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Contract 9175

Advance Engineering Study for the Proposed Downtown Line 2 Extension and a New Station on Existing North-South Line

Environmental Study Report
Biodiversity and Hydrology Study Report

Design Stage: Preliminary

Submitted by:
AECOM Singapore Pte Ltd

Submitted to:
Land Transport Authority

14 January 2025

Volume 4 of 5

11 Ground-borne Noise and Vibration

This section presents the ground-borne noise and vibration impacts assessment due to the Project's construction and operational phases (railway).

11.1 Introduction

11.1.1 Construction Phase

During construction, the activities generate vibration through the ground and nearby buildings. The vibration-generating equipment/activities for this Project are rock-breaking, rotary bored piling machine, tunnel boring machine (TBM), vibratory compactor and vibratory pile driver. The resulting vibration in a building structure can produce three effects:

- Perceptible vibration is known as 'ground-borne vibration' (GBV);
- A 'rumble noise' from the vibrating walls, floors and ceilings radiating sound into a room. This effect is known as 'ground-borne noise or 're-radiated / structure-borne noise' and
- When vibration levels are significantly higher, cosmetic building damage (e.g., plaster cracking) can occur. If the ground-borne noise and perceptible vibration are within the required limits, building damage does not happen.

Some receptors (e.g., semi-conductor manufacturers) may operate vibration sensitive equipment inside the building. Ground-borne vibration can affect the operation of the equipment if it does not have vibration mitigation measures. Based on the study, there are no vibration sensitive buildings near the construction areas.

In this report, vibration impact assessment was carried out for cosmetic building damage and human responses in a building. Ground-borne vibration is almost insignificant in an outdoor environment. However, the motion of the ground moving may be perceptible; this is less provoking to a human experiencing similar adverse effects inside a built environment. For assessing the ground-borne noise and vibration impacts, a study area of 100 m from the alignment/ worksites has been delineated as starting point of assessment for this study (as stated in Section 0).

The vibration impacts were also assessed for ecological fauna receptors at Sungei Pang Sua, Pang Sua Canal and Rail Corridor. Biodiversity's floral component is not considered sensitive to vibration impact and hence was excluded from the assessment. Since ground-borne noise occurs in a built environment and does not impact ecological receptors, this report has excluded the assessment.

11.1.2 Operational Phase

This section excludes detailed assessment of operational impacts on human receptors as the detailed assessment is provided in the Noise and Vibration Study (NVS) Prelim Report separately.

During the operational phase, the vibration generation occurs at the interface between the wheels and the rails. It is caused by the minor irregularities in the running surfaces (the wheel and rail 'roughness') and the vertical track alignment at the relevant wavelengths. The magnitude of the generated vibration depends on the roughness levels, the un-sprung mass of the rolling stock, the suspension design, and the track design. Features of the track alignment (viaduct, tunnel, at-grade) plus the ground vibration propagation characteristics determine the resulting vibration at the receptors. Similarly, ground-borne noise may be generated inside the buildings.

The potential future infrastructure that produce airborne noise and noise radiating from the vibrating structure. The impacts were assessed in Section 11.8.

Based on the literature review, fauna receptors detect very low vibration levels. The motion of the ground moving may be perceptible and provoking in an outdoor environment for fauna, thus operational ground-borne vibration impacts on ecological receptors were assessed.

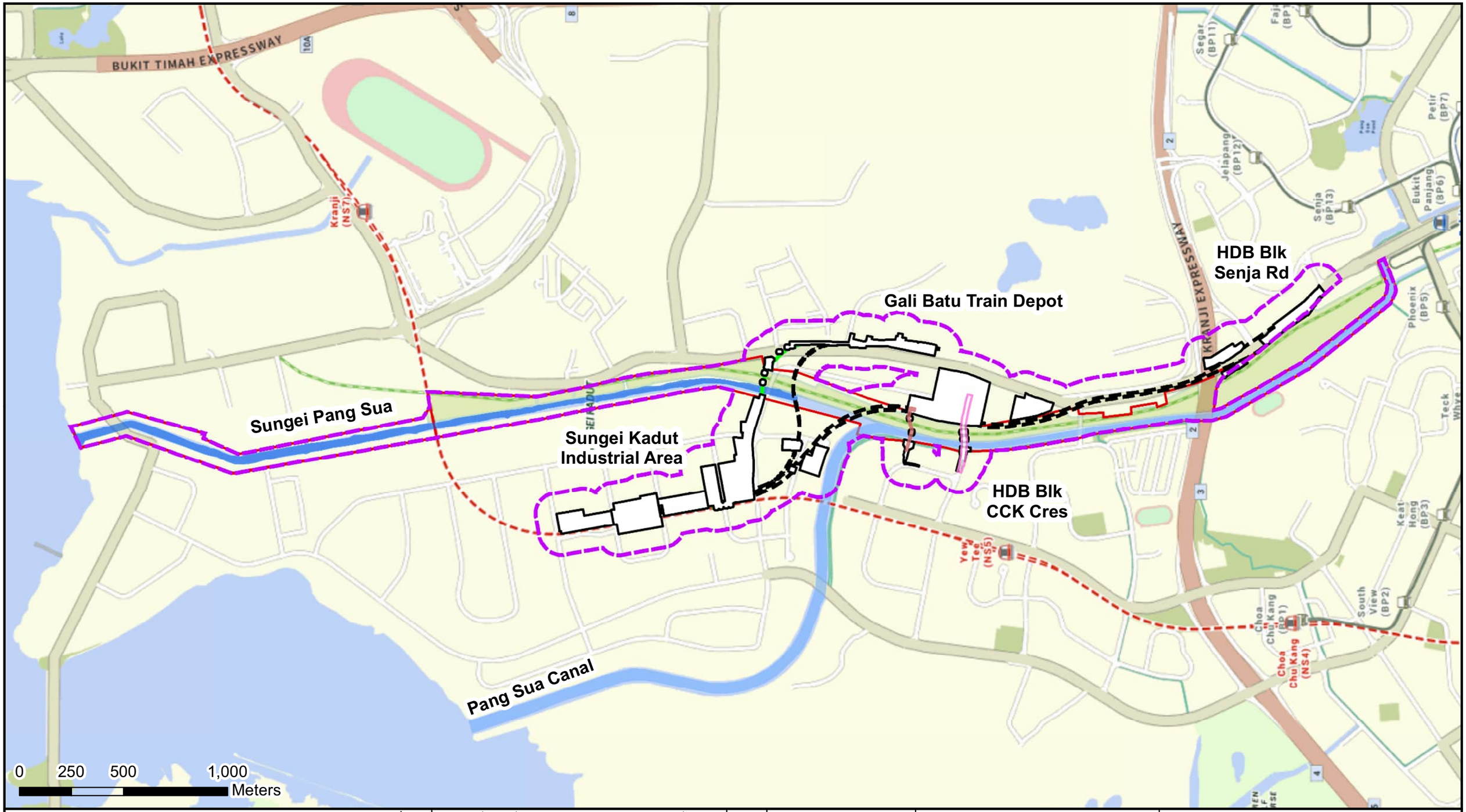
The key steps for conducting the ground-borne noise and vibration impact assessment are as follows:

Ecological Receptors

- Review secondary baseline vibration monitoring data and collect primary baseline levels to assess current baseline vibration levels in the study area;
- Establish assessment criteria for the ground-borne vibration impact assessment study;
- Identify activities in project construction and operational phase which may cause significant ground-borne vibration impact on the fauna in the study area;
- Identify and classify the sensitivity of the faunal receptors in the project study area;
- Identify minimum controls identified by the engineering team for managing or avoiding the ground-borne vibration impacts in these phases;
- Predict ground-borne vibration levels from significant activities on the identified faunal receptors assuming minimum controls are in place;
- Recommend additional mitigation measures to be implemented if applicable;
- Determine the overall significance of the residual ground-borne vibration impacts after commitment to and implementation of 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 the ES.

Human Receptors

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



Legend

- Vibration Study Area
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

N

Rev.	Date	By	Description	Chk'd	App'd
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
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CONTRACT 9175
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Figure Title :
GROUND-BORNE NOISE & VIBRATION STUDY AREA

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

CAD File Name :N/A — A3

Note: Source of basemap - OneMap

11.2 Methodology

11.2.1 Potential Sources of Impacts

The first step in this assessment was to study the construction and operational phases to identify equipment or activities that may cause significant vibration. These activities may include typical infrastructure construction activities like piling, tunnel boring, excavator usage, or site-specific ones like rock breaking and excavation, etc. For operational phase, such activities include, running of trains in this case. A comprehensive list of potential sources of impacts during construction and operational phases and their associated impacts on human and ecological receptors are listed in Section 11.3.

11.2.2 Identification of Sensitive Receptors

During the scoping phase for this ES, an initial screening of receptors in the Study Area was conducted as per Section 6.2.2. Human receptors and ecological receptors potentially impacted during the construction and operational phases were identified. These are detailed in Section 11.4 for human and ecological receptors.

11.2.3 Baseline Vibration Monitoring

The baseline vibration monitoring aims to understand the existing vibration levels at the sensitive receptors. These findings were used to establish the impact assessment criteria for ecological receptors and as a reference for monitoring during the Project's construction, operational or both phases. The baseline study comprised of monitoring (primary data collection) and data measured previously for other projects (secondary), if any. The baseline results are summarized in Section 11.5, and detailed in Appendix X.

11.2.3.1 Desktop Assessment (Secondary Data Collection)

Desktop research consists of a review of secondary data (including current land use and development activities, satellite images, etc.) to aid in determining the ideal baseline vibration monitoring locations based on the considerations detailed in Section 11.2.3.1. The information retrieved during the desktop research comprised publicly available data from the government and technical agencies, available data, relevant articles, and other online sources.

11.2.3.2 Field Assessment (Primary Data Collection)

Seventeen (17) baseline vibration monitoring locations were selected within the Study Area. Data collected represent the baseline vibration conditions for the human and faunal receptors. V1 – V11 vibration monitoring points were set up for one week at representative human receptor locations; VR1 – VR6 vibration monitoring points were set up for three days at locations with the fauna of high conservation value. The baseline monitoring locations were selected based on the following considerations:

- Identification of human VSRs (vibration sensitive receptors) nearest to the construction worksite/ Project footprint;
- Identification of fauna VSRs of high conversation value at the Biodiversity Study Areas;
- VSRs, more than 100 m (study area) from the construction worksite / Project footprint areas, were eliminated in the first cut for evaluation for human receptor locations;
- VSRs with areas having ongoing construction were avoided;
- VSRs under existing viaduct were selected;
- The closest VSR to the construction worksite areas was selected; and
- Ensure monitoring was conducted at the ground level / as-built foundation of buildings to capture the baseline vibration based on the existing geological profile.
- The monitoring duration for locations with less volatile activities was shorter as the vibration levels were fairly constant.

- Section 11.3 discusses the baseline vibration monitoring locations DTL2e and the potential future infrastructure in detail.

11.2.4 Assessment Criteria

For the assessment of cosmetic damage to buildings and human responses, the Project is guided by international regulations in the absence of local regulations for construction-induced ground-borne noise and ground-borne vibration criteria.

For the assessment of fauna responses, the Project proposes assessment criteria based on the results of the ecological survey of the Study Area and the baseline vibration conditions in the absence of local and international standards. A unique assessment criterion is proposed for this Project through AECOM's practical experiences on projects of similar size and scale and literature reviews on this subject matter.

11.2.4.1 Ecological Receptors

This report has developed a criterion for intensity for ecological receptors as proposed in Section 11.7.1.

11.2.4.2 Human Receptors

11.2.4.2.1 Ground-borne Noise

The Project ToR Appendix R has a ground-borne noise criterion for the operational phase. Although this criterion was initially set out for the NVS, the ground-borne noise responses for humans are similar for the construction and operational phases. Hence, AECOM assesses based on the same criteria for the ES. Table 11-1 presents the ground-borne noise criteria for this Project.

Table 11-1 Ground-borne Noise Criteria for Contract 9175

Type of Building or Room	Ground-borne Noise Criteria, $L_{Amax, slow}$ dB
Offices, Commercial and Institutional Buildings	45
Residential (low-rise and high-rise) and Hotels	35
Educational Buildings and Museums	40
Religious Buildings	40
Hospitals	35
Theatres	30
Studios (broadcasting and recording)	25

Vibration generated by construction activities may enter buildings via the ground. Vibration causes the floors, walls and ceilings to vibrate and radiate noise. This noise is referred to as structure or ground-borne or regenerated noise. Ground-borne noise is typically low frequency and, if audible, is perceived as a 'rumble'. Ground-borne noise is typically low frequency and, if audible, is perceived as a 'rumble'. It should be noted that ground-borne noise is reradiated noise from a building structure. Thus, ground-borne noise level values are generally noticeable only in the tranquil environment; hence it would typically be masked by airborne noise associated with surface construction activities.

In general, ground-borne noise level values are relevant only where they are higher than the airborne noise from construction activities. Suppose ground-borne noise exceedances in the assessment outcome and airborne noise impacts are higher than ground-borne noise. In that case, the airborne noise will overshadow the ground-borne noise. Hence ground-borne noise mitigation measures are not required.

11.2.4.2.2 Ground-borne Vibration

Cosmetic Damage to Buildings

The vibration threshold for cosmetic damage from BS 5228-2:2009+A1:2014 [R-24] is presented in peak particle velocities (PPV). The guideline vibration levels based on transient vibration guide values for building cosmetic damage are presented in Table 11-2**.**

For a conservative assessment at the time of the development of this report, the predicted results were assessed against the most stringent threshold value of PPV, 15.0 mm/s for Priority 2 and 3 sensitive receptors.

Table 11-2 Vibration Guidelines from BS 5228-2:2009+A1:2014 (Table B.2) [R-24]

Type of Building	Peak Component Particle Velocity in Frequency Range of Predominant Pulse	
	4 Hz to 15 Hz	15 Hz and above
Industrial and Heavy Commercial Buildings	50 mm/s at 4 Hz and above	50 mm/s at 4 Hz and above
Residential or Light Commercial Buildings	15 mm/s at 4 Hz, increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz, increasing to 50 mm/s at 40 Hz

Human Response Rock Breaking

Ground-borne vibration induced by rock breaking is known to cause disturbance to human beings. BS 6472-2:2008 [R-27] guides the impact assessment on rock breaking and vibration levels on human response. The Project assesses human responses to vibration impacts during the day as rock breaking (up to three) occur during the day

The magnitude of air overpressure impacts is more significant than ground-borne noise levels; therefore, an impact assessment of ground-borne noise is excluded. Refer to Section 10.7.1.2 for air overpressure impact assessment.

Table 11-3 presents the ground-borne vibration criterion for human receptors.

Table 11-3 Maximum Satisfactory Magnitudes of Vibration Concerning Human Response for up to Three Rock Breaking and Excavation Events per Day

Place	Time	Satisfactory Magnitude[A], PPV, mm/s[Note 1]	Adverse Comment Magnitude, PPV, mm/s[Note 2]
Residential[C]	Day Night Other times	6.0 to 10.0 2.0 4.5	12.0 to 20.0 4.0 9.0
Offices	Any time[B]	14.0	28.0
Workshops	Any time[B]	14.0	28.0

Note 1: This table recommends magnitudes of vibration below which the probability of the adverse comment is low (noise caused by any structural vibration is not considered).

Note 2: Doubling the suggested satisfactory vibration magnitudes could result in an adverse comment. This will increase significantly if the magnitudes are quadrupled.

Note 3: For more than three occurrences of vibrations per day, see the multiplication factor in Section 6.2.

A. The satisfactory magnitudes are the same for the working day and the rest of the day unless stated otherwise.

B. Critical working areas where delicate tasks impose more stringent criteria than human comfort is outside this standard's scope.

C. Within residential properties, people exhibit a wide variation of tolerance to vibration. Specific values depend upon social and cultural factors, psychological attitudes and the expected degree of intrusion. In practice, the lower satisfactory magnitude should be used, with the higher magnitude being justified on a case-by-case basis.

D. For rock breaking and excavation, daytime is considered to be 08h00 to 18h00 Monday to Friday and 0800 to 13h00 Saturday. Routine rock breaking and excavation would not usually be considered on Sundays or Public Holidays. Other times cover the period outside the working day but exclude night-time, defined as 2300 to 07h00.

Human Response to Other Construction Activities

BS5228-2:2009+A1:2014 [R-84] guides vibration levels' effects on human response to vibration for other construction activities.

Table 11-4 presents the vibration thresholds for human response.

Table 11-4 Human Response Guidance from BS5228-2:2009+A1:2014 [R-84]

Vibration Level	Effect
0.14 mm/s	Vibration might be perceptible in the most sensitive situations for most vibration frequencies associated with construction. At lower frequencies, people are less sensitive to vibration.
0.3 mm/s	Vibration might be just perceptible in residential environments.
1.0 mm/s	It is likely that vibration of this level in residential environments will cause complaints but can be tolerated if prior warning and explanation have been given to residents.
10 mm/s	In most building environments, vibration is likely intolerable for more than brief exposure to this level.

11.2.5 Prediction Methods

This section details the prediction methods used to calculate ground-borne noise and vibration levels during the construction phase and ground-borne vibration levels of moving trains during the operational phase.

11.2.5.1 Construction Phase

The assumptions, predictions and evaluation of impact assessment methodology for the construction and operational phases are presented in this section.

BS 5228-2:2009+A1:2014, BS 6472-1:2008 and BS 6472-2:2008 were used to guide the assessors in predicting the ground-borne vibration impacts during identified stages of construction phases. Where available, local data were used to increase the accuracy of the predictions to account for local ground conditions, including rock breaking, excavation, and TBM activities.

The construction activities' vibration levels were predicted using ArcGIS coding. Based on the matrix, the Impact Intensity is identified depending on the ambient surface thresholds and the area of each zone. This would be used to identify Impact consequences and, subsequently, Impact Significance.

11.2.5.1.1 Rock breaking

Rock breaking works will potentially be carried out at Sungei Kadut Station. When a charge is released in a rock-breaking hole, much energy is used to break up the rock and displace it from its original position. However, some energy is always left over, converted into a vibration that travels away from the rock-breaking area through the ground as the vibration attenuates with increasing distance away from the rock breaking-hole. The ground-borne vibration level is controlled by the rock breaking design, the distance to the rock breaking, charge weight and the intervening geology.

Rock breaking induced vibration is impulsive, and each event's duration depends on the charge's magnitude. The variable effects of a rock breaking include the number of delay intervals and charge quantities, the method of rock breaking, the separation distance between the charge and the rock breaking site and the geological profile between the receptors and the rock breaking 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 conditions (granite, rocks). Vibration associated with breaking is

predominantly due to the air overpressure exciting the building elements of receptor buildings rather than ground-borne vibration.

The maximum instantaneous charge (MIC) was calculated as part of the assessment. For the impact assessment, the depth of the rock breaking source was assumed to be 15 m below the ground surface at Sungei Kadut Station, based on the latest design levels available at the time of writing this section. The calculated MIC will be the maximum magnitude allowed for the rock breaking, so the ground-borne vibration levels and air overpressure levels will meet the project criteria. For a conservative calculation of the ground-borne noise, the entire transmission path was assumed to be rock, and no damping was applied.

The prediction in the ES is highly conservative. It provides a high-level assessment of the vibration impacts on ecologically sensitive receptors. A study [W-97] 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.

The vibration threshold used for determining the maximum allowable MIC was PPV 5 mm/s for ecological receptors and 15 mm/s for buildings.

Using the guidance of BS 6472-2-2008, the Project predicted 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

$$\boldsymbol{PPV = 1291\left(\frac{x}{\sqrt{MIC}}\right)^{-1.5}}$$

As the rock breaking point at Sungei Kadut Station is close to the existing North South Line (37 m), it is important to determine the allowable MIC that meets the criteria. Based on Equation 1 above, PPV, 14 mm/s occurred at 37 m (horizontal distance) from the source at Sungei Kadut Station, with an MIC of 3.8 kg.

Based on the results, the impact assessment on rock breaking and excavation was carried out based on MIC of 3.8 kg at Sungei Kadut Station.

Table 11-5 Predicted MIC Values Using BS 6472-2-2008 Equation

Sungei Kadut Station	Vertical Distance (m)	Horizontal Distance (m)	Slant Distance (m)	Maximum Instantaneous Charge, MIC (kg)				
				3.7	3.8	5.7	5.9	6.0
				PPV, mm/s				
Human Receptor	14.5	37	40	13.7	**14.0**	19.0	19.5	19.8
Ecological Receptor	13	534	534	0.3	0.3	0.4	0.4	0.4

The predicted vibration levels of rock breaking and excavation are presented in Section 11.8.

11.2.5.1.2 Rotary Bored Piling

Piling works will be carried out at Intermediate Station, Sungei Kadut Station (DTL and NSL), and structure columns of the vehicular bridge, Pedestrian Linkbridge and the above ground potential future infrastructure. For this study, the construction ground-borne vibration impact assessment assumed the rotary bore pilling method as this is the most commonly used piling method in Singapore during construction. However, at the time of writing this report, there is no formula to predict the vibration levels from the rotary bore piling.

AECOM predicted the vibration levels using regression analysis of the historical data set (**Figure 11-2**). For a conservative assessment, Contract 9175 considered 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: $\boldsymbol{PPV = 102.31x^{-2.073}}$

$\boldsymbol{y = 102.31x^{-2.073}}$

Where y is the predicted PPV level and x is the distance between source and receptor.

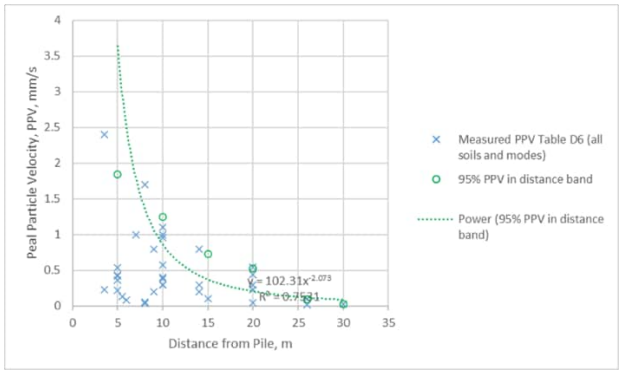


Figure 11-2 Vibration Prediction Curve for Rotary Bore Piling

The regression line calculation to predict vibration levels for rotary bore piling is detailed in Appendix T.

