00 - 0.02	Below Ambient	Below Ambient	Below Ambient
0.02 - 0.04	Negligible	Imperceptible	Negligible
0.04- 0.06		Very Low	Minor
0.06 - 0.09		Not Assessible	Not Assessible
0.09 - 0.12			

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
We Keep Your World Moving

Project Title :

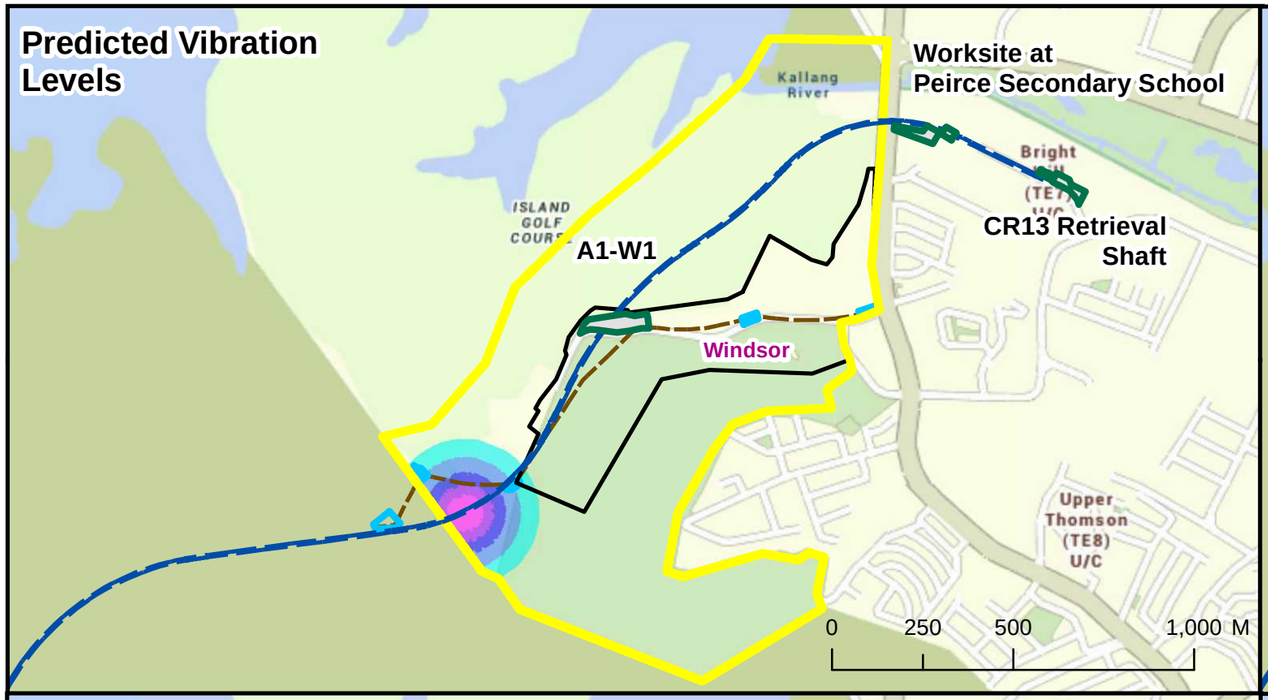
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY
(WINDSOR AND
ENG NEO AVENUE FOREST)

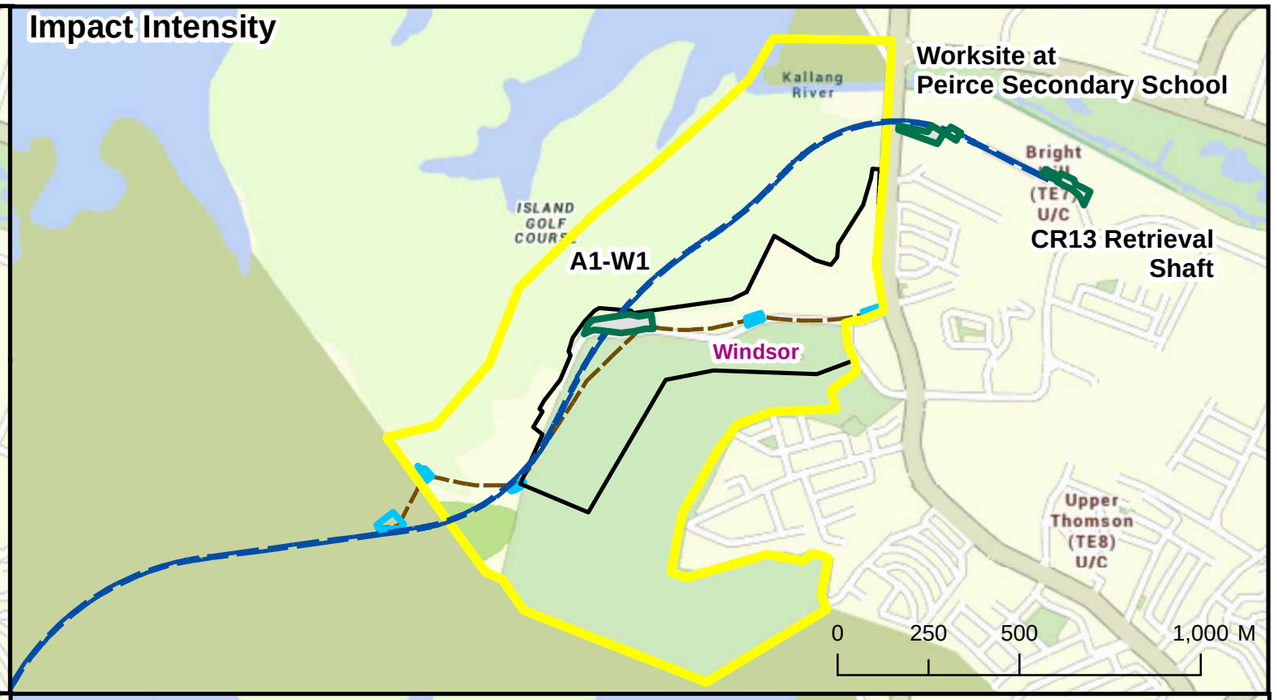
Drawing Title :