11.2.5.1.2.1 Vibratory Piling

Vibratory piling will happen at worksites for removal of temporary works and re-instatement. The ground-borne vibration levels caused by vibratory piling were predicted using the steady-state method stated in BS 5228-2:2009+A1:2004.

$$\boldsymbol{v_{res} = \frac{k_v}{x^{\delta}}}$$

Where:

$\boldsymbol{v_{res}}$ is the resultant $\boldsymbol{ppv}$, in millimetres per second (mm/s)

$\boldsymbol{k_v}$ is the scale factor, where 60.0 is used

$\boldsymbol{\delta}$ is 1.4 at steady-state operations

$1 \leq \boldsymbol{x} \leq 100$ m

$\boldsymbol{x}$ is the distance measured along the ground surface, m

11.2.5.1.3 Vibratory Compactors

Vibratory compactors will be used for temporary road diversions and at worksites. The construction ground-borne vibration impacts generated from vibratory compactors will depend on the type of compactor used (low or high). Generally, a low amplitude vibratory compactor is preferred to keep the vibration levels low during construction activities. For this study, assessments were conducted for both low and high vibratory compactors.

The vibration level from the vibratory compactor was predicted using the formula from BS5228-2:2009+A1:2004. The equation was 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 1.72 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, 2.13 mm

The ES assessed the vibration impacts from a typical sizeable vibratory compactor. Note that the elevation near the temporary road access differs slightly. However, backfilling was not included in our assessment.

11.2.5.1.4 Tunnel Boring

Tunnel boring will occur along the entire main DTLe alignment and sections of the Reception Track. Ground-borne vibration will potentially be prominent on the overlying ground surface and buildings. Typical sources of ground-borne vibration during the tunnelling process include tunnel boring machines and excavators, tunnel segmental lining placement and hydraulic drilling.

This study assessed the vibration impacts of tunnel boring in along the main DTL2e alignment and Reception Track. 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 homogeneous; however, to simplify the process for the assessment, it was assumed to be. The predicted results will potentially be highly conservative since the formula is applicable for all soil types.

$$\boldsymbol{v_{res}} \leq \frac{\boldsymbol{180}}{\boldsymbol{r^{1.3}}}$$

Where:
$\boldsymbol{v_{res}}$ is the resultant $\boldsymbol{ppv}$, in millimetres per second (mm/s)
$\boldsymbol{r}$ is the slope distance from the tunnel crown, in metres (m), $10 \leq \boldsymbol{r} \leq 100$ m

11.2.5.1.5 Ground-borne Noise

11.2.5.1.5.1 Tunnel Boring

The ground-borne noise levels caused by tunnel boring were predicted using the method stated in BS 5228-2:2009+A1:2004.

$$L_p = 127 - 54\, log_{10} r$$

Where

L_p is the ground-borne noise in dB(A)
r is the slope distance from the tunnel crown

11.2.5.1.5.2 Other Construction Activities

To predict ground-borne noise from other construction activities (i.e., rock breaking and excavation, rotary bored piling, vibratory compactor, and vibratory piling), AECOM converts the predicted PPV level from the construction activity into decibels:

$$L_v = 20 \log\left(\frac{\frac{PPV}{1000}}{1e-9}\right)$$

Where
PPV is the predicted Peak Particle Velocity in mm/s
L_v is the vibration velocity in dB re $1e-9$ m/s
Calculate ground-borne noise:

$$L_p = L_v - 27$$

Where
L_p is the ground-borne noise in dB
Assuming that the dominant frequency is 50 Hz, ground-borne noise in A-weighted decibel is:

$$L_{pA} = L_v - 27 - 30$$
$$= L_v - 57$$

Where
L_{pA} is the ground-borne noise in dB re 20 µPa

For a conservative calculation of the ground-borne noise, the entire transmission path is assumed to be soil/rock and no damping is applied. The correction from soil/bedrock to pile depends on actual site condition and correction of -10 dB is assumed for conservative approach when considering the coupling loss into the building structure, as the receptors are mainly buildings with more than 10 storeys. Sensitive building receptors which have levels below ground surface will consider basement as the worst affected level and other building receptors will consider the ground floor as the worst affected level.
The derived vibration velocity (L_v) in dB(V) is then converted to an A-weighted ground-borne level. The correction factor for conversion from vibration velocity to noise is -27 dB and the correction for A-weighting at 50 Hz is -30 dB(A). Therefore, the correction for conversion from linear to A-weighted noise is -57 dB(A).

11.2.5.2 Operational Phase

This section outlines the prediction method for ground-borne vibration generated by moving trains during the operational phase. The following assumptions were taken to develop the prediction model:

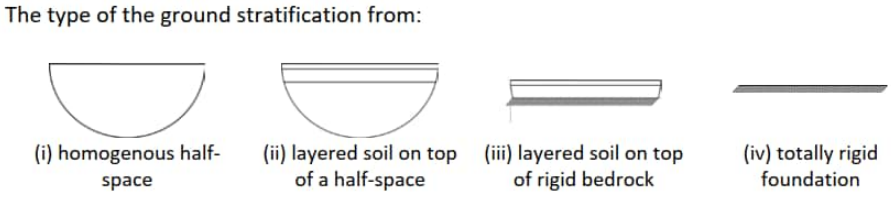
- Train speed of 90 km/h at the subsurface alignment;
- The peak number of train services per hour (in each direction) of 40 trains; and
- The base case track is a slab track.

11.2.5.2.1 Prediction Model for Vibration

The prediction model was developed in the MOTIV (Modelling of Train Induced Vibration) software. This software is a semi-analytical computational tool for calculating vibration from the surface and underground railways and assessing the performance of vibration countermeasures at the track and/or the train vehicle(s).

In underground cases, the track/tunnel was modelled as an infinitely long structure, and the ground was modelled as a layered infinite soil medium. Some examples of the ground model, slab track, tunnel model and vehicle model are shown in Figure 11-3.

Detailed parameters and graphical results can be seen in Appendix Z.



Example of the ground models in MOTIV.

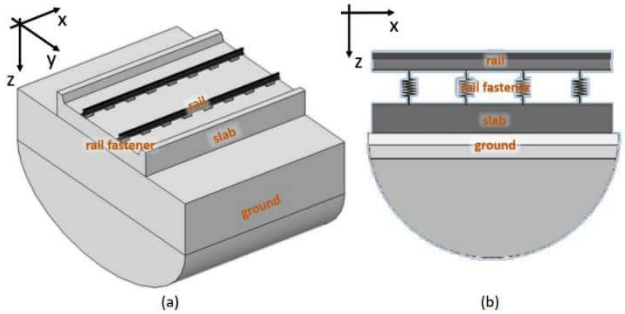
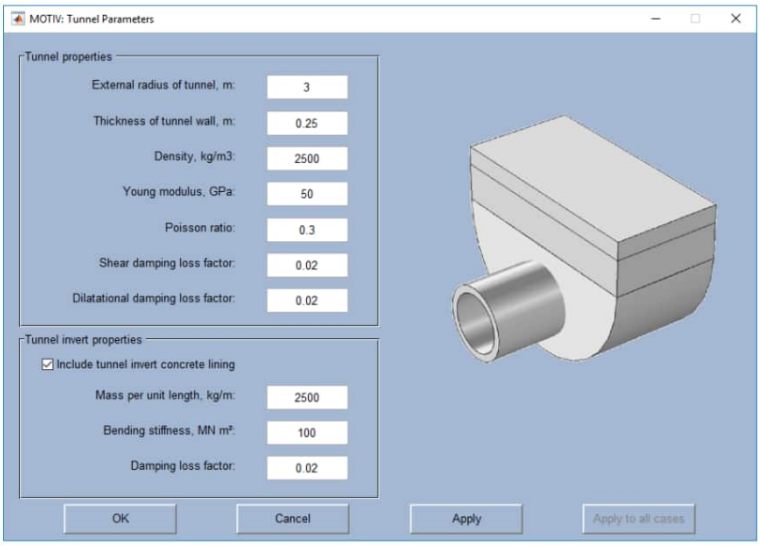


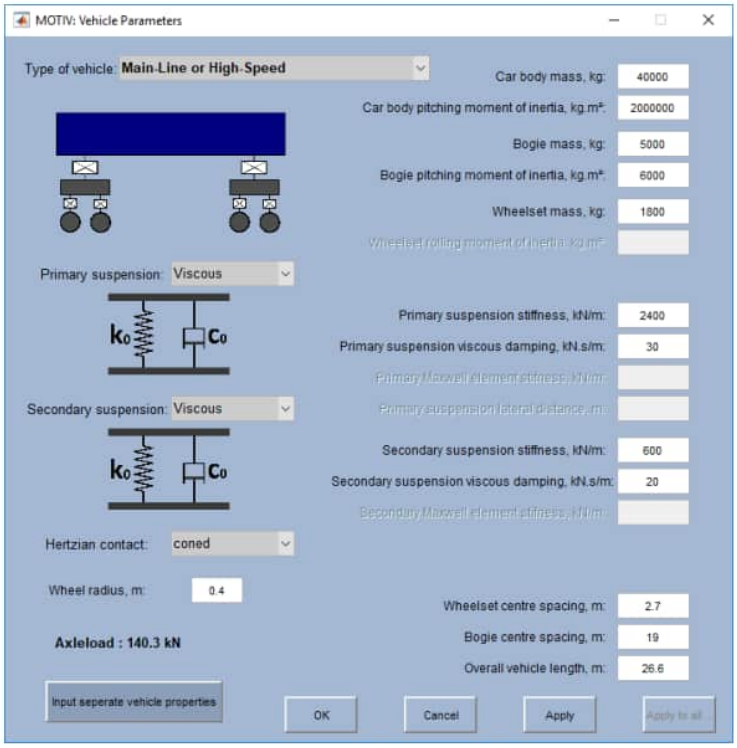
Figure 3.84. The standard slabtrack: (a) graphical illustration; (b) the spring-mass-beam model

Example of the slab track model in MOTIV.



Example of the tunnel parameters in MOTIV.

Figure 4.17. The Tunnel Parameters window



Example of the vehicle parameters in MOTIV.

Figure 5.4. The Vehicle Parameters window.

Figure 11-3 Examples of Parameters in MOTIV

The results from the vibration prediction model were used to calculate the PPV and VDV for ground-borne vibration plus the sound pressure level as follows:

1. The vibration prediction model produced an RMS Velocity output in dB m/s.
2. The RMS Velocity in dB m/s was converted into Peak Particle Velocity (PPV) in mm/s using an RMS to Peak factor of 3.16.
3. The RMS Velocity results were also used to calculate the overall A-weighted acceleration for the one-third octave band frequency (Hz) in m/s2, which was used to calculate the VDV in m/s1.75 for one train.
4. The VDV in m/s1.75 for one train was used to calculate the day and night time VDV according to the number of trains during the day and night:
5. The daytime VDV was calculated based on a 16-hour day period, referring to 7 am – 11 pm for any day.
6. The corresponding 8-hour night period was 11 pm - 7 am.

7. Finally, the A-weighted acceleration for the one-third octave band frequency was used to calculate the overall Sound Pressure Levels (SPL) LA, RMS in dB
8. An estimated correction of 10 dB was added to LA, RMS to convert into SPL LAmax, slow in dB, which are the ground-borne noise levels seen in Section 11.8.

11.2.6 Impact Consequence

A consequence category is derived based on receptor sensitivity and impact intensity, as shown in Section 6.4.2.1.

11.2.7 Likelihood

Following the assessment matrix in Table 6-8 and Table 6-9, the impact intensity and classification of the sensitive ecological species derive the impact consequence. Given the effect of impact consequence and the likelihood of vibrational impacts on the species, an impact significance is derived for the ecological vibration study area.

The likelihood is estimated based on experience and evidence that previously occurred such an outcome. Impacts resulting from routine/planned events (normal operations) are classified under **High Likelihood**.

For operational phase impact assessment, the ground-borne vibration impact assessment will use a quantitative manner to assess impacts from the operation of the underground train movements.

Table 11-6 discusses the calculation of the percentage of occurrence (Likelihood).

Table 11-6 Likelihood Evaluation for Ground-borne Noise and Vibration Impact Assessment

Activity	Frequency of Exposure	Likelihood of Occurrence
Rock Breaking and Excavation	Work period = 1 (Instantaneous) Active vibration period for Machinery = 1 1 x 1 = 1	**Certain**
Rotary Bore Piling	Work period = 0.5 (Diurnal) Active vibration period for Machinery = 0.5 0.5 x 0.5 = 0.25	**Possible**
Vibratory Compactor	Work period = 0.5 (Diurnal) Active vibration period for Machinery = 0.14 0.5 x 0.14 = 0.07	**Less Likely**
Vibratory Pile Driver	Work period = 0.5 Active vibration period for Machinery = 0.5 0.5 x 0.5 = 0.25	**Possible**
Tunnel Boring Machine (TBM)	Work period = 1 (One day) Active vibration period for Machinery = 0.72 0.72 x 1 = 0.72	**Certain**
Operational	MRT operational period per 24 h = 0.8 Single direction* passing within 24 h = 0.23 0.8 x 0.23 = 0.20	**Possible**

Note: *Each train is isolated in its individual single-bored tunnel passing in one direction (Sungei Kadut Bound or Sungei Bedok Bound). Should two trains cross paths in opposite directions, ground-borne vibration will still remain low as the PPV will be logarithmically added.

11.2.8 Impact Significance

Impact Significance is 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 11-6. Impact Significance was evaluated in accordance with the matrix presented in Table 6-9.

11.2.8.1 Mitigation Measures and Monitoring Programme Recommendation

Based on the impact evaluation outcome, ground-borne vibration mitigation measures were recommended for the affected ecological and human sensitive receptors using the principle of elimination, substitution, engineering controls, administrative controls etc. Besides this, an environmental monitoring program should be suggested to make sure that the findings of the ES are validated during the actual phase and controlled/ monitored or re-evaluated if the reality is different from the predicted levels and corrected on ad hoc basis before resuming works.

11.2.8.2 Establishing Residual Impact Significance

Once mitigation measures were recommended, a residual impact significance using the same significance matrix was used to re-evaluate the residual impact. Ideally, this residual impact should be reduced to insignificant levels, else iterative process of suggesting mitigating measures should continue unless the impacts are reduced to as low as reasonably practicable using cost benefit analysis. The residual Impact Significance was evaluated using the matrix outlined in Table 6-9.

11.3 Potential Sources of Impacts

11.3.1 Construction Phase

Traffic vibration is mainly due to heavy vehicles passing at relatively high speeds on the access roads or an uneven surface profile of internal roads or a worksite. Interaction between wheels and road surface causes a dynamic excitation, generating waves propagating in the soil and nearby sensitive receptors. The road-induced ground-borne vibration impacts are usually minimal unless there are frequent potholes in the road and the heavy construction vehicles travel at high speed to and from the worksites.

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 of about 50 Hz. Material absorption will aggressively attenuate those vibrations about this frequency (and higher). Such vibrations are unlikely to remain significant outside the worksite boundary, but these are more significant than heavy construction vehicles hence assessed in this section. Table 11-7 below summarizes the potential sources of ground-borne noise and vibration impacts during construction phase.

Table 11-7 Potential Sources of Ground-borne Noise and Vibration Impacts during Construction Phase

Construction Activity	Associated Impacts
• Rock breaking and excavation • Tunnel boring using the TBM • Compacting concrete using the vibrator equipment	Human Receptors (Ground-borne noise and vibration) • Human annoyance • Building cosmetic damage

Construction Activity	Associated Impacts
• Piling works for Station, Pedestrian Linkbridge, vehicular bridge, and potential future infrastructure • Heavy construction vehicles • Other construction equipment • Stationary equipment with diesel engines	• Interference with vibration sensitive equipment <u>Ecological Receptors (Ground-borne vibration)</u> • Ecological foraging behaviour • Breeding season

11.3.2 Operational Phase

During the operational phase, the vibration sources will potentially be the operation of the alignment and traffic in the Study Area, affecting the ecological receptors. Train-induced vibration is mainly caused by the roughness of the wheel and rail. Vibration from operating trains also depends on the resonance frequencies of the train suspension and track support systems. These mechanical systems have resonances that result in increased vibration response.

Traffic vibration is mainly due to heavy vehicles passing at relatively high speeds on the road with an uneven surface profile. Interaction between wheels and road surface causes a dynamic excitation which generates waves propagating in the soil and to the foundations of nearby sensitive building receptor structures. During the operational phase, the vibration sources are presented in Table 11-8.

Vibration due to operational phase on human receptors was assessed in detail in the Contract 9175 Noise & Vibration Study (NVS) Preliminary Report. The summary of sources and potential associated impacts on human receptors extracted from the NVS report are presented in Table 11-8.

Table 11-8 Potential Sources of Ground-borne Vibration Impacts during Operational Phase

Operation Activity	Potential Associated Impacts
• Alignment • Road Traffic	Human Receptors (Ground-borne noise and vibration) • Human annoyance • Building cosmetic damage • Interference with vibration sensitive equipment <u>Ecological Receptors (Ground-borne vibration)</u> • Ecological foraging • Behaviour disruption and potential displacement over a while

Based on the land use of the Project site, the presence of heavy vehicles at relatively high speed will be rare. Given that the construction of roads in Singapore will relatively have an even surface profile, it is unlikely that the road traffic will cause high ground-borne vibration levels in the Project site and will not significantly impact nearby sensitive receptor buildings and ecological receptors. Section 11.8.2 discusses the impact prediction and evaluation during the operational phase.

11.4 Identification of Sensitive Receptors

11.4.1 Ecological Receptors

Vibration sensitive ecological receptors were 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 were not assessed.

Based on Section 7.3.2, the faunistic baseline results recorded 293 faunal species, broadly categorised into 227 terrestrial species (odonates, butterflies, herpetofauna and mammals) and 66 aquatic species

(fish, decapod crustaceans, mollusc and limulids). The terrestrial fauna community is dominated by birds (99 species) and butterflies (59 species). The aquatic fauna community is dominated by molluscs (37 species). Due to the construction activities' proximity and trains' operation to the ecologically sensitive areas - Sungei Pang Sua, Pang Sua Canal and the Rail Corridor; ground-borne vibration impacts on fauna were assessed.

11.4.1.1 Terrestrial Fauna

Based on observations from other site surveys at Mandai and literature on the species' behaviour, 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.

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. 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 Mouse-deer [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 7.2.2.3). Therefore, the site's fossorial fauna 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 acts 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 11.2.5.1.1). 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 susceptible 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 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 depend highly on hearing to avoid bat predation (Yack & Fullard, 2000). As such, lepidopterans are highly vibration sensitive species

Snakes, in general, are deaf as they do not have an ear [P-76]. Therefore, vibration energy usually impacts the behaviour of these creatures, and they are startled by vibration.

Sunda colugo (Galeopterus variegatus) is a nocturnal mammal. It 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). 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 they spend most of their time above ground on trees, these creatures potentially experience low sensitivity to ground-borne vibration.

Insufficient research or literature on vibration impacts on the Greater Mouse-eared Bats. However, a study conducted 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 of PPV, 0.4 - 0.6 mm/s and a noise level of 60 dB(A) were measured at 50 m from the drill. 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).

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 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.

Arial 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.

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 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 different. 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 they have a high sensitivity to ground-borne vibration. Table 11-9 discusses the literature review's vibration thresholds for different terrestrial species.

Table 11-9 Vibration Thresholds (PPV, mm/s) from Literature Review of Terrestrial Species

Receptors	Frequency, Hz	Acceleration, m/s^2	Vibration Thresholds, PPV, mm/s
Bees	2500	0.3	< 0.1
Caterpillars (*Lipidopteran larvae)*	-	-	0.6
Frogs	-	-	< 0.1
Pilbara Leaf-Nosed and Ghost Bat	-	-	0.4 - 0.6
Snakes	300	< 0.1	< 0.1
Rats	20	1.2 – 39.2	0.3 – 312
Mice	70 – 110	0.25 - 1	0.4 – 2.3
Pigs	2 – 80	3 – 32	8.8 – 238.7
Tortoise Burrow	-	-	25.4
Rhesus monkeys	6 – 30	9.8	52 – 260.1

11.4.1.2 Aquatic Fauna

Literature reviews showed that different substrate-borne and water-borne species were affected by vibration in different frequencies, acceleration and PPV.

There are several forms of vibrations within the substrate. One form of substrate vibration is the seismic surface wave that propagates along the surface of the substrate and produces particle motion that enters the water column to generate underwater noise [P-56]. Therefore, aquatic fauna living close to, on, and/or within the substrate can detect the vibration signals. The ability to detect these signals is related to the species' biological sensitivity frequency range. Based on the literature review, some fishes and many invertebrates can detect pressure changes in water, but very little is known about their sensitivity to the vibration generated within and close to the substrate.

According to a study which examined vibration from piling and dredging propagation in substrate medium, finite element (FE) modelling showed that seismic surface waves do not radiate energy into

the water above or the sediment below but create evanescent sound waves confined mainly to the bottom 1 m of water.

Based on research [P-58], fishes and their embryos have a high tolerance toward vibration levels. A study shows that mortality was recorded for the Rainbow trout embryos at vibration levels above Peak Particle Velocity (PPV), 132 mm/s, caused by blasting. Other species of embryos have recordings showing 10% mortality caused by vibration levels, PPV, 145 – 838 mm/s. Records have shown that aquatic vertebrates are more sensitive to substrate vibration.

Crabs displayed sensitivity (such as startling and spikes in nerve recordings) from 20 Hz to 200 Hz. The RMS does not exceed 0.1 $m/s^{2,}$ and PPV does not exceed 0.2 mm/s at these frequencies. At a higher frequency of 400 Hz, the Ocypode ceratophtalmus (horn-eyed ghost crabs) and Uca pugilator (Atlantic sand fiddler crab) experienced different sensitivity, failure, and electrophysiological effects, with an RMS of 0.12 m/s^2 and PPV of 0.05 mm/s.