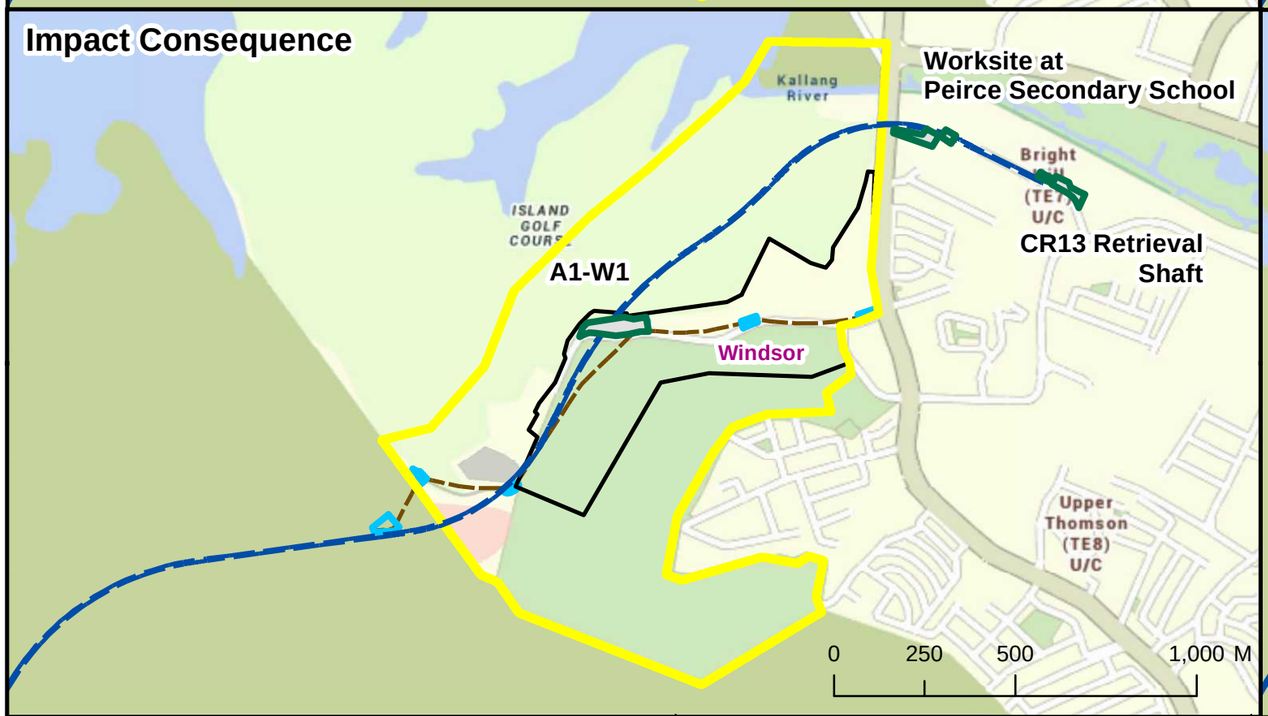
VIBRATION ASSESSMENT
FOR OPERATIONAL PHASE
IN WINDSOR
(MITIGATED SCENARIO)

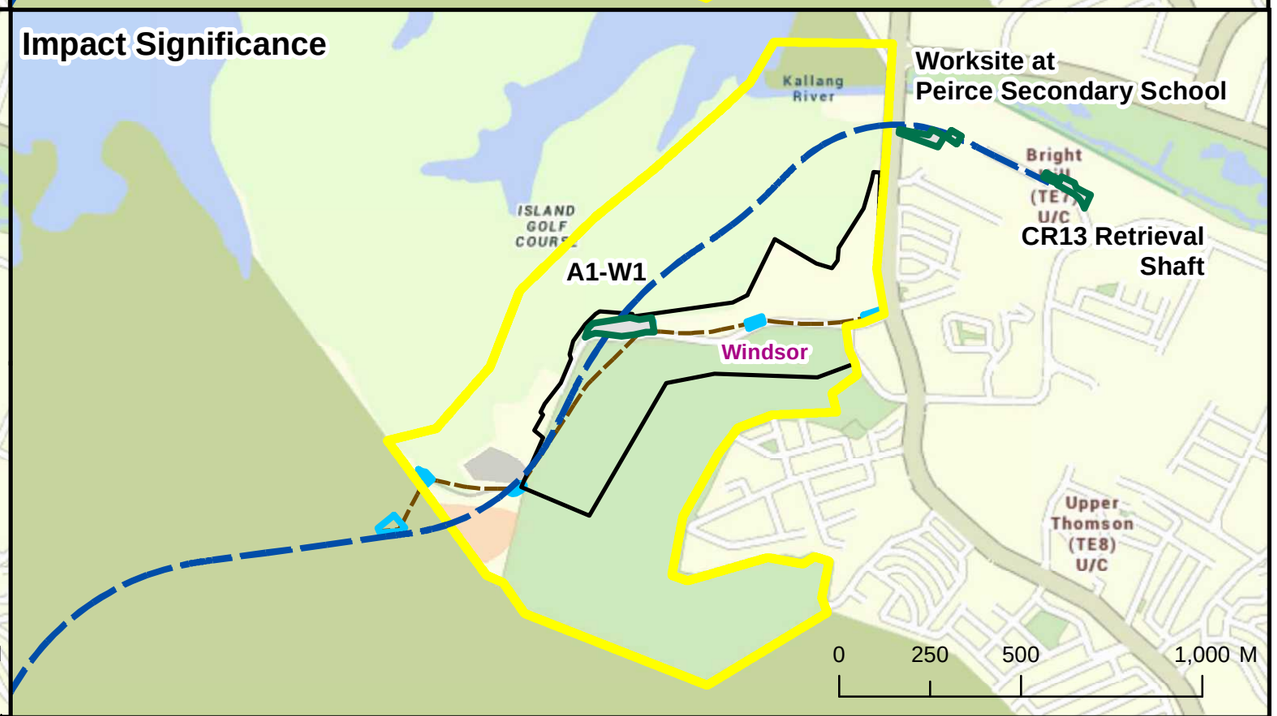
Designed	Checked	Approved	Drawing No. :	Rev.	Sheet
EGY	JAG	JAG	12 - 40	-	1 of 1
	Drawn EGY	Date MAR 2022	CAD File Name : NA		A3

Note: Source of basemap - OneMap









Legend

- Mitigated Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Mitigated)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level	Impact Intensity	Impact Consequence	Impact Significance
PPV (mm/s)	Value	Value	Value
0.04 - 0.05	Below Ambient	Below Ambient	Below Ambient
0.05 - 0.07	Negligible	Imperceptible	Negligible
0.07 - 0.09		Very Low	Minor
0.09 - 0.11		Not Assessible	Not Assessible
0.11 - 0.13			

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

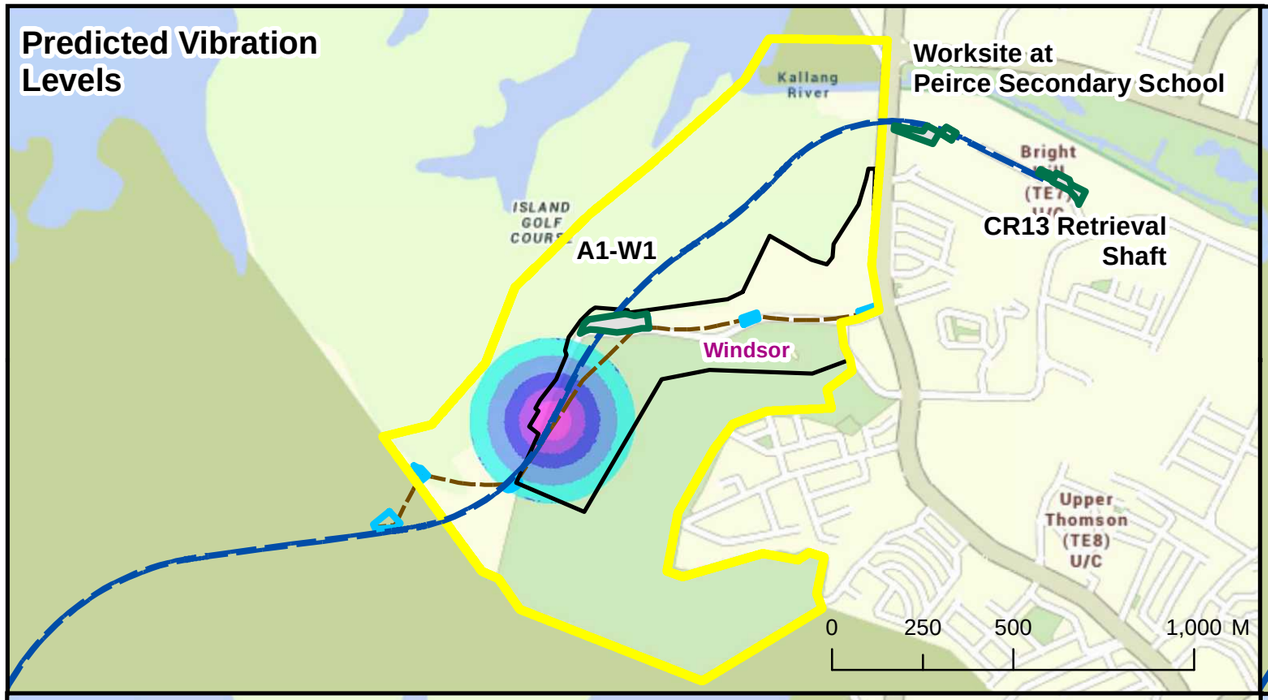
Drawing Title :
VIBRATION ASSESSMENT FOR OPERATIONAL PHASE IN WINDSOR - SPOT 1 (MITIGATED SCENARIO)

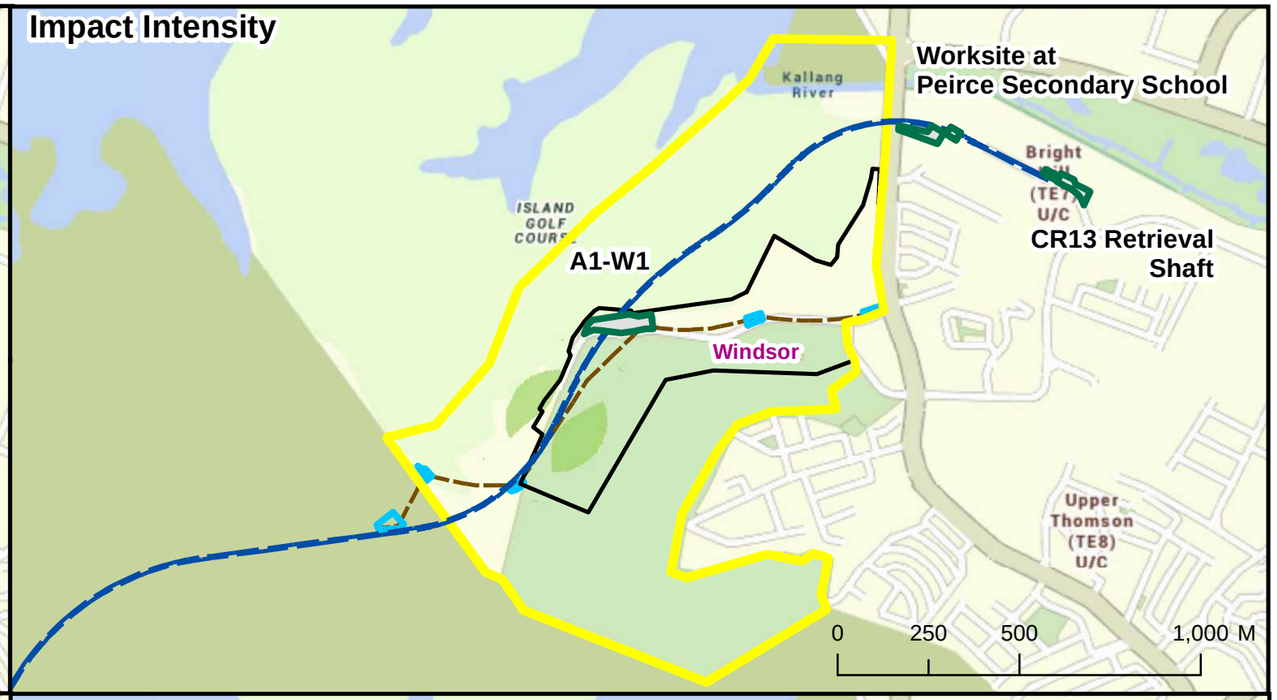
Designed	Checked	Approved
EGY	JAG	JAG
	Drawn EGY	Date MAR 2022