Likewise, shrimps, lobsters and crayfishes experienced adverse effects such as bradychardia and flicking of the large antenna at a vibration frequency ranging from 20 – 200 Hz. The RMS experienced was up to 1.4 m/s^2 while the PPV was up to 1.11mm/s. However, at 113 Hz and RMS of 50.2 m/s^2, the *Pandalus borealis* (caridean shrimp) displayed movements such as grasping the substrate, stretching the abdomen and intense beating in response to the stimulus.

The *Mytilus edulis* (marine bivalve) showed clear valve gap changes, with full and partial valve closure responses. This occurred at 210 Hz, at RMS, 0.55 m/s^2 and PPV, 0.42 mm/s. The *Dreissena polymorpha* (juvenile zebra mussel) could be detached from the surface at 8000 – 140000 Hz, RMS 33.6 - 58.9 m/s^2 and PPV, 0.67-1.17 mm/s.

Studies have shown 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. Hence, it is assumed that the species have low sensitivity.

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.

Table 11-10 discusses the literature review's vibration thresholds for different aquatic species.

Table 11-10 Vibration Thresholds (PPV, mm/s) from Literature Review of Aquatic Species

Receptors	Frequency, Hz	Acceleration, m/s^2	Vibration Thresholds, PPV, mm/s
Shore Crabs	20	0.1	1.1
Uca pugilator (Atlantic sand fiddler crab)	400 30 20	0.1	< 0.1
Carcinus Maenas (european green crab)	20 – 200	< 0.1	< 0.1
Pagurus bernhardus (common hermit crab or soldier crab)	90	0.1	0.2
Uca rapax (mudflat fiddler crab)	60	0.1	0.2
Uca minax (red-jointed fiddler crab or brackish-water fiddler crab)	90 50	< 0.1	< 0.1
Pandalus borealis (caridean shrimp)	170	50.2	0.9
Mytilus edulis (marine bivalve)	210	0.6	0.4
Dreissena polymorpha (juvenile zebra mussel)	8000 – 14000	33.6 – 58.9	0.7 – 1.2
Fish	-	-	0.5 – 1.1

In summary, the sensitivity of the ecological receptors for terrestrial and aquatic species is categorised into Priorities 1, 2 and 3. The assessment focuses on Priority 1 vibration sensitive species with conservation status and low mobility.

Table 11-11 discusses the classification of ecological receptor sensitivity for ground-borne vibration.

Table 11-11 Ecological Receptor Sensitivity for Ground-borne Vibration

Environmental Parameter	Receptor Sensitivity		
	Priority 1	**Priority 2**	**Priority 3**
Ground-borne Vibration	Vibration sensitive species with conservation status and low mobility (e.g., mud lobster, Sunda pangolin)	Vibration sensitive species without conservation status and low mobility (e.g., *Athanas polymorphus*)	Vibration sensitive species with high mobility; and species not sensitive to vibration (e.g., Brown rat)

11.4.2 Human Receptors

Ground-borne noise and ground-borne vibration sensitive receptors were identified within 100 m from the construction worksites and 100 m from the centre of alignment. The sensitive receptors were classified per Priority 1, Priority 2 and Priority 3 based on their sensitivity to ground-borne noise and ground-borne vibration impacts, as shown in Table 6-2. Based on the human receptors surveyed for this Project, there are no Priority 1 sensitive receptors within 100 m of the worksite and 100 m from the centre of the alignment. Thus, only Priority 2 and Priority 3 sensitive receptors were assessed in this report. LTA has requested AECOM to also include the assessment to a future JTC building that will sit directly on top of the alignment. Based on the timeline, the only activity that will cause vibration impact to the future JTC building is tunnel boring, as all other construction activities are likely to be completed at this stage. Thus, AECOM has included this building in the assessment for TBM. A summary of ground-

borne noise and vibration sensitive receptors are presented in Table 11-12. The detailed list of sensitive receptors is listed in Appendix Y.

Table 11-12 Summary of Ground-borne Noise and Ground-borne Vibration Sensitive Receptors

Priority	Number of Sensitive Receptors
Priority 1	0
Priority 2	Residential – 37 Educational Institution – 1 Place of Worship – 1
Priority 3	Recreational – 2 Commercial – 2 Industrial – 104+1*
Total	147+1*
Note: * The future JTC building above the alignment was only included in the assessment for TBM impacts.	

11.5 Ground-borne Vibration Baseline Findings

Primary and secondary data were used to establish the baseline conditions of vibration levels from existing natural and anthropogenic (human) sources.

Baseline ground-borne vibration monitoring was conducted at seventeen (17) locations to represent the baseline vibration levels of the study area. AECOM used the Svantek 958A with the SV207B tri-axial accelerometer to monitor the baseline vibration levels. The monitoring equipment was set to record Peak Particle Velocity PPV data at 1-minute intervals for one week at V1-11 and three days at VR1-6. The monitoring duration for locations with less volatile activities was shorter as the vibration levels were fairly constant.

Vibration monitoring locations V1, V2, V4 to V6, VR1 to VR4 and VR6 were located near roads/bridges with frequent vehicular activities, cyclists and passers-by. Monitoring locations V3, VR6 and V9 are within the Sungei Kadut Industrial Area, and the surroundings are factories and roads. V9 was near the Rail Corridor, and VR6 was close to passers-by and heavy vehicles (buses, trucks, and lorries). V10 and V11 were near the existing NSL viaduct. Other vibration sources could be due to weather elements and wildlife movement in the vicinity. Therefore, this study used the assessment's 99th percentile of the baseline vibration levels; refer to Table 11-13 and Appendix X.

Table 11-13 Summary of Baseline Ground-borne Vibration Levels

Monitoring Location	Date & Time	99th Percentile Baseline Vibration Levels, PPV, mm/s		
		x-axis	*y-axis*	*z-axis*
V1: Opp Sungei Kadut Firepost	21st December 2021 – 27th December 2021	0.19	0.19	0.23
V2: Groundwork Interior	3rd February 2022 – 10th February 2022	0.08	0.07	0.09
V3: BHL Factory	10th December 2021 – 16th December 2021	0.08	0.07	0.15
V4: 691B CCK Crescent	2nd December 2021 – 8th December 2021	0.06	0.06	0.03
V5: Behind 5 Stagmont Ring	24th January 2022 – 31st January 2022	0.08	0.08	0.08

Monitoring Location	Date & Time	99th Percentile Baseline Vibration Levels, PPV, mm/s		
		x-axis	*y-axis*	*z-axis*
V6: 5 Stagmont Ring	24th January 2022 – 31st January 2022	0.04	0.06	0.09
V7: Under KJE	3rd February 2022 – 10th February 2022	0.07	0.05	0.09
V8: 634A Senja Road	2nd December 2021 – 8th December 2021	0.02	0.02	0.03
V9: Sri Arasakesari Sivan Temple	10th December 2021 – 16th December 2021	0.04	0.04	0.07
V10: Beside Existing NSL Viaduct	21st July 2022 – 28th July 2022	0.15	0.19	0.20
V11: Beside Mud Lobster Mounds	28th July 2022 – 4th August 2022	0.22	0.24	0.28
VR1: End of Rail Corridor	18th February 2022 – 20th February 2022	0.03	0.02	0.05
VR2: Near Sri Ava Temple	18th February 2022 – 20th February 2022	0.05	0.06	0.04
VR3: Along Rail Corridor Opposite MSCP	14th February 2022 – 17th February 2022	0.02	0.03	0.03
VR4: Near 5 Stagmont Ring	14th February 2022 – 17th February 2022	0.04	0.04	0.05
VR5: Behind Heavy Vehicle Parking	11th February 2022 – 14th February 2022	0.06	0.05	0.08
VR6: Near Junction 10	11th February 2022 – 14th February 2022	0.05	0.06	0.06

Table 11-14 discusses the dominant frequency for the 99th percentile acceleration levels, RMS (root mean square) monitored during baseline. The dominant frequency does not indicate the PPV peak during that time domain. The RMS (root mean square) value is directly related to the vibration profile's energy content and, thus, the vibration's destructive capability. RMS also considers the time history of the waveform. The RMS values were reviewed to draw parallel conclusions against the literature on vibration thresholds for fauna.

Table 11-14 Dominant Frequency of Z-axis

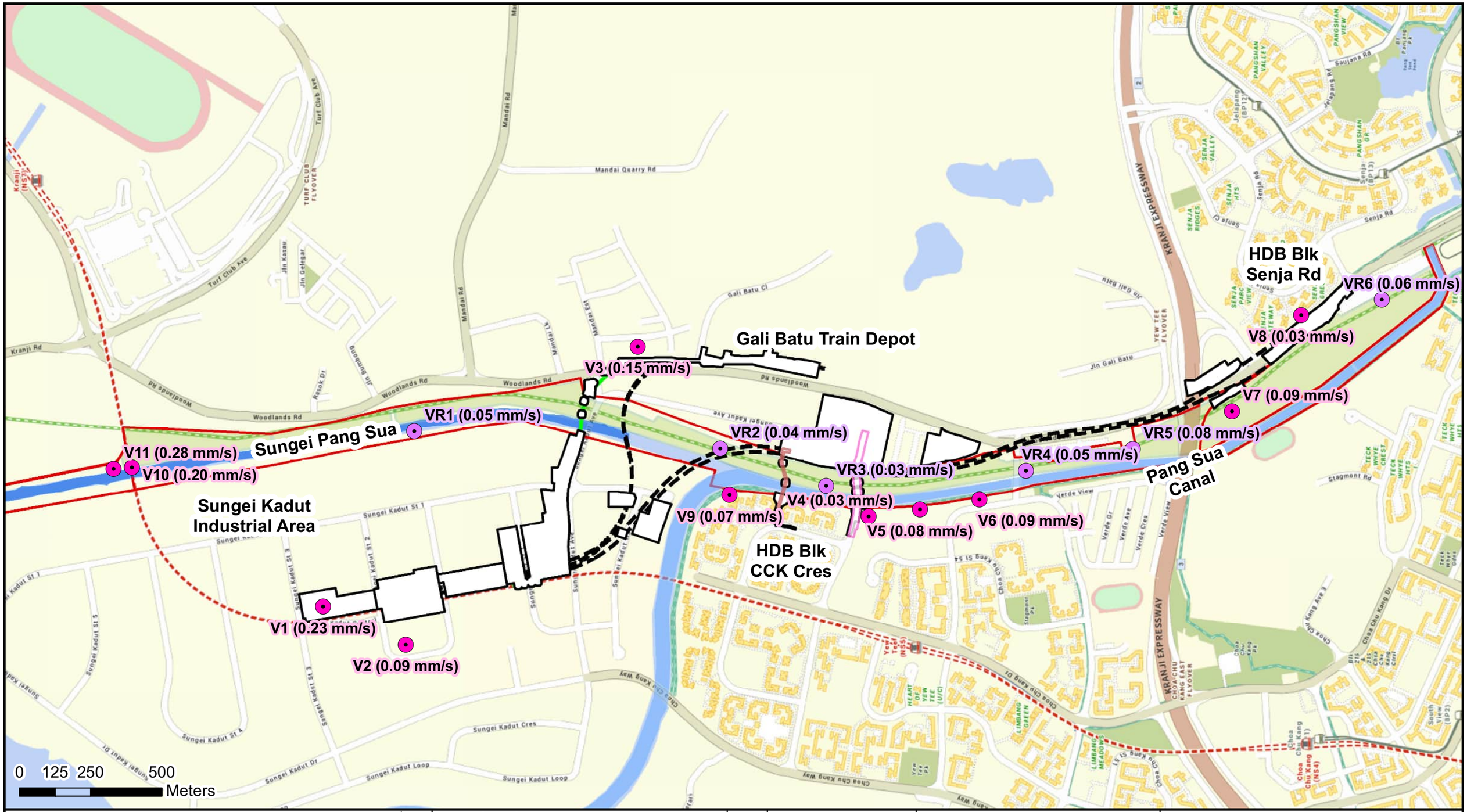
Monitoring Location	Date & Time	Z-axis 99th Percentile Acceleration Levels, RMS, mm/s^2	Dominant Frequency, Hz
V1: Opp Sungei Kadut Firepost	21st December 2021 – 27th December 2021	5.56	25
V2: Groundwork Interior	3rd February 2022 – 10th February 2022	5.13	125
V3: BHL Factory	10th December 2021 – 16th December 2021	2.88	160 & 200
V4: 691B CCK Crescent	2nd December 2021 – 8th December 2021	0.50	20
V5: Behind 5 Stagmont Ring	24th January 2022 – 31st January 2022	0.56	63
V6: 5 Stagmont Ring	24th January 2022 – 31st January 2022	0.77	6.3 & 8
V7: Under KJE	3rd February 2022 – 10th February 2022	2.01	160
V8: 634A Senja Road	2nd December 2021 – 8th December 2021	0.65	1600
V9: Sri Arasakesari Sivan Temple	10th December 2021 – 16th December 2021	0.004	1600

Monitoring Location	Date & Time	Z-axis 99th Percentile Acceleration Levels, RMS, mm/s^2	Dominant Frequency, Hz
V10: Beside Existing NSL Viaduct	21st July 2022 – 28th July 2022	0.018	160
V11: Beside Mud Lobster Mounds	28th July 2022 – 4th August 2022	0.002	100
VR1: End of Rail Corridor	18th February 2022 – 20th February 2022	1.50	1250
VR2: Near Sri Ava Temple	18th February 2022 – 20th February 2022	0.75	160
VR3: Along Rail Corridor Opposite MSCP	14th February 2022 – 17th February 2022	0.48	100
VR4: Near 5 Stagmont Ring	14th February 2022 – 17th February 2022	0.66	100 & 5000
VR5: Behind Heavy Vehicle Parking	11th February 2022 – 14th February 2022	2.19	160
VR6: Near Junction 10	11th February 2022 – 14th February 2022	2.41	125 & 5000

The nearest vibration baseline monitoring location to the mouth of Sungei Pang Sua is VR1 with a PPV of 0.05 mm/s and RMS of 1.50 mm/s^2 at 1250 Hz. Thus, these values were referenced to compare against the literature review on underwater and mudflat species. The existing baseline at VR1 was considered high compared to the literature review of the crabs, shrimps, lobsters and crayfish. Despite the RMS of VR1 being higher than the thresholds of the marine bivalves, the dominant frequency differs. The baseline results at VR1 were significantly lower compared to the thresholds of the juvenile zebra mussels. For terrestrial species, baseline monitoring results from V5 - V7 and VR2 - VR5 along the Rail Corridor were referenced to compare against the lithe literature review.

Table 11-10 discusses the frequencies at which the fauna will be affected. It is noted that the frequencies of interest are similar for the aqua species, except for bees at 2500 Hz.

In addition, the baseline results at these locations have dominant frequencies within this range, and the RMS of the baselines were lower than most of the fauna thresholds except mice (with the lowest threshold at 0.245 m/s2). Likewise, the baseline vibration levels were generally lower than the thresholds of fauna except for bees (PPV, 0.02 mm/s), frogs (PPV, 0.00159 mm/s) and snakes (PPV, 0.0016 mm/s).



Legend

- Vibration Baseline Rail Monitoring Locations
- Vibration Baseline Monitoring Locations
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Proposed Worksite Areas
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Pang Sua Canal
- Sungei Pang Sua
- Existing Vegetated Area

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Project Title :
CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
VIBRATION BASELINE MONITORING LOCATIONS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	11 - 4	A	1 of 1
	Drawn TTR	Date MAY 2023	CAD File Name :N/A		A3

Note: Source of basemap - OneMap

11.6 Minimum Control Measures

11.6.1 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. It shall be noted that for all construction activities, surveys of burrows shall be conducted when the predicted vibration levels approach or exceed a level of 80 % of the lowest criteria, in this case, ecological criteria.

The minimum control measures are summarised in Table 11-15. Generally, the minimum control has also considered design optimization detailed in Section 3.2.1.

Table 11-15 Minimum Controls during Construction Phase (Ground-borne Vibration)

Potential Source of Impacts	Minimum Controls
• Rock breaking and excavation	• The maximum instantaneous charge per delay must be calculated, planned, and controlled using delay detonators • Ensure that the design of the activities promotes forward movement of the rock mass and allocate proper delay timings between rock breaking holes
• Tunnel boring using the TBM	-
• Compacting concrete using the vibrator equipment	• Use low vibration equipment and construction techniques
• Piling works for Station, Pedestrian Linkbridge, vehicular bridge, and potential future infrastructure	• Use low vibration equipment and construction techniques
• Heavy construction vehicles	• 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 • Limiting the number of vehicles on site during working hours
• Other Construction Equipment	• Use low vibration equipment and construction techniques
• Stationary equipment with diesel engines	• Use low vibration equipment and construction techniques
Note: For all activities, surveys of burrows shall be conducted when the predicted vibration levels approach or exceed a level of 80 % of the lowest criteria, in this case, ecological criteria.	

11.6.2 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 11-16. The Contractor will determine concrete material/density at a later stage.

Table 11-16 Minimum Control Measures during Operational Phase (Ground-borne Vibration)

Minimum Controls
Train, track and tunnel design
Maintenance of vertical track alignment at the relevant longitudinal wavelengths
Maintenance of roughness of the rail head and wheel thread at the relevant longitudinal and circumferential wavelengths, respectively.

Minimum Controls
Maintenance of resilient elements in track construction, e.g., rail pads
Maintenance of rail joints, switches and crossings.

11.7 Assessment Criteria

11.7.1 Impact Intensity

This section outlines the ground-borne vibration assessment criteria for ecological receptors during construction and operation phases. The assessment criteria for human receptors are detailed in Section 11.2.4.

Studies on the behaviour of ecology to vibration are less comprehensive compared to the studies carried out for human behaviour. The vibration sensitivity of ecological receptors is complex and varies across species; thus, developing a standard criterion that fits all applications is challenging. The guiding principles of the assessment criterion are baseline studies of the fauna and vibration conditions.

Section 7 states that 302 faunal species have been recorded within the Study Area during the fauna survey. Details of the baseline vibration monitoring results are presented in Section 11.5.

11.7.1.1 Structural Integrity of Burrows and Mud Lobster Mounds

While not recorded in this study, the globally and nationally critically endangered terrestrial Sunda pangolin (Manis javanica) was deemed likely to occur in the Study Area. The Study Area lies partially along the Rail Corridor. It can serve as a passageway for the dispersal of this wildlife. A study [W-98] has reported that at PPV, 10.0 mm/s, the motion of the ground may cause burrows of fossorial species to be damaged or collapse, causing potential entombment of the fauna and leading to loss of life. The pangolins nest in burrows and have a homerange of 6 hectares. It is unclear what the vibration threshold is for a pangolin burrow to suffer damage due to the lack of information on this species. However, as a preventive measure, vibration impacts on the structural integrity of terrestrial burrows are assessed. Based on AECOM's past project experience, we proposed conservative criteria:

- PPV, 5.0 mm/s to screen for high vibration generating construction and operational activities; and
- PPV, 8.0 mm/s (equivalent to 80% of the vibration threshold recorded in the literature review for a different species) for assessing the structural integrity of terrestrial burrows and mud lobster mounds.

Mudlobster in its mound
(Source: http://www.wildsingapore.com/wildfacts/crustacea/otherc rust/lobster/thalassina.)htm#:~:text=The%20mud%20lobster%20is%20actually,and%20rarely%20emerges%20above%20ground.)

During the fauna survey, active burrows of the mud lobsters (*Thalassina* spp.) were recorded, as seen in Section 7.3.2.3.10. Unlike terrestrial species, the mud lobsters can dig their way out when a burrow collapses. However, since mud lobsters do not have high mobility, vibration impacts on the structural integrity of the mud lobsters are still required.

11.7.1.2 Behavioural Response of Ecological Receptors

In Section 11.4.1, the vibration threshold of observable behavioural changes for terrestrial fauna species varies from zero to PPV, 260 mm/s and the vibration threshold for aquatic species is lower, varying up to PPV, 2.0 mm/s.

There are vibration-generating construction activities and train-induced vibration during the operational phase. Therefore, AECOM proposed an upper bound of PPV, 1.2 mm/s for the Low impact intensity threshold (see Table 6-6), as studies have shown that zebra mussels tend to detach at this PPV (see Section 11.4.1.2). AECOM proposed a vibration threshold of PPV, 5.0 mm/s, for screening behavioural impacts of both terrestrial and aquatic fauna, as seen in Section 11.7.1.1.

Mudlobster in its mound (Source: https://www.usgs.gov/faqs/what-are-zebra-mussels-and-why-should-we-care-about-them)

The ground-borne vibration is more perceptible to some ground-dwelling terrestrial species than to bird and butterfly species [P-64]. For instance, the Sunda pangolin (*Manis javanica*) is a shy creature, and small movements of the ground are likely to provoke them. On the contrary, smooth otters (*Lutrogale perspicillata*) are generally not shy creatures and have high mobility. They also appear to adapt to the activities in the environment. They are unlikely to be provoked by construction and operational-induced vibration.

The vibration of the riverbed is more perceptible to the aquatic fauna - mollusc species, horseshoe crab (*Carcinoscorpius rotundicauda*) and mud lobsters (*Thalassina* spp.) compared to fish species [P-65].

11.8 Prediction and Evaluation of Ground-borne Noise and Vibration Impacts

11.8.1 Construction Phase

The assessments for vibration on ecology and human comfort were conducted to construct the main alignment, reception track, potential future infrastructure, three stations, vehicular bridge and worksites.

11.8.1.1 Impact Assessment of Ground-borne Vibration on Ecological Receptors

11.8.1.1.1 Impact on Structural Integrity of Mud Lobster Mounds

Based on the baseline fauna survey, mud lobster species were sighted and recorded at the Biodiversity Study Area – Rail Corridor of Sungei Pang Sua. The study predicted vibration levels of various construction activities for the assessment. The construction activities for the base scenario are summarised in Table 11-17. Out of all the assessments, only rock breaking and excavation at the docking shaft and tunnel boring had vibration levels that exceeded the screening criteria of PPV 5.0 mm/s.