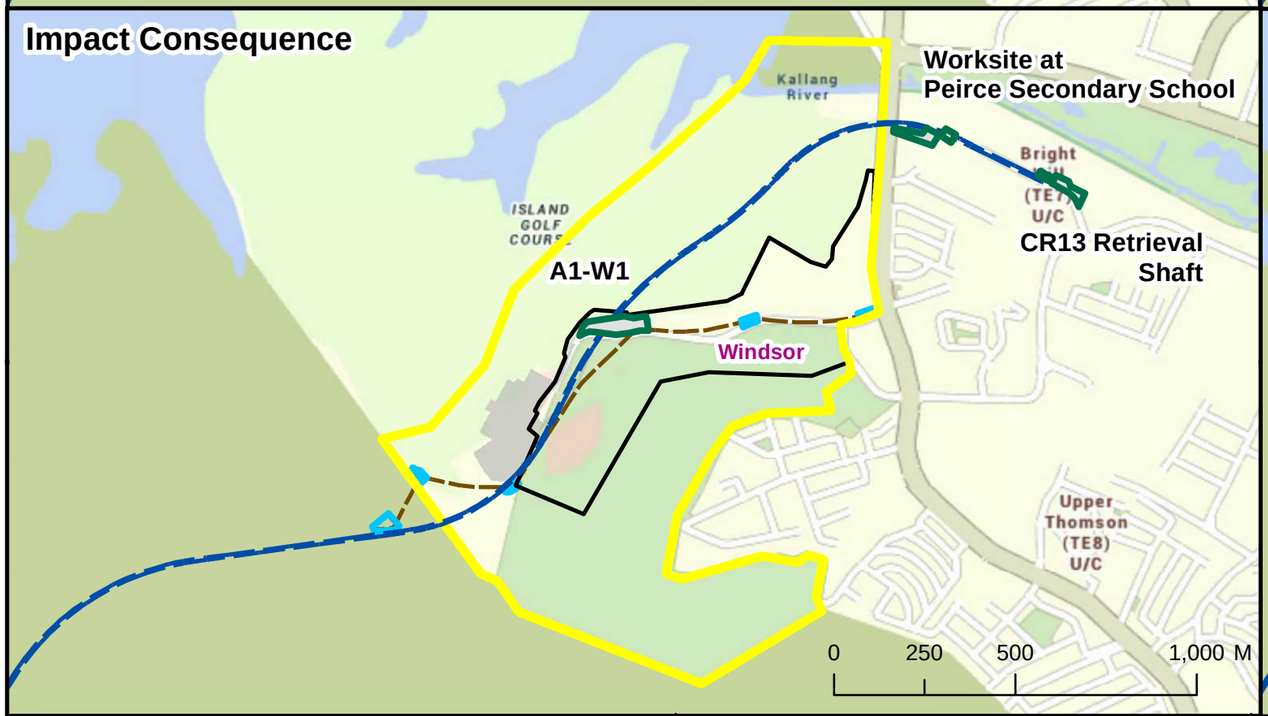
Drawing No. : 12 - 41 | Rev. : - | Sheet : 1 of 1

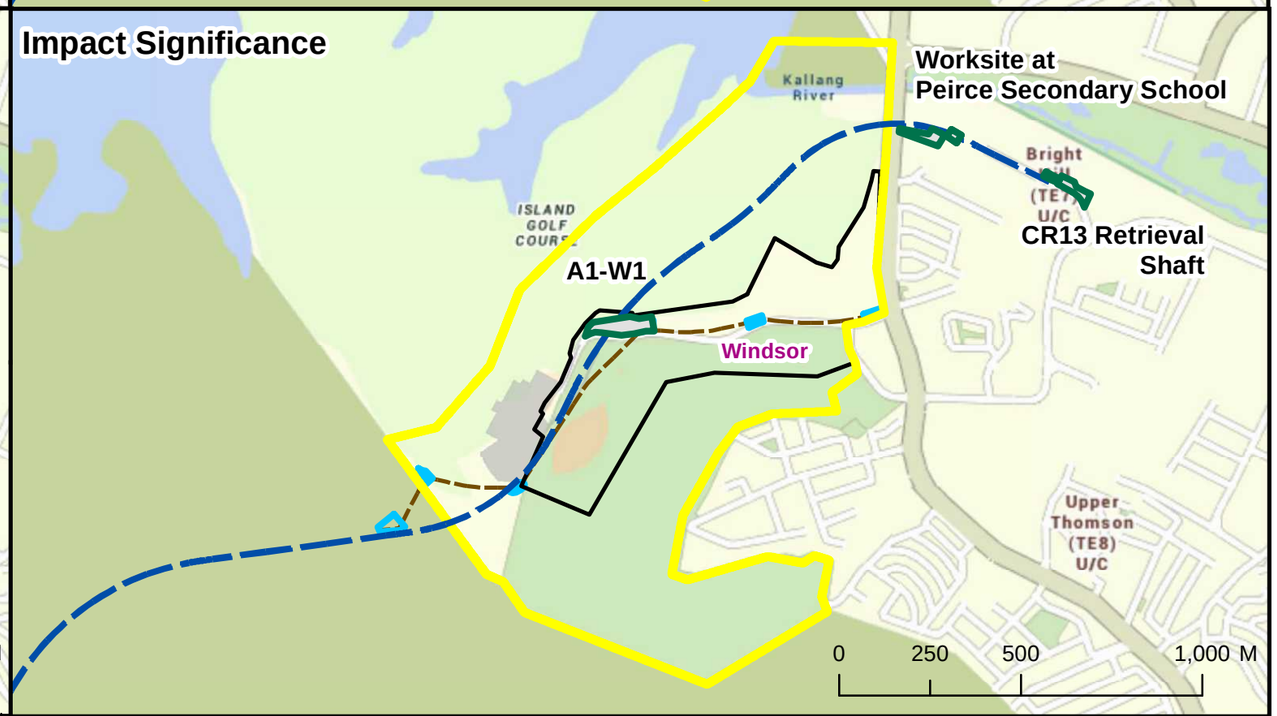
CAD File Name : NA | A3

Note: Source of basemap - OneMap









Legend

- Mitigated Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Mitigated)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level	Impact Intensity	Impact Consequence	Impact Significance
PPV (mm/s)	Value	Value	Value
0.04 - 0.05	Below Ambient	Below Ambient	Below Ambient
0.05 - 0.07	Negligible	Imperceptible	Negligible
0.07 - 0.09		Very Low	Minor
0.09 - 0.11		Not Assessible	Not Assessible
0.11 - 0.13			

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
CONTRACT CR2005 ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

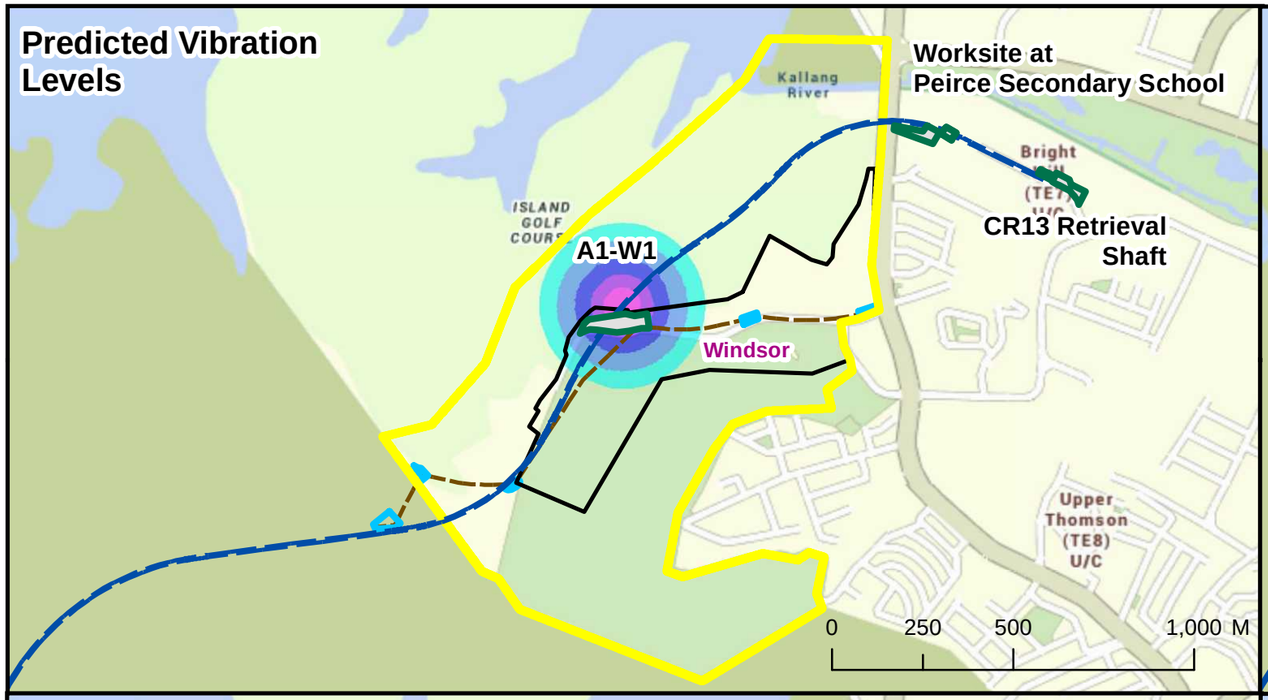
Drawing Title :
VIBRATION ASSESSMENT FOR OPERATIONAL PHASE IN WINDSOR - SPOT 2 (MITIGATED SCENARIO)