As the depth of the source becomes deeper and further from the source point, 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 engage with a qualified Ecologist to review and ensure that the impact's magnitude and duration are appropriate. It should be noted that minimal or no ecological use of the worksite happens during the active construction 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. Table 11-17 summarises the assessment of vibration exceedances against the PPV, 8.0 mm/s vibration threshold.

Table 11-17 Summary of Maximum Predicted PPV for Construction Activities (Base Scenario)

Construction Worksite and Activities	Maximum Predicted PPV (mm/s)
	Rail Corridor
Rock Breaking and Excavation (Sungei Kadut Station)	0*
Rotary Bored Piling	1
Vibratory Pile Driver	2
Vibratory Compactor (Low)	1
Vibratory Compactor (High)	4
Tunnel Boring Machine (Hypothetical Overall[11])	4
Tunnel Boring Machine Spot 1 at Reception Track	4
Tunnel Boring Machine Spot 2 at DTLe	5
Tunnel Boring Machine Spot 3 at DTLe	0*
Notes: *The predicted PPV was rounded, PPV level of 0 indicates the predicted PPV is less than 0.5 mm/s. All maximum predicted PPV levels except Tunnel Boring Machine Spot 2 at DTLe, are below the vibration threshold for partial burrow & mud lobster mound collapse (i.e., 8.0 mm/s), as well as the screening criteria of 5.0 mm/s. The maximum predicted PPV at Rail Corridor for Tunnel Boring Machine Spot 2 at DTLe meets the screening criteria of 5.0 mm/s, but below the vibration threshold (i.e., 8.0 mm/s).	

11.8.1.1.2 Behavioural Impacts on Fauna

The assessments in this section focus on the behavioural impacts on Priority 1 fauna receptors within the Rail Corridor. It shall be noted that for TBM for Reception Track requires 37 – 52 days to leave the Biodiversity Study Area, while it takes 237 – 332 days for the main tunnel, depending on the rate of TBM (i.e., 5 – 7 m /day). However, at each spot, the Moderate/ Major impacts only occur at small areas (less than 10 ha). A summary of the impact significances and behavioural impacts can be seen in Table 11-18 and from Figure 11-5 to Figure 11-13.

[11] The hypothetical overall TBM was assessed as complete affected alignment. It should be noted that the tunnel boring machine will only bore section by section along the alignment at a rate of 5-7 m/day. Thus, this assessment also identified the critical spots for detailed hotspot analysis of TBM passage impact on fauna at any particular time.

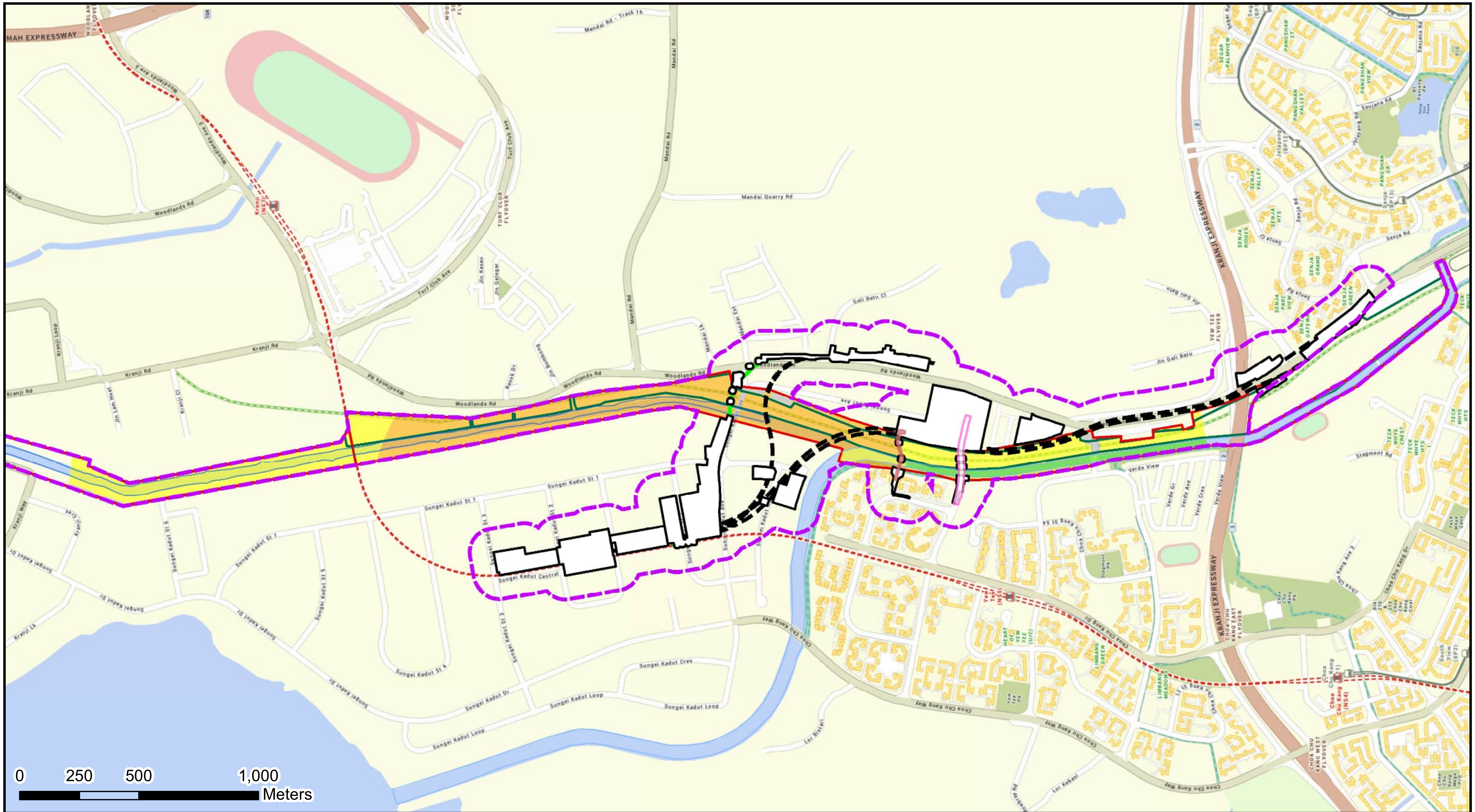
Table 11-18 Predicted Impact Significances and Behavioural Impacts of Construction Activities for Base Scenario

Construction Worksite and Activities	Base Scenario Impact Significance
Worksite	
Rock Breaking and Excavation (Sungei Kadut Station)	Negligible – Moderate
	Impacted Area, ha
	Moderate, 27.5
Rotary Bored Piling	Negligible – Minor
Vibratory Pile Driver	Negligible – Moderate
	Impacted Area, ha
	Moderate, 2.3
Vibratory Compactor (Low)	Negligible – Minor
Vibratory Compactor (High)	Negligible – Minor
Tunnel Boring Machine (Hypothetical overall[12])	Negligible – Major[13]
	Impacted Area, ha
	Moderate, 17.6 Major, 9.2
Tunnel Boring Machine at Spot 1 at Reception Track	Negligible – Major[13]
	Impacted area, ha
	Moderate, 8.8 Major, 0.5
Tunnel Boring Machine at Spot 2 at DTLe	Negligible – Major[13]
	Impacted area, ha
	Moderate, 8.1 Major, 0.4
Tunnel Boring Machine at Spot 3 at DTLe	Negligible – Moderate
	Impacted area, ha
	Moderate, 0.5
Summary: Overall, the construction activities impact the significance of **Minor, Moderate** and **Major**. 1. For **Minor** impact significances, some sensitive fauna may be impacted. At the same time, other species may avoid the area because of the increased levels of activity in the area. Many species would become habituated to the tunnel boring machine. When the machine passed, they would return to regular activity in a few days. 2. For **Moderate** impact significance, it 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. Displacement is expected to be temporary, and they are expected to return after a while. 3. **Major** impact significances may cause permanent effects, and affected indicator species are not expected to adapt to using this area. Reasonable to assume that vibration from tunnel boring may impact part of their habitat (pangolins' burrows), breeding and foraging opportunities.	

[12] The hypothetical overall TBM was assessed as complete affected alignment. It should be noted that the tunnel boring machine will only bore section by section along the alignment at a rate of 5-7 m/day. Thus, this assessment also identified the critical spots for detailed hotspot analysis of TBM passage impact on fauna at any particular time.

[13] Note that the impact of the TBM is only for a short duration and at a small area when the TBM passes the receptors.

Construction Worksite and Activities	Base Scenario Impact Significance
Worksite	
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. a. During rock breaking and excavation, sensitive fauna may also flee, freeze or be frightened by the instantaneous vibration. Thus, mitigation measures are recommended, as discussed in Section 11.9.1.	



Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor
- Moderate
- Not Assessible

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ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :

GROUND-BORNE VIBRATION IMPACT SIGNIFICANCE FOR ROCK BREAKING AND EXCAVATION (SUNGEI KADUT STATION) ON ECOLOGICAL RECEPTORS

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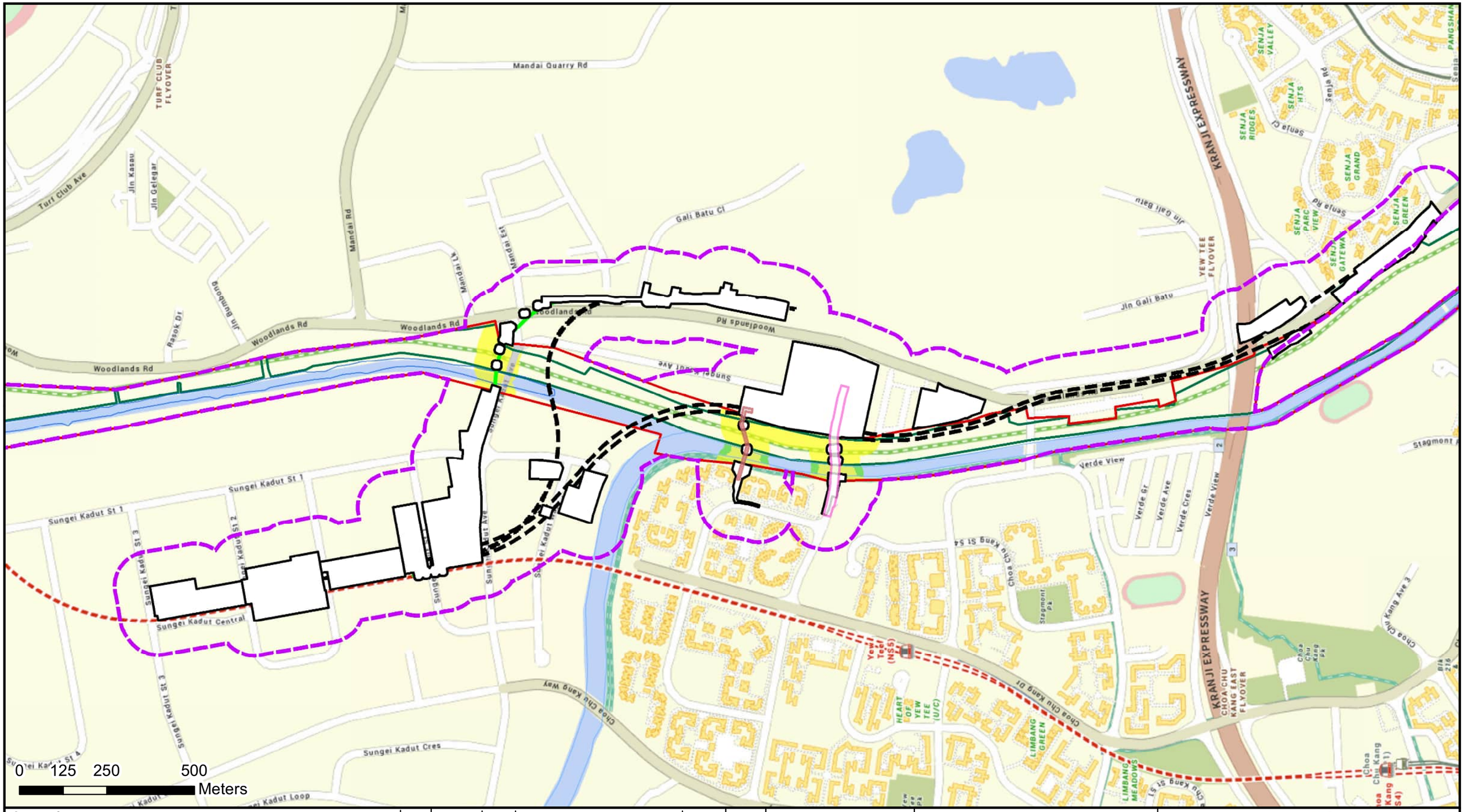

Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor
- Not Assessible

N

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ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
GROUND-BORNE VIBRATION IMPACT SIGNIFICANCE FOR ROTARY BORE PILING ON ECOLOGICAL RECEPTORS

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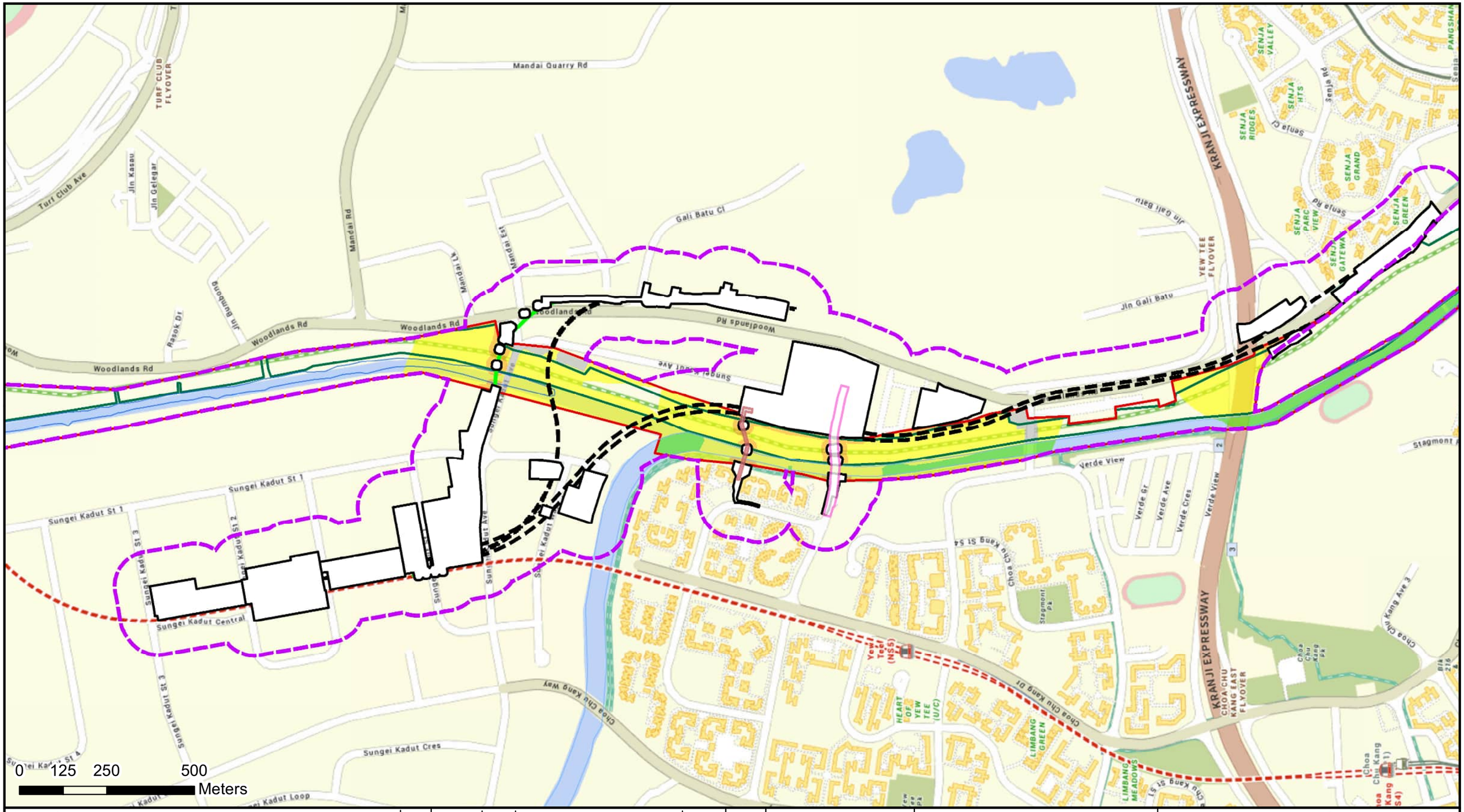

Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor
- Moderate
- Not Assessible

N

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ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
GROUND-BORNE VIBRATION IMPACT SIGNIFICANCE FOR VIBRATORY PILING ON ECOLOGICAL RECEPTORS

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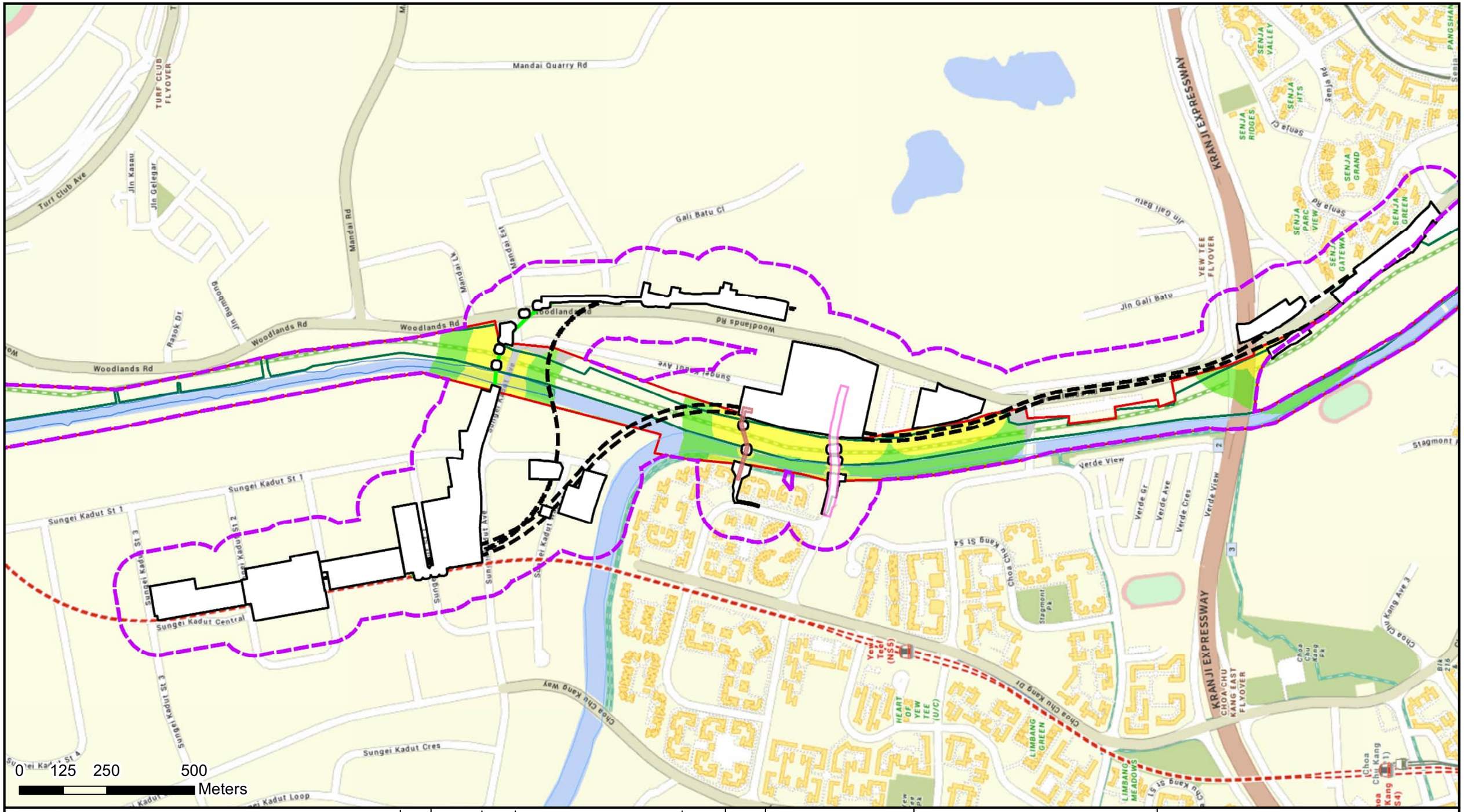

Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor
- Not Assessible

N

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Figure Title :
GROUND-BORNE VIBRATION IMPACT SIGNIFICANCE FOR VIBRATORY COMPACTOR (LOW) ON ECOLOGICAL RECEPTORS