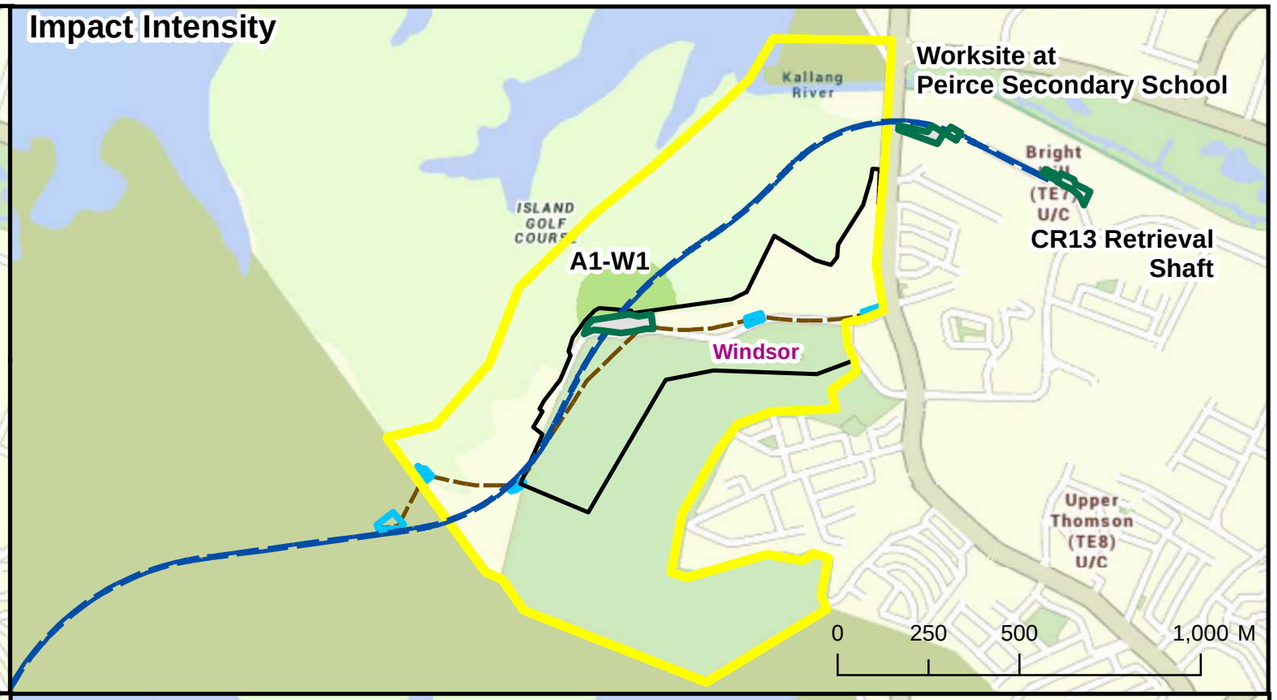
Designed	Checked	Approved
EGY	JAG	JAG
	Drawn: EGY	Date: MAR 2022

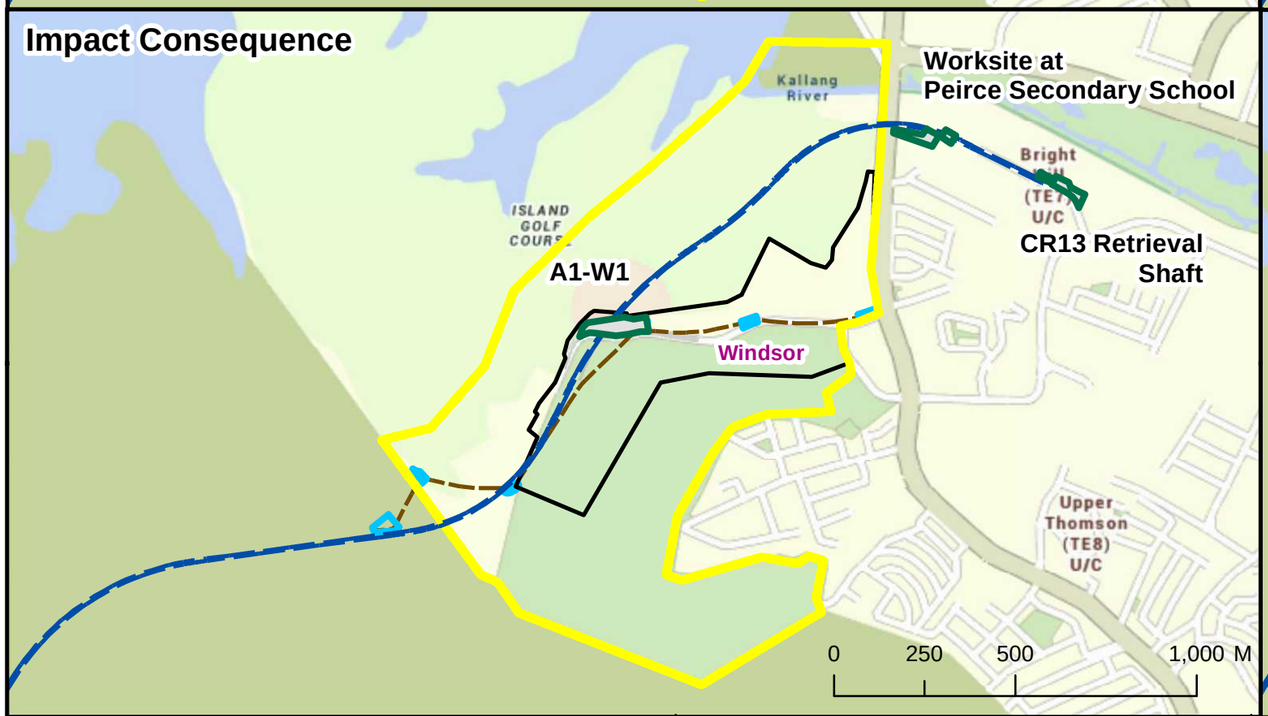
Drawing No. : 12 - 42 | Rev. : - | Sheet : 1 of 1

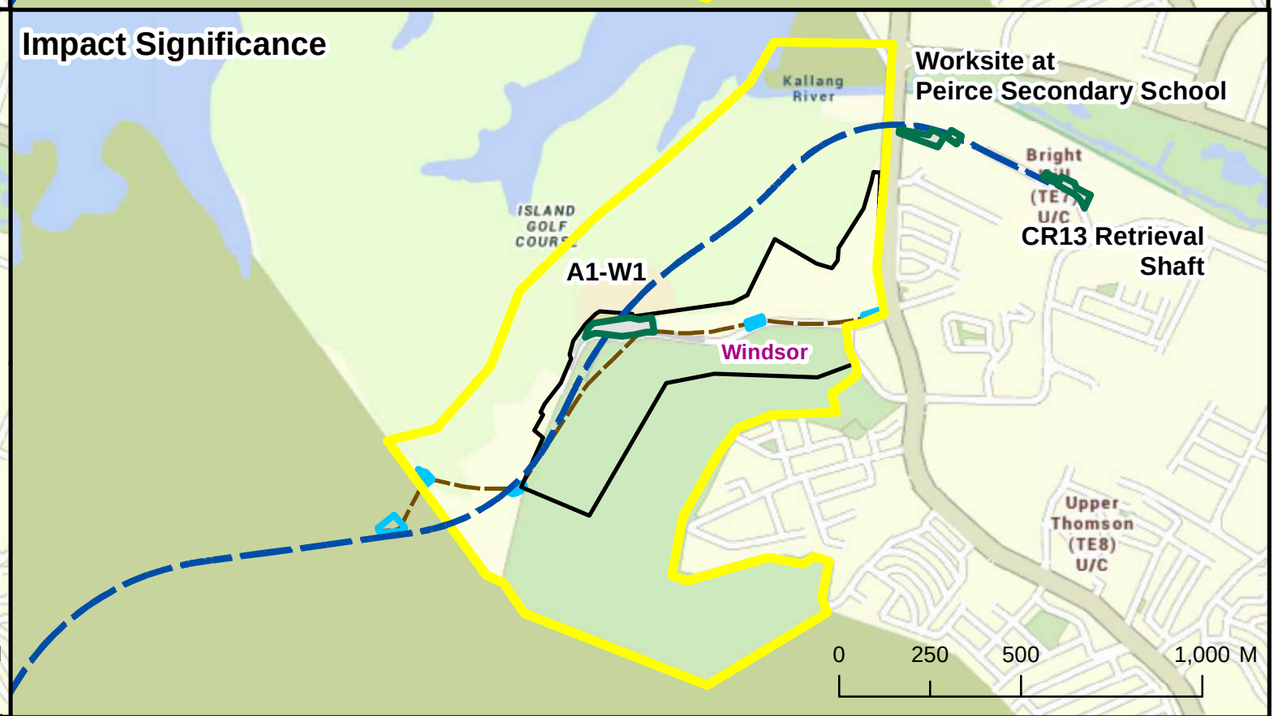
CAD File Name : NA | A3

Note: Source of basemap - OneMap









Legend

- Mitigated Scenario Construction Worksite Footprint
- Proposed CRL Alignment (Mitigated)
- Study Area
- Biodiversity Study Area (Windsor)
- PUB Water Pipeline Project at BKSR (Shafts)
- PUB Water Pipeline Project at BKSR (Pipeline)

Predicted Vibration Level	Impact Intensity	Impact Consequence	Impact Significance
PPV (mm/s)	Value	Value	Value
0.04 - 0.05	Below Ambient	Below Ambient	Below Ambient
0.05 - 0.07	Negligible	Imperceptible	Negligible
0.07 - 0.09		Very Low	Minor
0.09 - 0.11		Not Assessible	Not Assessible
0.11 - 0.13			

N

Rev.	Date	By	Description	Chk'd	App'd
-	Mar 2022	EGY	EIS (Windsor and Eng Neo Avenue Forest)	JAG	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
CONTRACT CR2005
ENVIRONMENTAL IMPACT STUDY (WINDSOR AND ENG NEO AVENUE FOREST)

Drawing Title :
VIBRATION ASSESSMENT FOR OPERATIONAL PHASE IN WINDSOR - SPOT 3 (MITIGATED SCENARIO)

Designed	Checked	Approved
EGY	JAG	JAG
	Drawn: EGY	Date: MAR 2022

Drawing No. : 12 - 43 | Rev. : - | Sheet : 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap

12.10 Cumulative Impacts from Other Major Concurrent Development

Regarding Section 3.4.1, there are other major concurrent developments during the construction and operational phases of CR2005. The ground-borne vibration cumulative impacts from these developments are discussed in this section qualitatively.

12.11 Construction Phase

There is potentially some overlapping schedule in construction works with BKSR. The ground-borne vibration caused by the construction works at BKSR is potentially low as the construction activities mainly involve the construction of potable water pipelines and pipelaying works. In addition, the ground-borne vibration caused by rock breaking and excavation and piling works at the A1-W1 worksite is more prominent during the construction phase.

At A1-W2, there could be some overlap with CR14 works. Potential construction activities are tunnel boring, rock breaking and excavation. Due to a lack of information, the vibration impacts can only be qualitatively assessed at the moment. There is a potential for **Moderate** - **Major** impact significance on the impacted ecological sensitive receptors.

12.11.1 Operational Phase

No significant high vibration activities or works are known to be ongoing during the operational phase; therefore, cumulative impacts are unlikely.

12.12 Summary of Key Findings

A vibration impact assessment was carried out to assess the vibration impacts arising from the construction and operational phases of the Project on ecologically sensitive receptors in the Study Area. Ground-borne vibration from construction activities (at A1-W1, A1-W2 worksites and alignment) and operational activities may be felt by or cause a disturbance, especially on the ecological receptors proximity to the Project. The local geological profile along the alignment is mainly dominated by Bukit Timah Granite (Rengam Facies).

Five construction activities assessed were rock breaking and excavation, rotary bore piling, bulldozing, vibratory compacting and tunnel boring. The predicted vibration levels from the construction and operational phases of the Project are then evaluated against the impact assessment matrix for impact intensity, impact consequence, likelihood and impact Significance on the ecological behaviours of the ecologically sensitive receptors.

Flora is not considered to be sensitive to vibration impact. Hence the impact assessment was for the behaviour of fauna only. The main focus of the assessment was Priority 1 sensitive ecological receptors. The indicator species for the assessment were sunda pangolin (Manis javanica) and lesser mousedeer (Tragulus kanchil). Ground-borne noise is generated by the vibration of walls, ceilings and floors inside buildings. Therefore ground-borne noise only occurs indoors; and is excluded from the assessment of fauna which lives in the open.