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	Drawn TTR	Date MAY 2023

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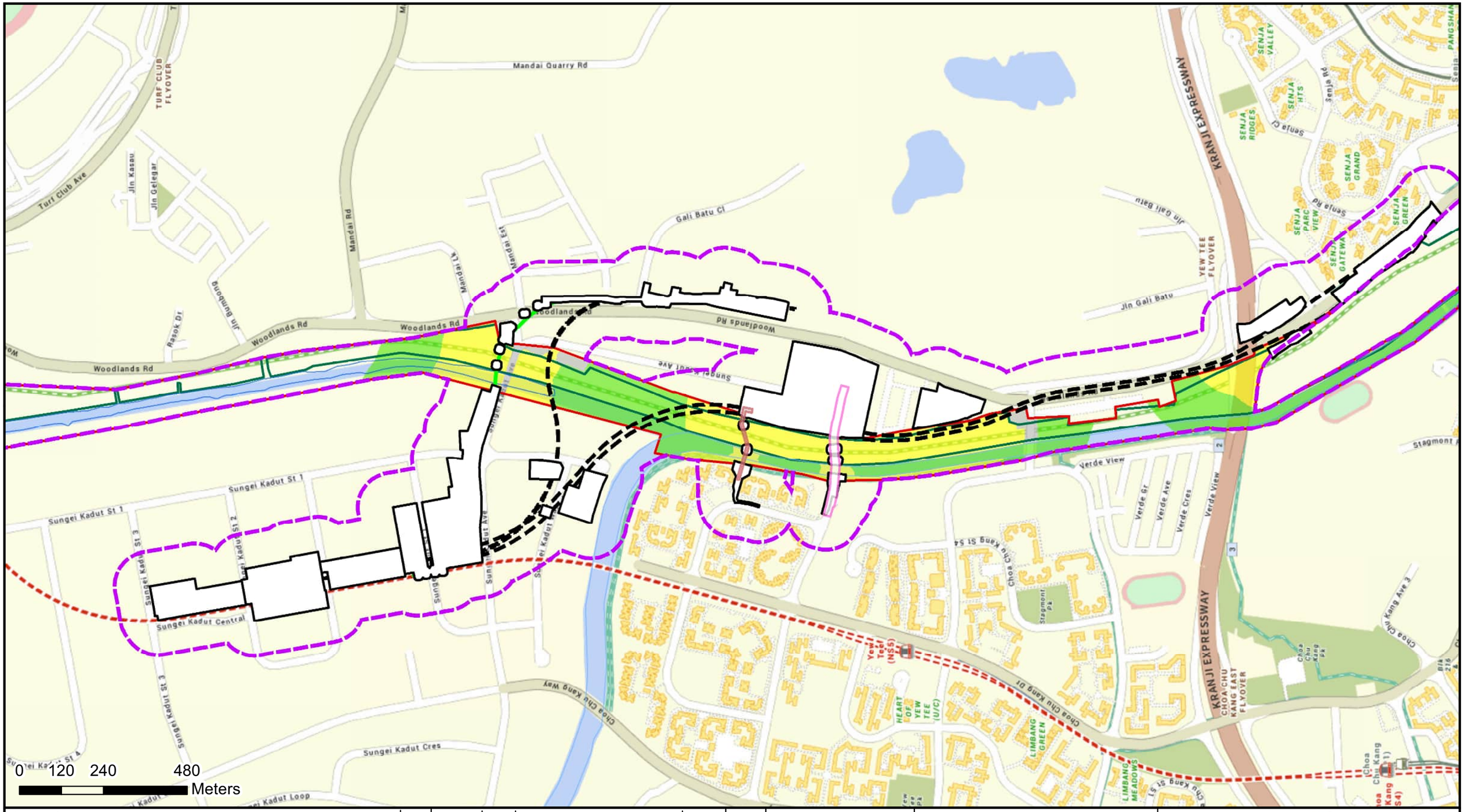

Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor
- Not Assessible

N

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Figure Title :
GROUND-BORNE VIBRATION IMPACT SIGNIFICANCE FOR VIBRATORY COMPACTOR (HIGH) ON ECOLOGICAL RECEPTORS

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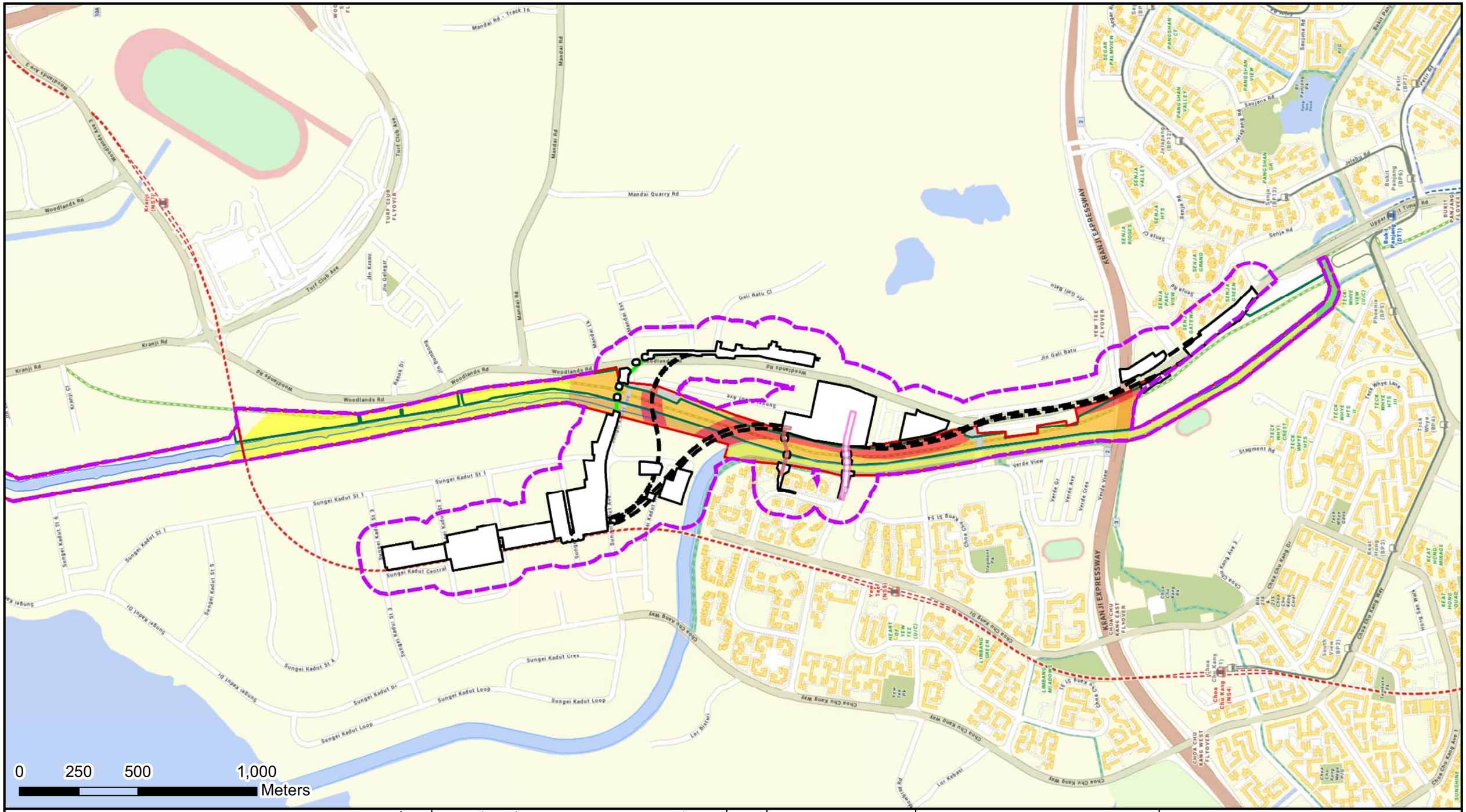

Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Minor
- Moderate
- Major
- Not Assessible

N

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Figure Title :
GROUND-BORNE VIBRATION IMPACT SIGNIFICANCE FOR TUNNEL BORING MACHINE (HYPOTHETICAL OVERALL) ON ECOLOGICAL RECEPTORS

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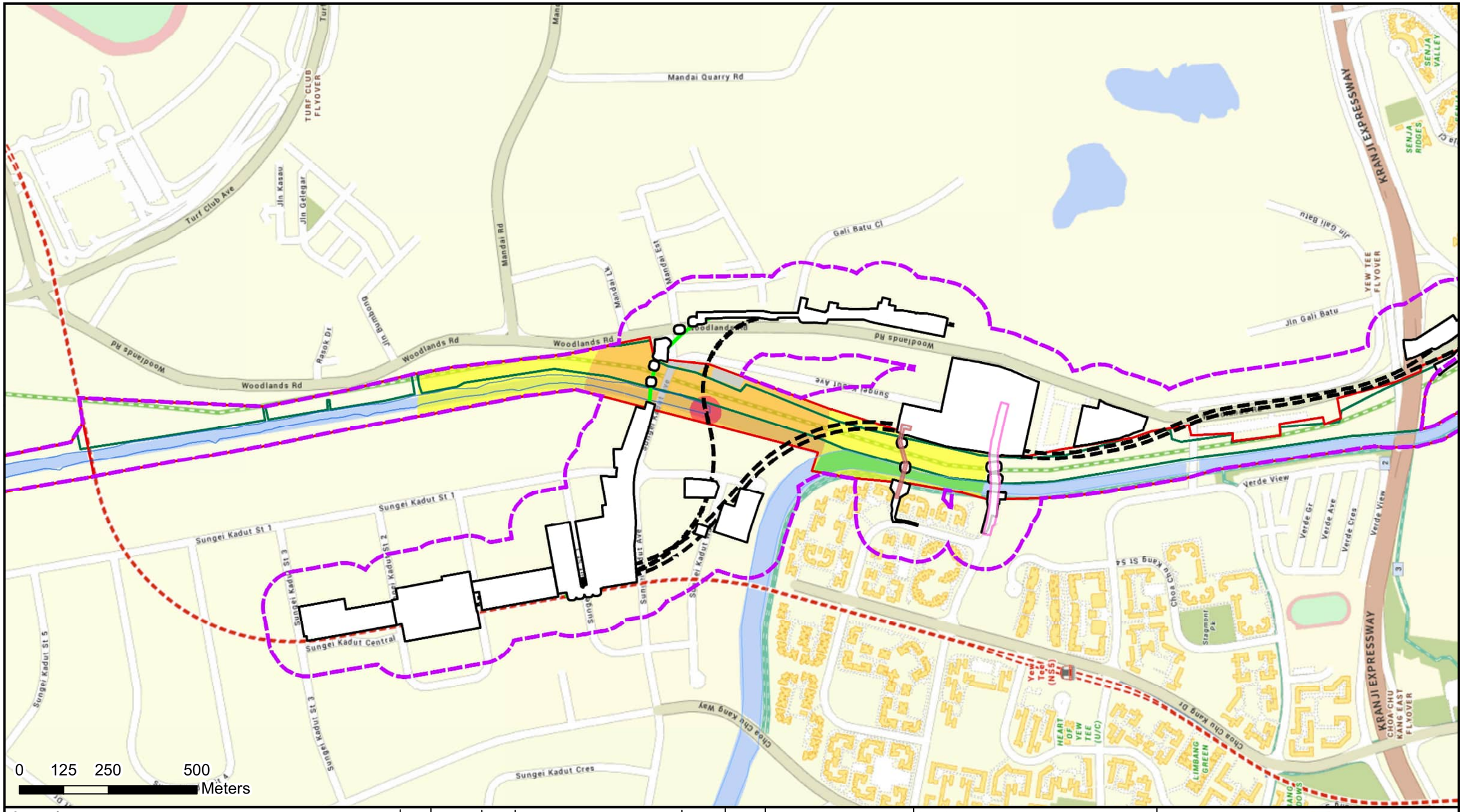

Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
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- Pang Sua Canal
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- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

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Figure Title :
GROUND-BORNE VIBRATION IMPACT SIGNIFICANCE FOR TUNNEL BORING MACHINE (SPOT 1 AT RECEPTION TRACK) ON ECOLOGICAL RECEPTORS

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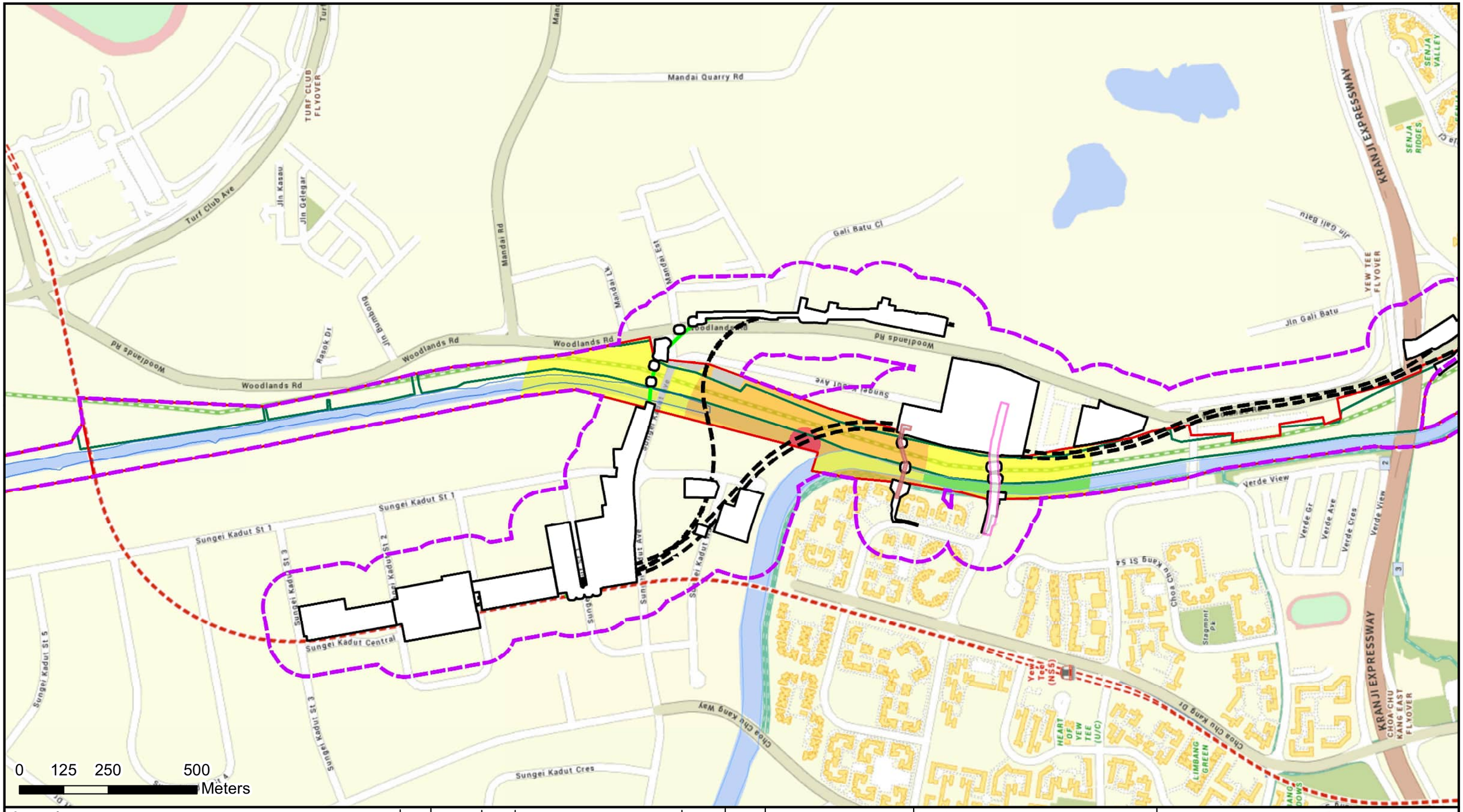

Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
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- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

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Figure Title :
GROUND-BORNE VIBRATION IMPACT SIGNIFICANCE FOR TUNNEL BORING MACHINE (SPOT 2 AT DTLE) ON ECOLOGICAL RECEPTORS

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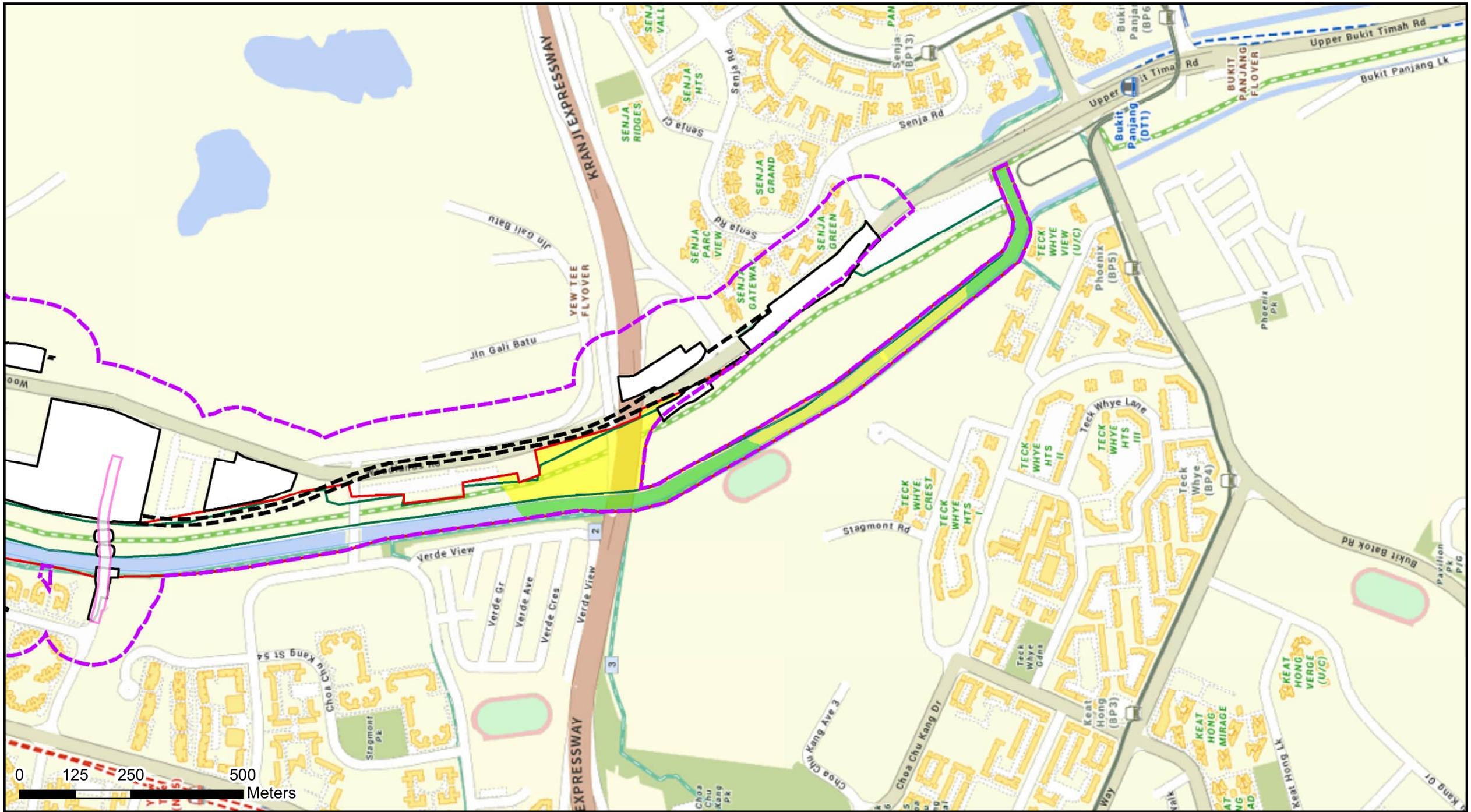

Legend

- Vibration Study Area
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Pang Sua Canal
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor
- Moderate
- Not Assessible

N

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Project Title :
CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
GROUND-BORNE VIBRATION IMPACT SIGNIFICANCE FOR TUNNEL BORING MACHINE (SPOT 3 AT DTLE) ON ECOLOGICAL RECEPTORS

Designed	Checked	Approved
TTR	HHL	JAG
	Drawn TTR	Date MAY 2023

Figure No. : 11-13 | Rev. A | Sheet 1 of 1

CAD File Name :N/A | A3

Note: Source of basemap - OneMap

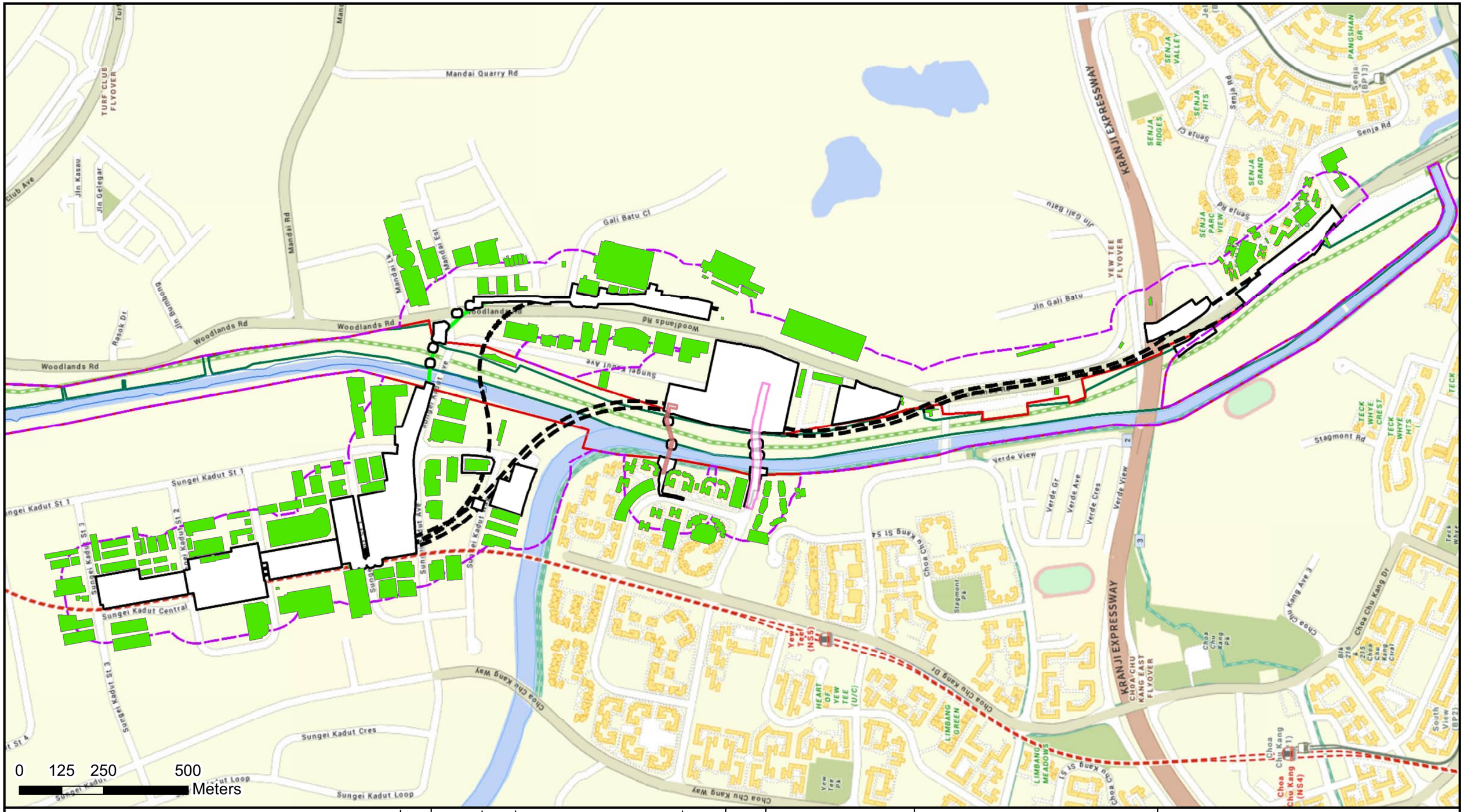
11.8.1.2 Impact Assessment of Ground-borne Vibration on Human Receptors

This section identified the maximum predicted vibration levels at human receptors for each construction activity. The number of buildings per impact significance is shown in Table 11-19. The impact significance of each building can be seen in Figure 11-14 to Figure 11-23. In contrast, detailed results with the complete list of receptors can be seen in Appendix BB.