Currently, there are no applicable Singapore or international standards or guidelines that assess the impacts of ground-borne vibration from the construction and operation of the railway on faunal/ ecological receptors. There are limitations concerning established reliable criteria for assessing vibration impact on fauna. Based on the literature review, the impacts on the behaviour of ecological species and burrow collapse depend on the vibration level and the frequency of vibration.

The baseline vibration study aims to understand the existing vibration levels at the sensitive receptors. 99th percentile of baseline vibration data was used to develop a criterion for Eng Neo Avenue Forest; used as an input to a regression equation to calculate the impact intensity criteria for Windsor. The baseline study comprises monitoring carried out (primary data collection) and data measured previously for other Projects (secondary). The Peak Particle Velocity (PPV) vibration metric has been used throughout. A matrix for impact intensity was formulated with two components, vibration thresholds and impacted area (based on the home range of the sunda pangolin).

The study assesses the vibration impacts on the structural integrity of the burrows belonging to the fossorial species and the behaviour of the ecologically sensitive receptors in the biodiversity area. The vibration threshold for partial burrow collapse in a desert environment is PPV, 10.00 mm/s [W-87]. The predicted construction vibration levels were screened to identify levels equal to or greater than PPV, 5.00 mm/s (equivalent to 50 % of the recorded vibration threshold). Rock breaking and excavation; high amplitude vibratory compacting could generate vibrations greater than PPV, 5.00 mm/s at the biodiversity study areas. The burrows may be susceptible to vibration damage

and collapse, thus entombing the fossorial species. To avoid an overly onerous assessment that may be impractical for the Singapore context, the Project considered taking the 80% value of the vibration threshold as the assessment criteria – PPV, 8.00 mm/s for burrows. Supposed the Contractor implements vibration control measures, damage/partial collapse of the burrows may be avoided.

In terms of behavourial impacts, the predicted vibration levels from the five construction activities were assessed. Based on the results, the construction vibration levels (with minimum control measures) would likely cause Minor - Major impact significance at Eng Neo Avenue Forest; Negligible - Moderate impact significance at Site I and II and; Minor - Major impact significance at Windsor. Hence, mitigation measures were recommended to reduce the impacts.

The mitigation measures were:

- Removal of TBM launch/ retrieval at A1-W1, which reduced trucks and heavy equipment on-site;
- Optimising A1-W1 and A1-W2 worksites;
- Apply best available techniques (BAT) to control construction vibration levels to PPV, 8.00 mm/s at the biodiversity areas;
- Implement temporary water barriers at Island Club Road to prevent fauna from fleeing across the road, resulting in roadkills;
- Restrict the entry of visitors into the trails of Windsor;
- Keep the impact zone as small as possible;
- Avoid construction activities at night; and
- Use low vibration construction methods, e.g. use secant bored piling instead of rotary bore piling.

Based on the results, the construction vibration levels (with mitigation measures) would likely cause **Minor - Moderate** impact significance at Eng Neo Avenue Forest; **Negligible** - **Moderate** impact significance at Site I and II and; **Minor** - **Moderate** impact significance at Windsor.

Although Contractors may limit their construction levels to PPV, 8.00 mm/s at the biodiversity areas, the size of the impacted area would remain the same, which is equal to or greater than 6 ha. Hence there would be **Moderate** residual impacts. The study recommended that the contractors implement the best available technology (BAT) for low vibration construction methods and the EMMP. The EMMP required Contractors to carry out continuous vibration monitoring and fauna behaviour monitoring (using camera traps and observing specialists) during the construction and commissioning stages. The ecologist monitors the environment for any faunal behaviours (e.g. charging) that could result in roadkill, burrow damage/collapse resulting in mortality and their presence and absence in and around the worksite. Suppose the mortality of fauna is under threat, the work is immediately halted, and mitigation measures are adapted to avoid such events in the future.

To determine and quantify impact amplitude for the operational phase, LTA provided predicted vibration levels from the operation of the trains. The study assessed the given vibration levels (with standard track form and deep tunnel depth as minimum control measures) for potential damages/collapse of the burrows and behavioural impacts on fauna. As the operational train vibration levels were low, the resulting impact significances in the biodiversity study areas were Minor. Mitigation measures were not required to reduce the impacts further; thus, residual impacts remain **Minor**.

In terms of cumulative vibration impact significance, there are other concurrent developments during the construction and operational phases of this Project. There could be some overlapping schedules in construction works with BKSR. The ground-borne vibration caused by the construction works at BKSR would probably be low as the construction activities mainly involve the construction of potable water pipelines and pipelaying works. Therefore, the ground-borne vibration caused by rock breaking and excavation and piling works at the A1-W1 worksite would be more prominent during the construction phase.

At A1-W2, there could be some overlap with CR14 works. Potential construction activities are tunnel boring, rock breaking and excavation. Due to a lack of information on the future work site, the vibration impacts can only be qualitatively assessed at the moment. There is a potential for Moderate - Major impact significance on the impacted ecological sensitive receptors.

No significant high vibration activities or works are known to be ongoing during the operational phase; therefore, the cumulative impacts are unlikely.

Table 12-38 Summary of Ground-borne Vibration Impact Assessment

Sensitive Receptor	Impact Significance with Minimum Controls	Residual Impact Significance with Mitigation Measures (if required)
Construction Phase		
Eng Neo Avenue Forest	Minor - Major	Minor - Moderate
Site I and Site II	Negligible - Moderate	Negligible - Moderate
Windsor	Minor - Major	Minor - Moderate
Operational Phase		
Eng Neo Avenue Forest	Minor	Minor
Site I and Site II	Minor	Minor
Windsor	Minor	Minor

Note:

During construction phase, Moderate residual impact on all the Biodiversity Study Areas, although with mitigation measures, is due to construction activities such as pipe jacking, rock breaking and excavation and tunnel boring produce high PPV levels at the studied forested areas. Thus, EMMP measures should be implemented.