Table 11-19 Maximum Predicted Ground-borne Vibration Levels Due to Construction Activities for Human Receptors

Construction Worksite and Activities	Number of Buildings per Impact Significance Due to Construction Activities				Maximum Predicted Ground-borne Vibration Levels, PPV	Exceedances of Vibration Threshold for Cosmetic Damage at 15 mm/s, mm/s	Impact Significance at Receptor with Maximum Predicted PPV
	Negligible	Minor	Moderate	Major			
Rock Breaking and Excavation at Sungei Kadut Station	147	0	0	0	4 mm/s at 5 Sungei Kadut Street 2 (Priority 3[2])	-	Negligible
Rotary Bore Piling	144	3	0	0	1 mm/s at 691B Choa Chu Kang Cres (Priority 2[1])	-	Minor
Vibratory Pile Driver	97	50	0	0	2 mm/s at 21A Woodlands Road (Priority 3[2])	-	Minor
Vibratory Compactor (Low)	145	2	0	0	1 mm/s at 21A Woodlands Road (Priority 3[2])	-	Negligible
Vibratory Compactor (High)	137	10	0	0	4 mm/s at 21A Woodlands Road (Priority 3[2])	-	Negligible
Tunnel Boring Machine[3]	92	50	6	0	6 mm/s at Future JTC Building (Priority 3[2])	-	Moderate

[1] Priority 2: Residential buildings, community centres, religious buildings, schools and education buildings, hospitals or medical centres, nursing homes, heritage buildings and national monuments.
[2] Priority 3: Commercial buildings, industrial buildings, infrastructure, industrial food centres, sports and recreation centres (e.g., golf courses, stadiums, club houses).
[3] The future JTC building was only included in the assessment for TBM.



Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor

N

Rev.	Date	By	Description	Chk'd	App'd
C	NOV 2023	TWB	Draft Final Report	HHL	JAG
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
-	AUG 2022	TTR	Draft Final Report	HHL	JAG

Qualified Person Endorsement :
N/A

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Project Title :
CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
GROUND-BORNE VIBRATION IMPACT SIGNIFICANCE FOR ROCK BREAKING AND EXCAVATION (SUNGEI KADUT STATION) ON HUMAN RECEPTORS

Designed	Checked	Approved
TWB	HHL	JAG
	Drawn: TWB	Date: NOV 2023

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

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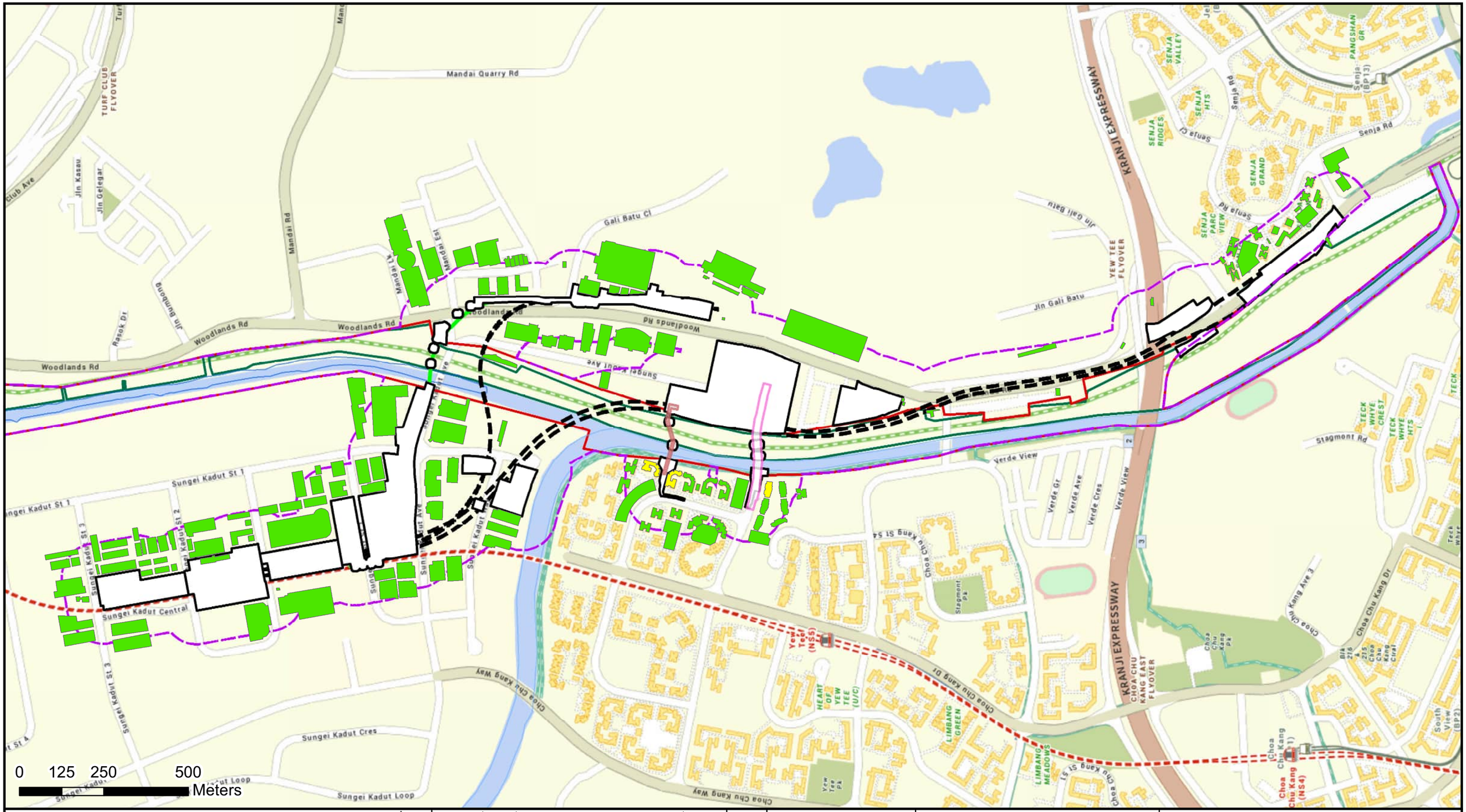
Note: Source of basemap - OneMap



Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor

N

Rev.	Date	By	Description	Chk'd	App'd
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
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Project Title :
CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

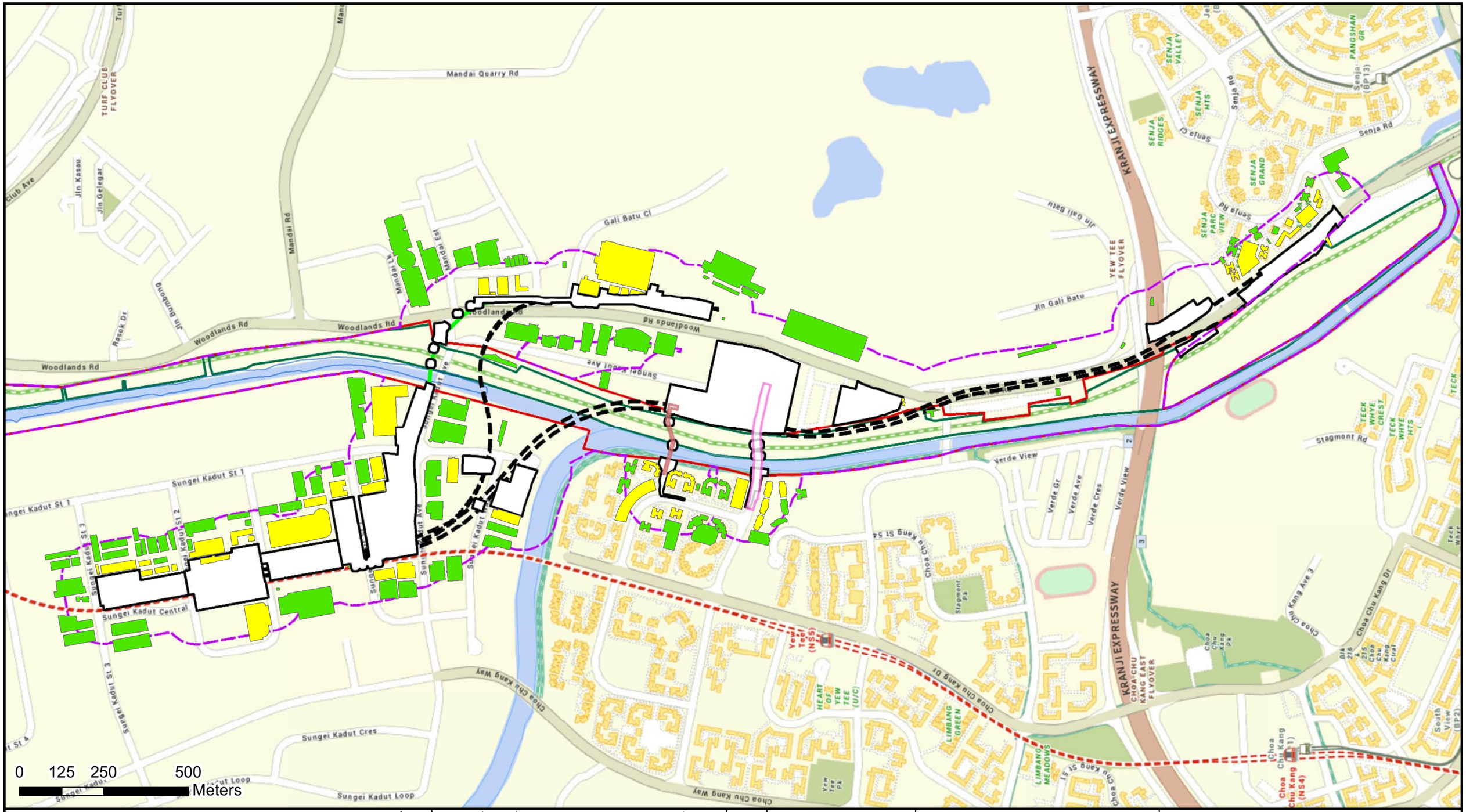
Figure Title :
GROUND-BORNE VIBRATION IMPACT SIGNIFICANCE FOR ROTARY BORE PILING ON HUMAN RECEPTORS

Designed	Checked	Approved
TTR	HHL	JAG
	Drawn TTR	Date MAY 2023

Figure No. : 11 - 15 | Rev. A | Sheet 1 of 1

CAD File Name :N/A | A3

Note: Source of basemap - OneMap



Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor

N

Rev.	Date	By	Description	Chk'd	App'd
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
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Project Title :
CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
GROUND-BORNE VIBRATION IMPACT SIGNIFICANCE FOR VIBRATORY PILING ON HUMAN RECEPTORS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	11 - 16	A	1 of 1
	Drawn TTR	Date MAY 2023	CAD File Name :N/A		A3

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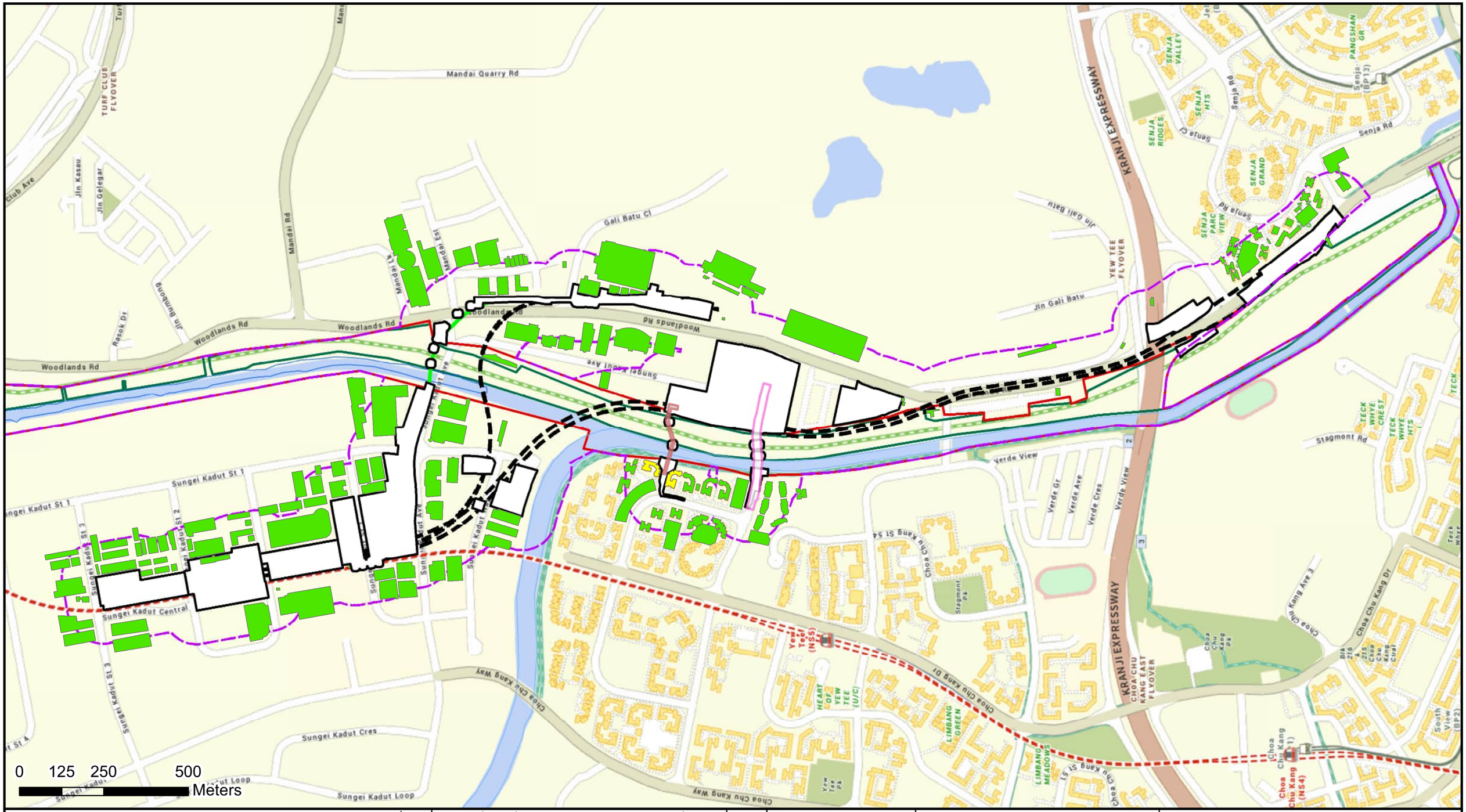

Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor

N

Rev.	Date	By	Description	Chk'd	App'd
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
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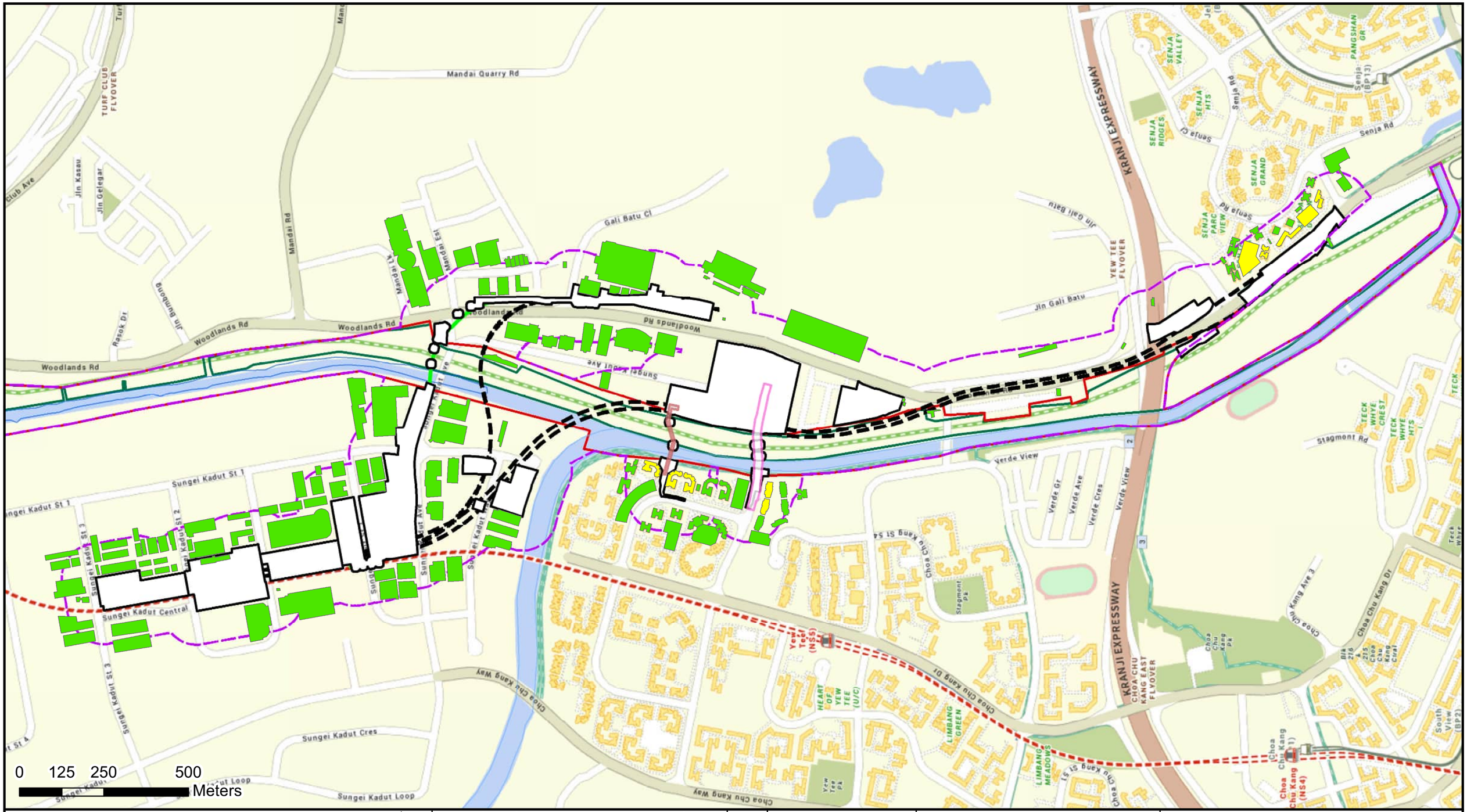
Project Title :
CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
GROUND-BORNE VIBRATION IMPACT SIGNIFICANCE FOR VIBRATORY COMPACTOR (LOW) ON HUMAN RECEPTORS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	11 - 17	A	1 of 1
	Drawn TTR	Date MAY 2023	CAD File Name :N/A		A3

Note: Source of basemap - OneMap



Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor

N

Rev.	Date	By	Description	Chk'd	App'd
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
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ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
GROUND-BORNE VIBRATION IMPACT SIGNIFICANCE FOR VIBRATORY COMPACTOR (HIGH) ON HUMAN RECEPTORS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	11 - 18	A	1 of 1
	Drawn TTR	Date MAY 2023	CAD File Name :N/A		A3

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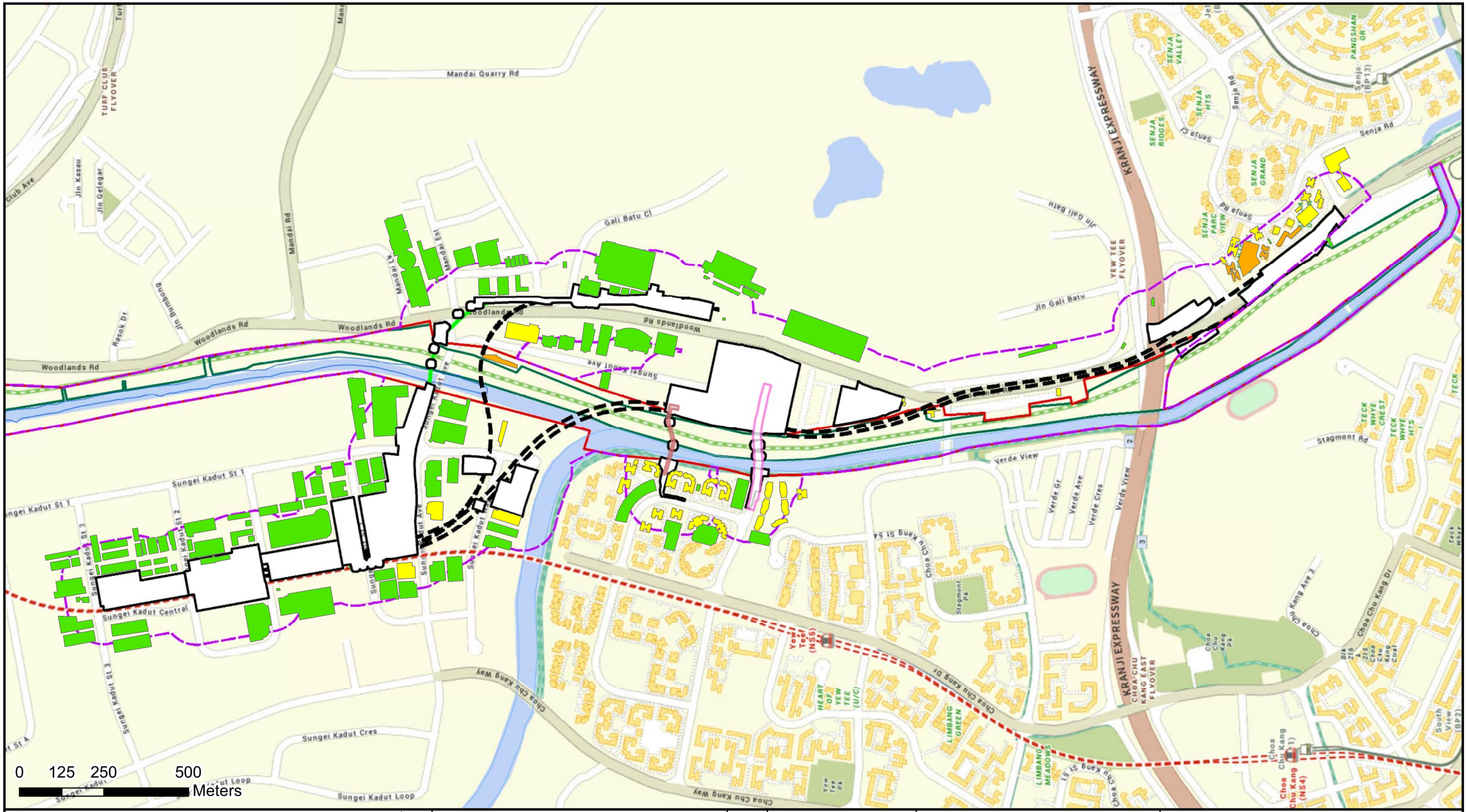

Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor
- Moderate

N

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A	MAY 2023	TTR	Draft Final Report	HHL	JAG
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Project Title :
CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
GROUND-BORNE VIBRATION IMPACT SIGNIFICANCE FOR TUNNEL BORING MACHINE ON HUMAN RECEPTORS

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TTR	HHL	JAG	11 - 19	A	1 of 1
	Drawn TTR	Date MAY 2023	CAD File Name :N/A		A3

Note: Source of basemap - OneMap

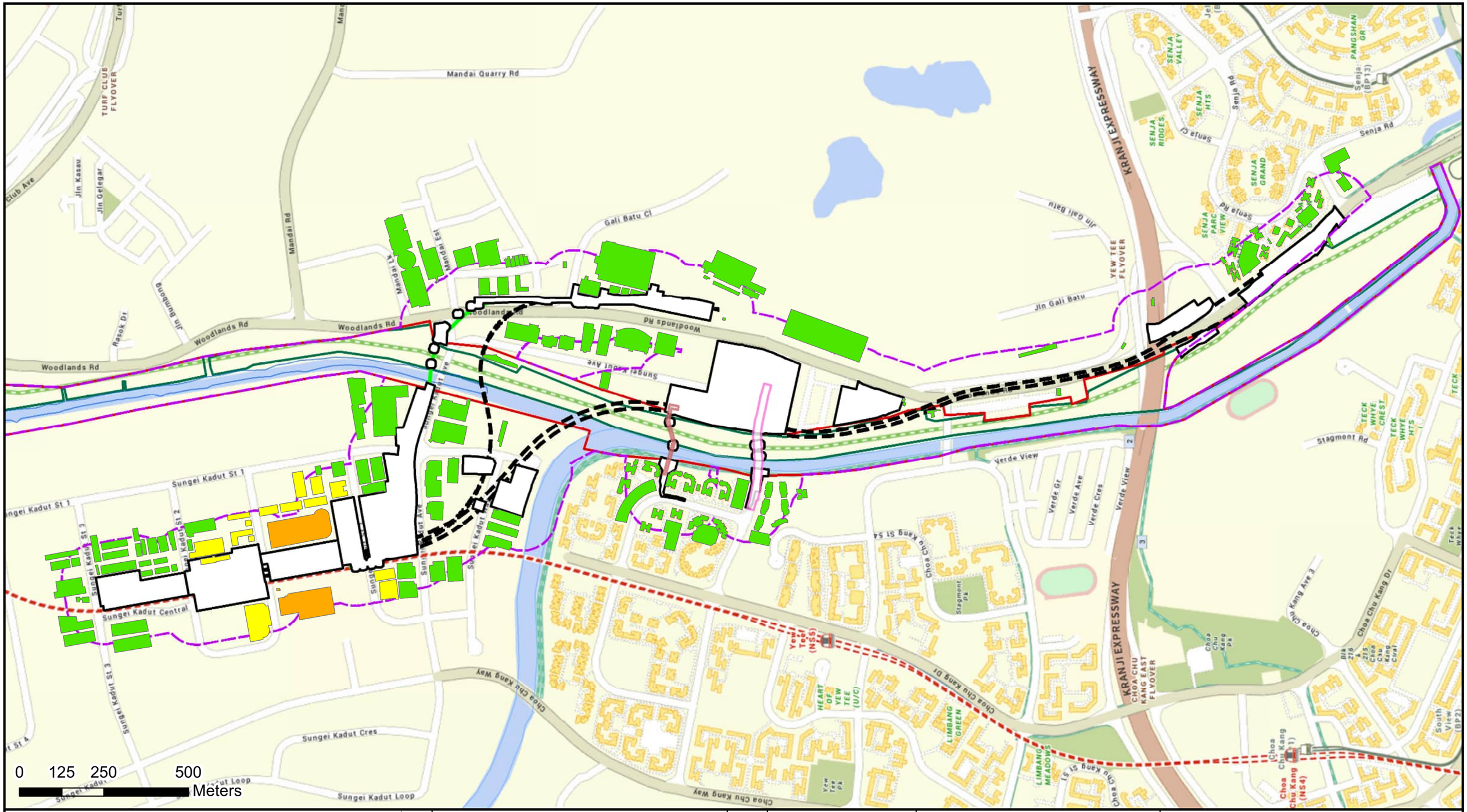
11.8.1.3 Impact Assessment of Ground-borne Noise on Human Receptors

This section identified the maximum predicted ground-borne noise at human receptors for each construction activity. The number of buildings per impact significance is shown in Table 11-20. The impact significance of each building can be seen in Figure 11-20 to Figure 11-25. In contrast, detailed results with the complete list of receptors can be seen in Appendix BB. It should be noted that ground-borne noise is reradiated noise from a building structure. Thus, ground-borne noise level values are generally noticeable only in the tranquil environment; hence it would typically be masked by airborne noise associated with surface construction activities.

Table 11-20 Maximum Predicted Ground-borne Noise Levels Due to Construction Activities for Human Receptors

Construction Worksite and Activities	Number of Buildings per Impact Significance Due to Construction Activities				Maximum Ground-borne Noise Levels	Exceedances of Ground-borne Noise Threshold, L_{ASmax} dB	Impact Significance at Receptor with Maximum Ground-borne Noise Levels
	Negligible	Minor	Moderate	Major			
Rock Breaking and Excavation at Sungei Kadut Station	129	15	3	0	L_{ASmax} 64 dB at 5 Sungei Kadut Street 2 (Priority 3 [2])	9	Moderate
Rotary Bored Piling	122	23	2	0	L_{ASmax} 50 dB at 691B Choa Chu Kang Street 64 (Priority 2 [1])	5	Moderate
Vibratory Pile Driver	80	55	12	0	L_{ASmax} 59 dB at 21A Woodlands Road (Priority 3 [2])	4	Minor
Vibratory Compactor (Low)	105	45	0	0	L_{ASmax} 54 dB at 21A Woodlands Road (Priority 3 [2])	-	Minor
Vibratory Compactor (High)	87	60	0	0	L_{ASmax} 63 dB at 21A Woodlands Road (Priority 3 [2])	8	Minor
Tunnel Boring Machine [3]	137	5	2	4	L_{ASmax} 65 dB at future JTC building (Priority 3 [2])	10	Moderate

Note:
[1] Priority 2: Residential buildings, community centres, religious buildings, schools and education buildings, hospitals or medical centres, nursing homes, heritage buildings and national monuments.
[2] Priority 3: Commercial buildings, industrial buildings, infrastructure, industrial food centres, sports and recreation centres (e.g., golf courses, stadiums, club houses).
[3] The future JTC building was only included in the assessment for TBM.



Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor
- Moderate

N

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ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
GROUND-BORNE NOISE IMPACT SIGNIFICANCE FOR ROCK BREAKING AND EXCAVATION (SUNGEI KADUT STATION) ON HUMAN RECEPTORS

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TTR	HHL	JAG	11 - 20	A	1 of 1
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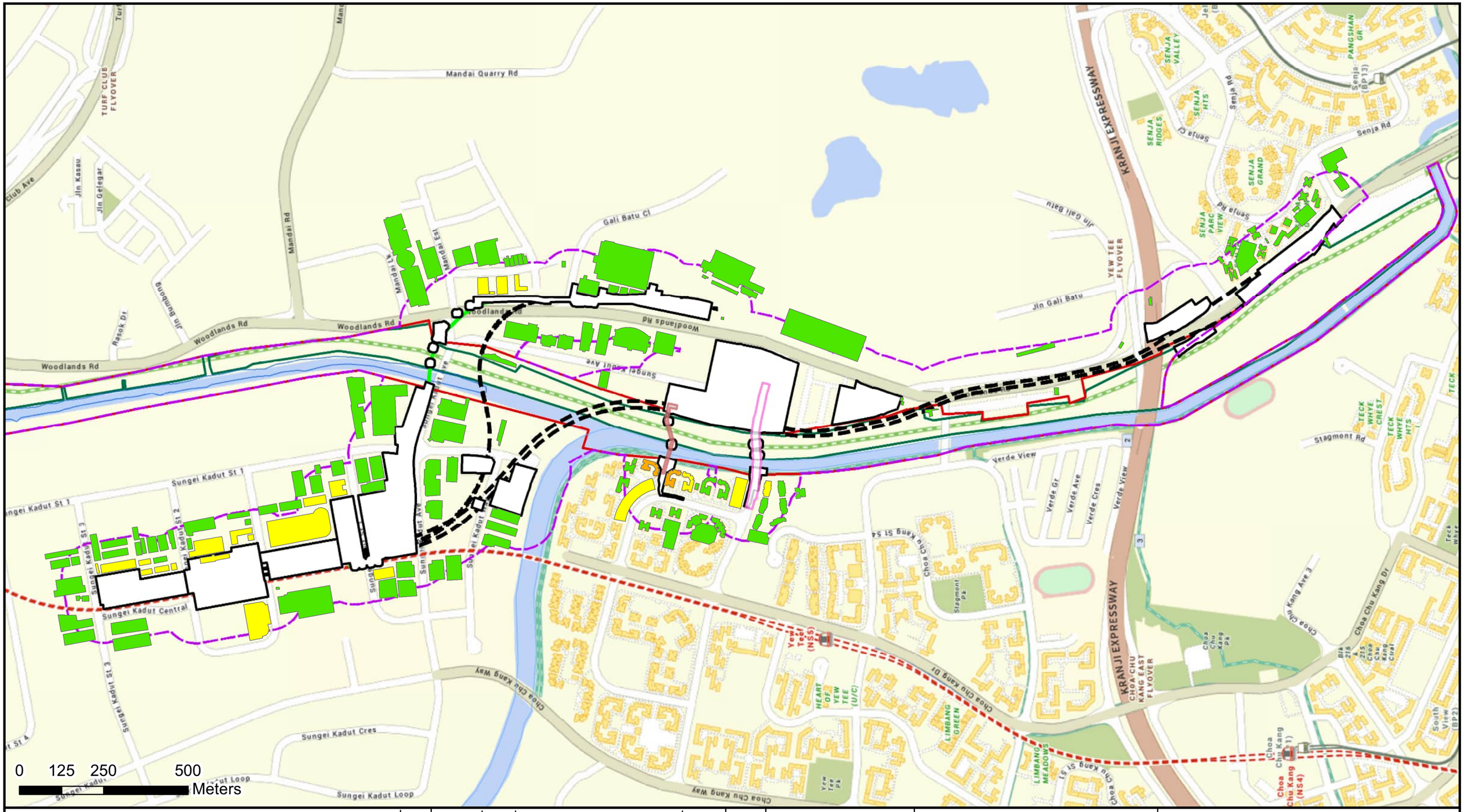

Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor
- Moderate

N

Rev.	Date	By	Description	Chk'd	App'd
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
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ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
GROUND-BORNE NOISE IMPACT SIGNIFICANCE FOR ROTARY BORE PILING ON HUMAN RECEPTORS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	11 - 21	A	1 of 1
	Drawn TTR	Date MAY 2023	CAD File Name :N/A		A3

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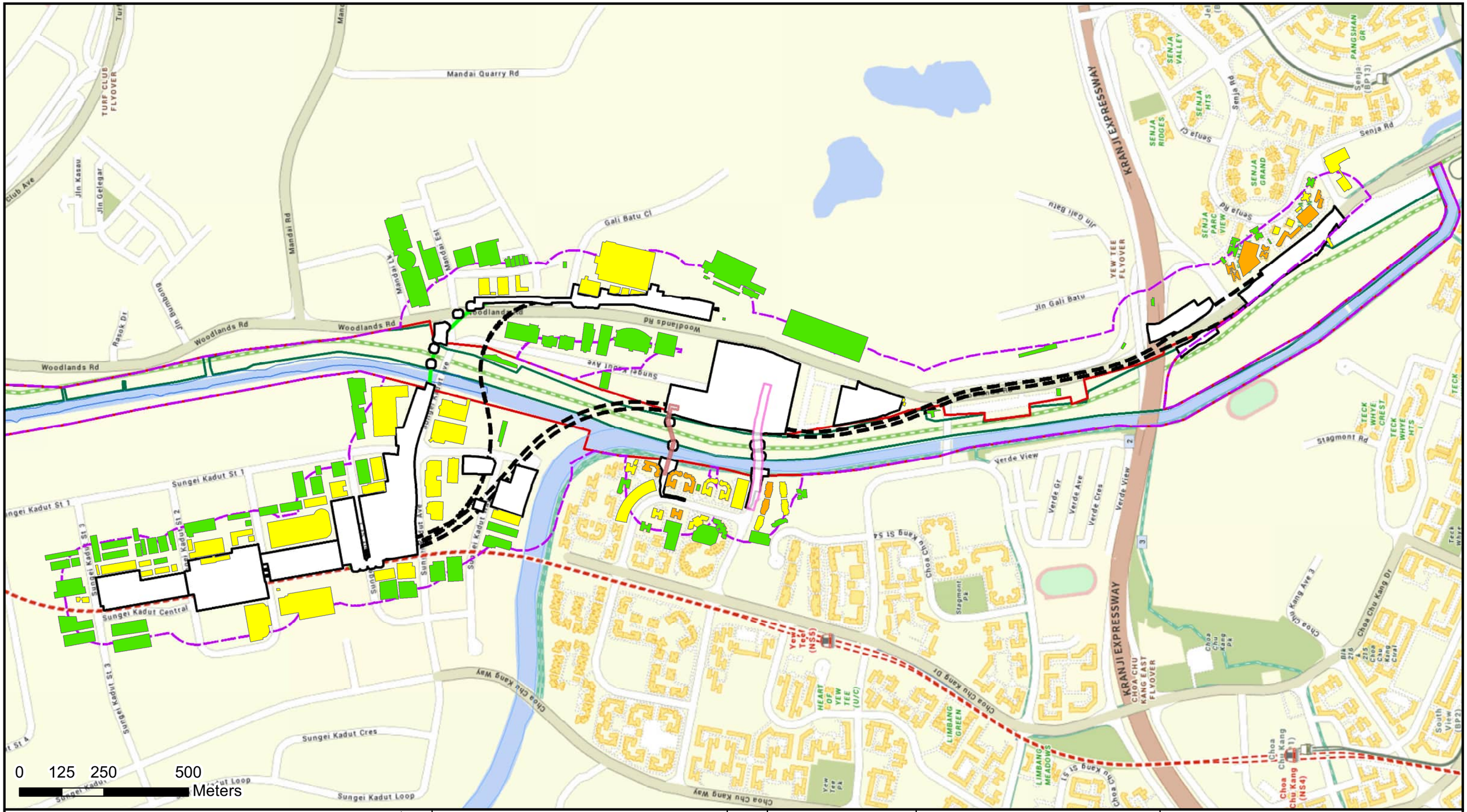

Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor
- Moderate

N

Rev.	Date	By	Description	Chk'd	App'd
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
-	AUG 2022	TTR	Draft Final Report	HHL	JAG

Qualified Person Endorsement :
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Project Title :
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ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
GROUND-BORNE NOISE IMPACT SIGNIFICANCE FOR VIBRATORY PILING ON HUMAN RECEPTORS

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	Drawn TTR	Date MAY 2023	CAD File Name :N/A		A3

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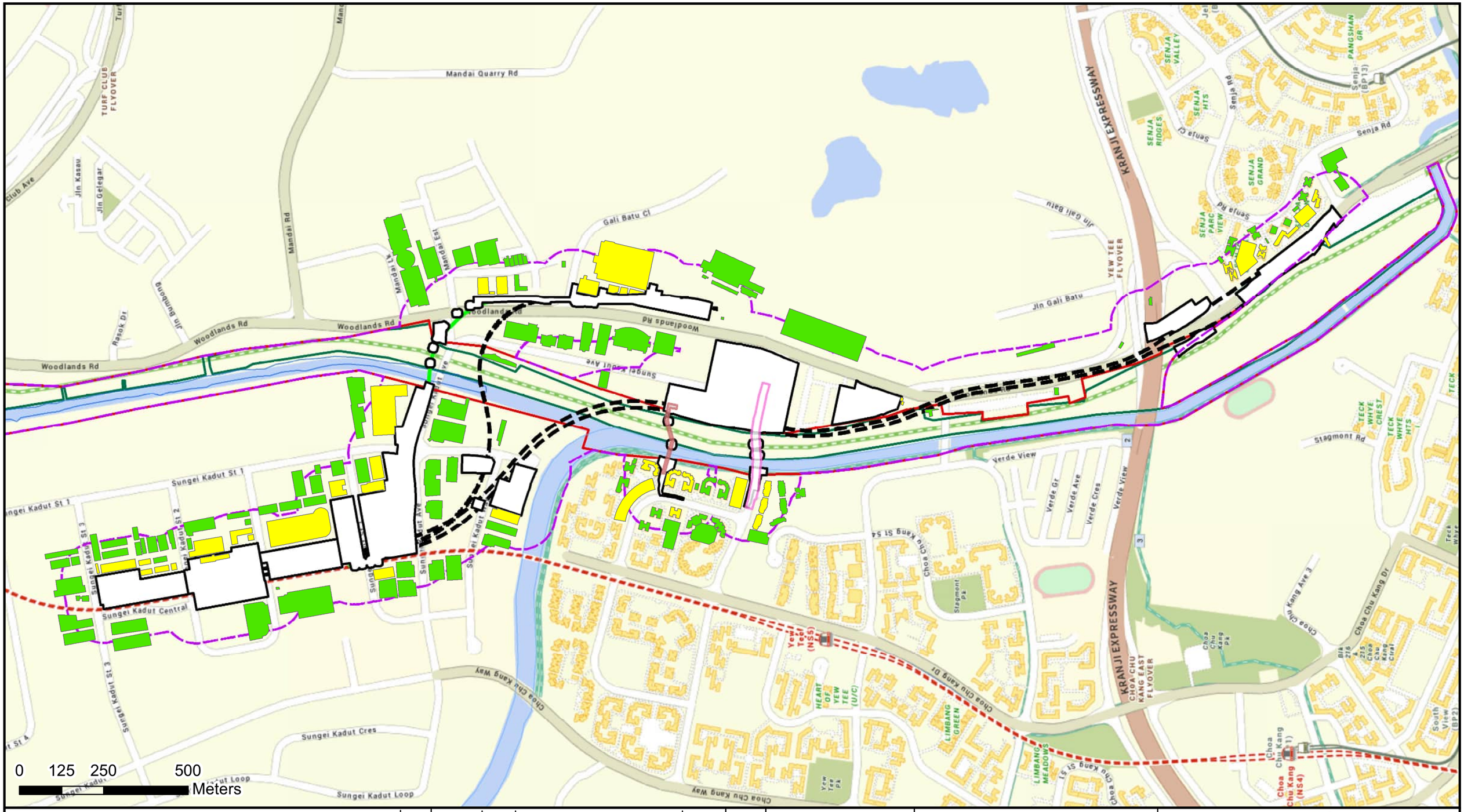

Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor

N

Rev.	Date	By	Description	Chk'd	App'd
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
-	AUG 2022	TTR	Draft Final Report	HHL	JAG

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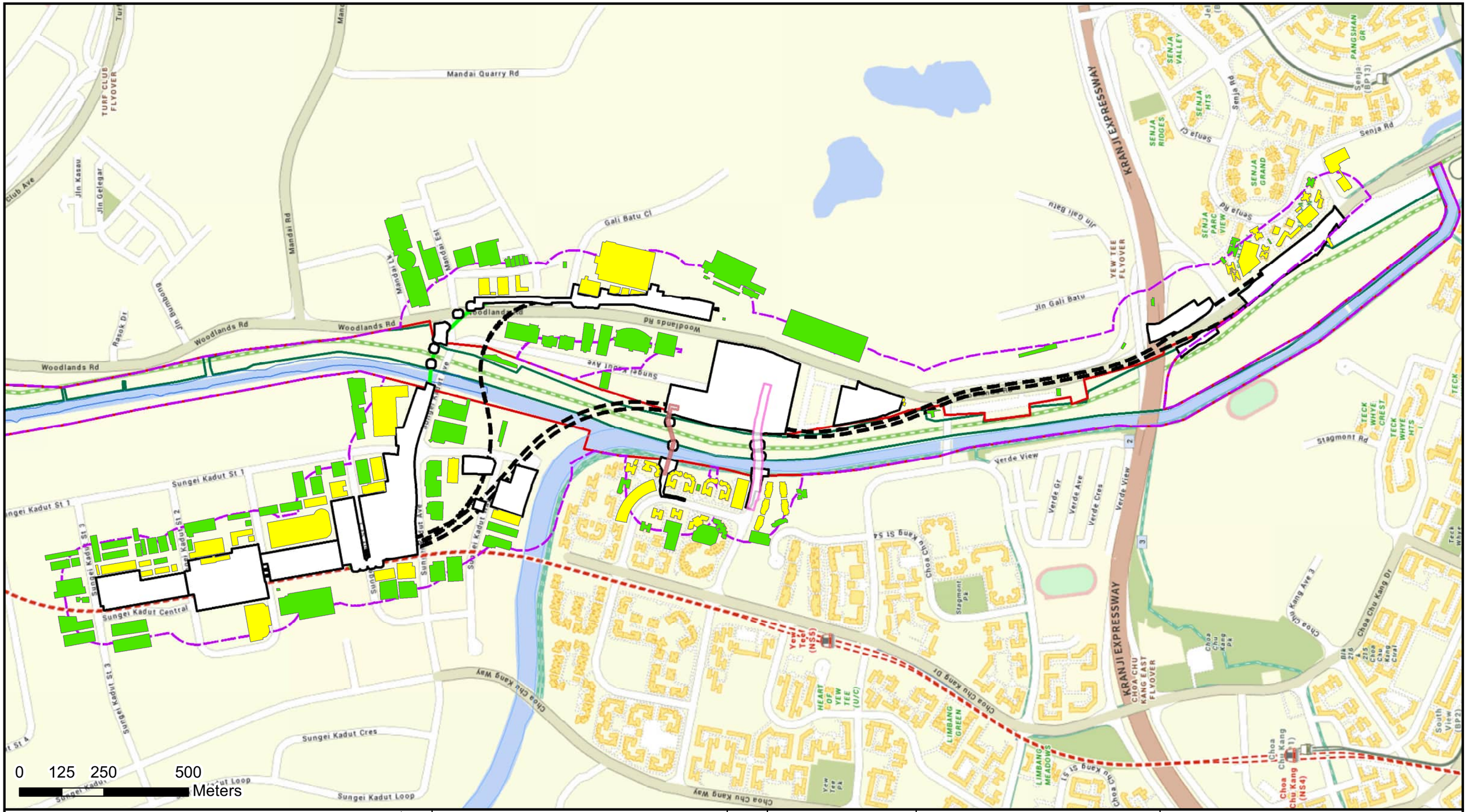
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
GROUND-BORNE NOISE IMPACT SIGNIFICANCE FOR VIBRATORY COMPACTOR (LOW) ON HUMAN RECEPTORS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	11 - 23	A	1 of 1
	Drawn TTR	Date MAY 2023	CAD File Name :N/A		A3

Note: Source of basemap - OneMap



Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor

N

Rev.	Date	By	Description	Chk'd	App'd
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
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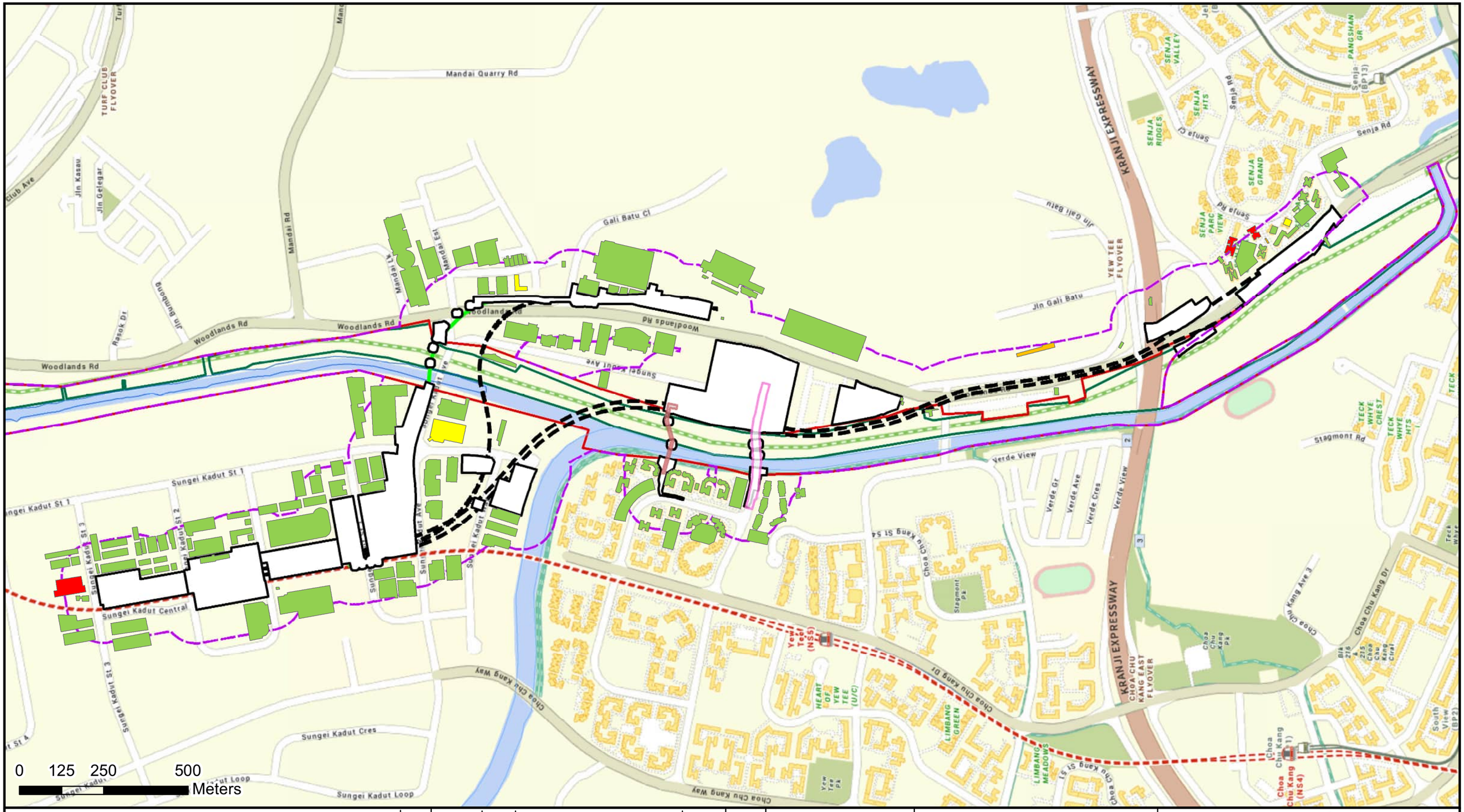
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
GROUND-BORNE NOISE IMPACT SIGNIFICANCE FOR VIBRATORY COMPACTOR (HIGH) ON HUMAN RECEPTORS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	11 - 24	A	1 of 1
	Drawn TTR	Date MAY 2023	CAD File Name :N/A		A3

Note: Source of basemap - OneMap



Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Major
- Moderate
- Minor
- Negligible

N

Rev.	Date	By	Description	Chk'd	App'd
D	APR 2024	TTR	Draft Final Report	HHL	JAG
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
-	AUG 2022	TTR	Draft Final Report	HHL	JAG

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LTA Endorsement :
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Project Title :
CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
GROUND-BORNE NOISE IMPACT SIGNIFICANCE FOR TUNNEL BORING MACHINE ON HUMAN RECEPTORS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	11 - 25	D	1 of 1
	Drawn TTR	Date APR 2024	CAD File Name :N/A		A3

Note: Source of basemap - OneMap

11.8.2 Operational Phase

The Vibration Study (NVS) Prelim Report documents the predicted operational train vibration levels and the assessment of vibration impacts on humans. This report will discuss impacts on ecology only.

11.8.2.1 Impact Assessment of Ground-borne Vibration for Ecological Receptors

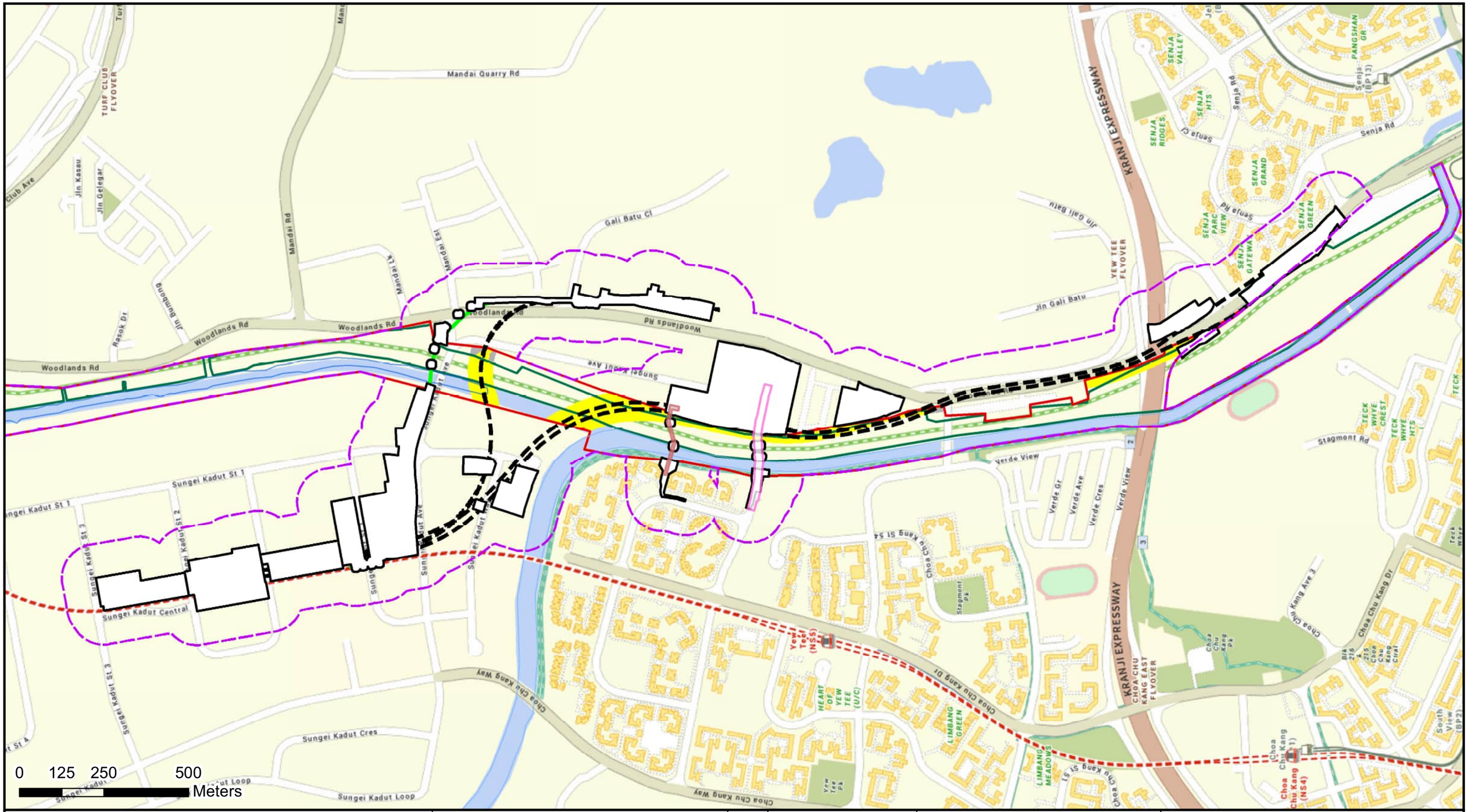
Operational vibrational levels during train operation were predicted in the NVS Report. The trackform for the main DTLe alignment and reception track was modelled as a standard slab track form for the base scenario. Relevant calculations depicting the detailed working of these findings are in Appendix T.

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 the NVS 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 11.7.1.2, 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 used for the construction phase impact evaluation. The results can be seen in Table 11-21.

Table 11-21 Summary of Maximum Predicted PPV for Operational Phase (Base Scenario)

Construction Worksite and Activities	Maximum Predicted PPV (mm/s)	Exceedances of Vibration Threshold for Partial Burrow & Mud Lobster Mound Collapse, mm/s	Impact Significance
	Rail Corridor		
Operational, Overall	0.17	-	Minor
Operational, Spot 1 at Reception Track	0.05	-	Minor
Operational, Spot 2 at DTLe	0.10	-	Minor
Operational, Spot 3 at DTLe*	0.00	-	-
Note: * The predicted vibration levels at the biodiversity study area nearest to the Docking Shaft were lower than the lower bound of baseline (0.03 mm/s), hence, no Impact Significance is provided at this point.			



Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
-	AUG 2022	TTR	Draft Final Report	HHL	JAG

Qualified Person Endorsement :
N/A

LTA Endorsement :
N/A

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

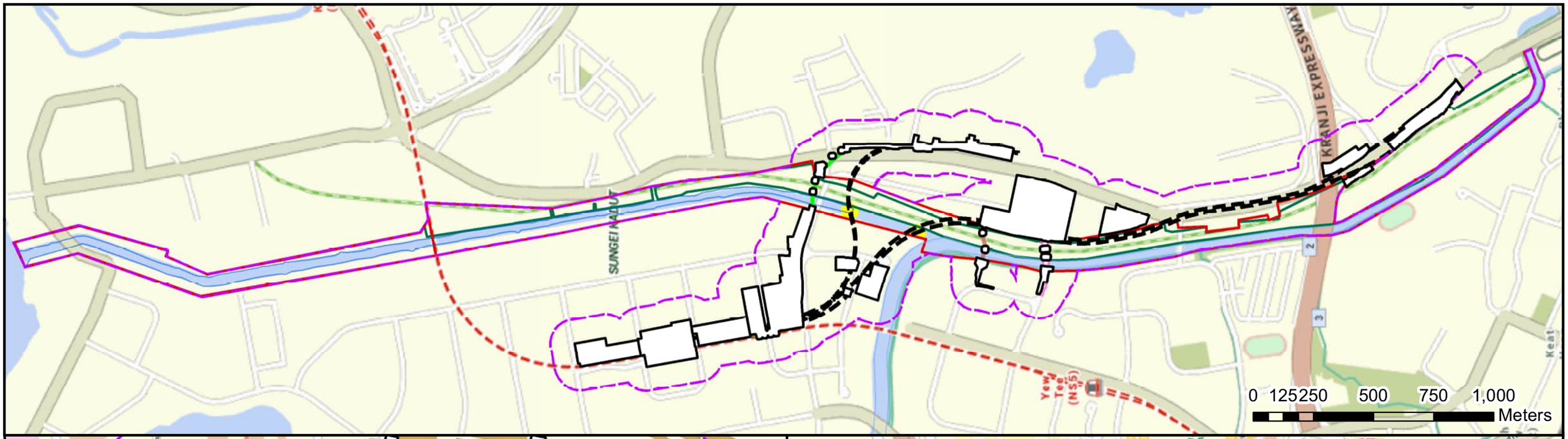
Figure Title :
GROUND-BORNE NOISE IMPACT SIGNIFICANCE FOR OPERATIONAL PHASE ON ECOLOGICAL RECEPTORS

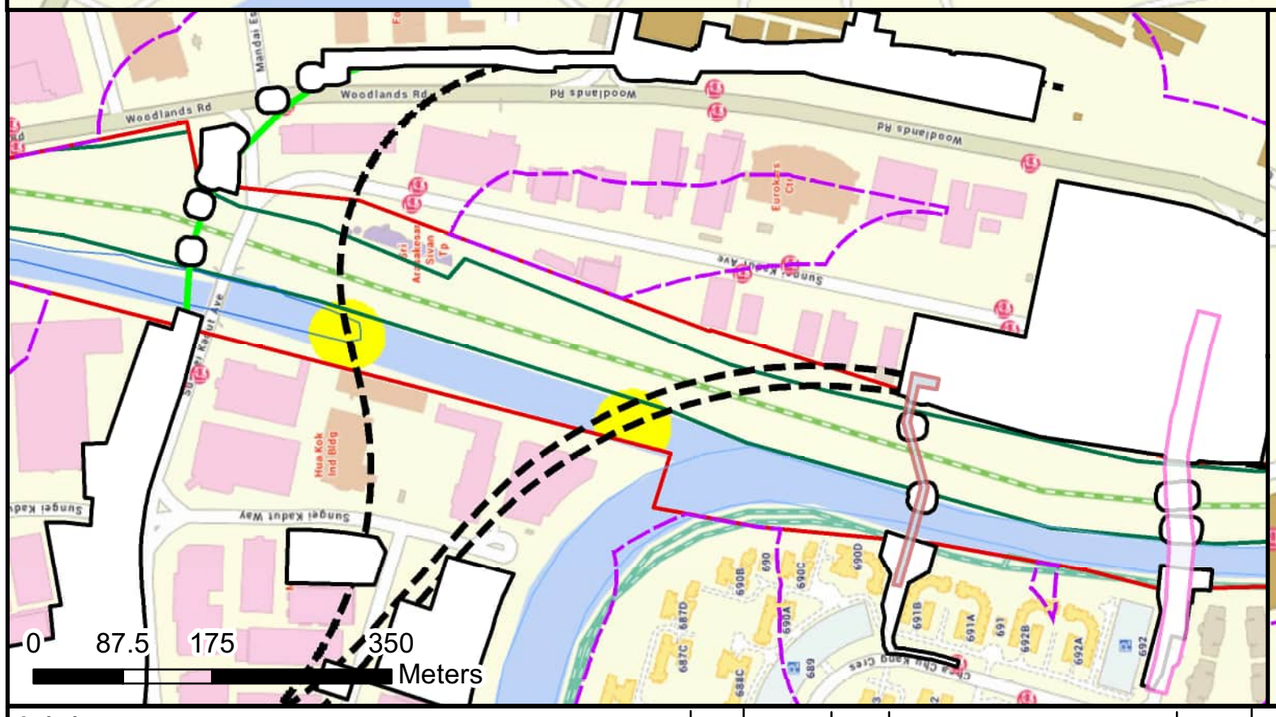
Designed	Checked	Approved
TTR	HHL	JAG
	Drawn TTR	Date MAY 2023

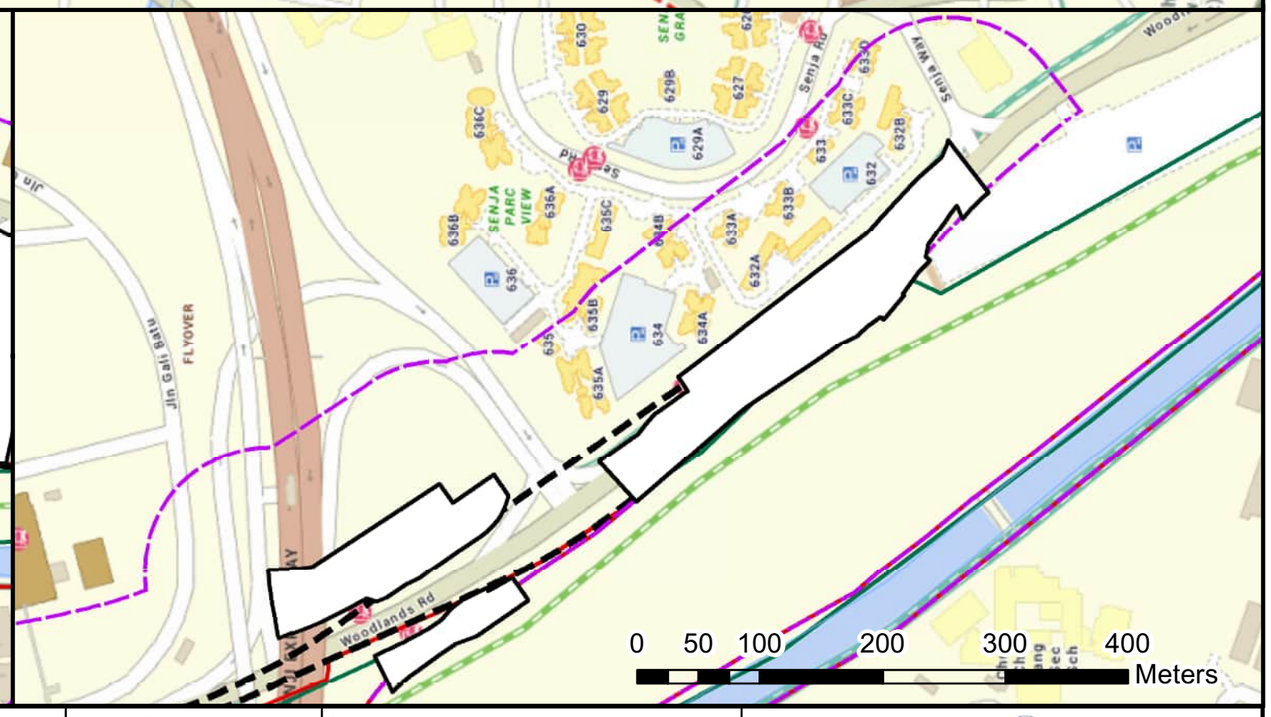
Figure No. : 11 - 26 | Rev. : A | Sheet : 1 of 1

CAD File Name :N/A | A3

Note: Source of basemap - OneMap







Label

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
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Qualified Person Endorsement :
N/A

LTA Endorsement :
N/A

Consultant : AECOM

Land Transport Authority
We Keep Your World Moving

Project Title :
CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
GROUND-BORNE VIBRATION IMPACT SIGNIFICANCE FOR OPERATIONAL PHASE (SPOTS 1, 2 AND 3) ON ECOLOGICAL RECEPTORS

Designed	Checked	Approved
TTR	HHL	JAG
	Drawn TTR	Date MAY 2023

Figure No. : 11 - 27 | Rev. : - | Sheet : 1 of 1

CAD File Name :N/A | A3

Note: Source of basemap - OneMap

11.8.2.2 Impact Assessment of Ground-borne Noise and Vibration on Human Receptors

The impact assessment on humans is detailed in the NVS Report. From the report, no receptor was predicted to experience any exceedances for ground-borne noise and vibration.

11.9 Recommended Mitigation Measures

11.9.1 Construction Phase

Based on best practices for building near an area of high biodiversity value, mitigation measures for construction vibration impacts on sensitive fauna species and human receptors are recommended.

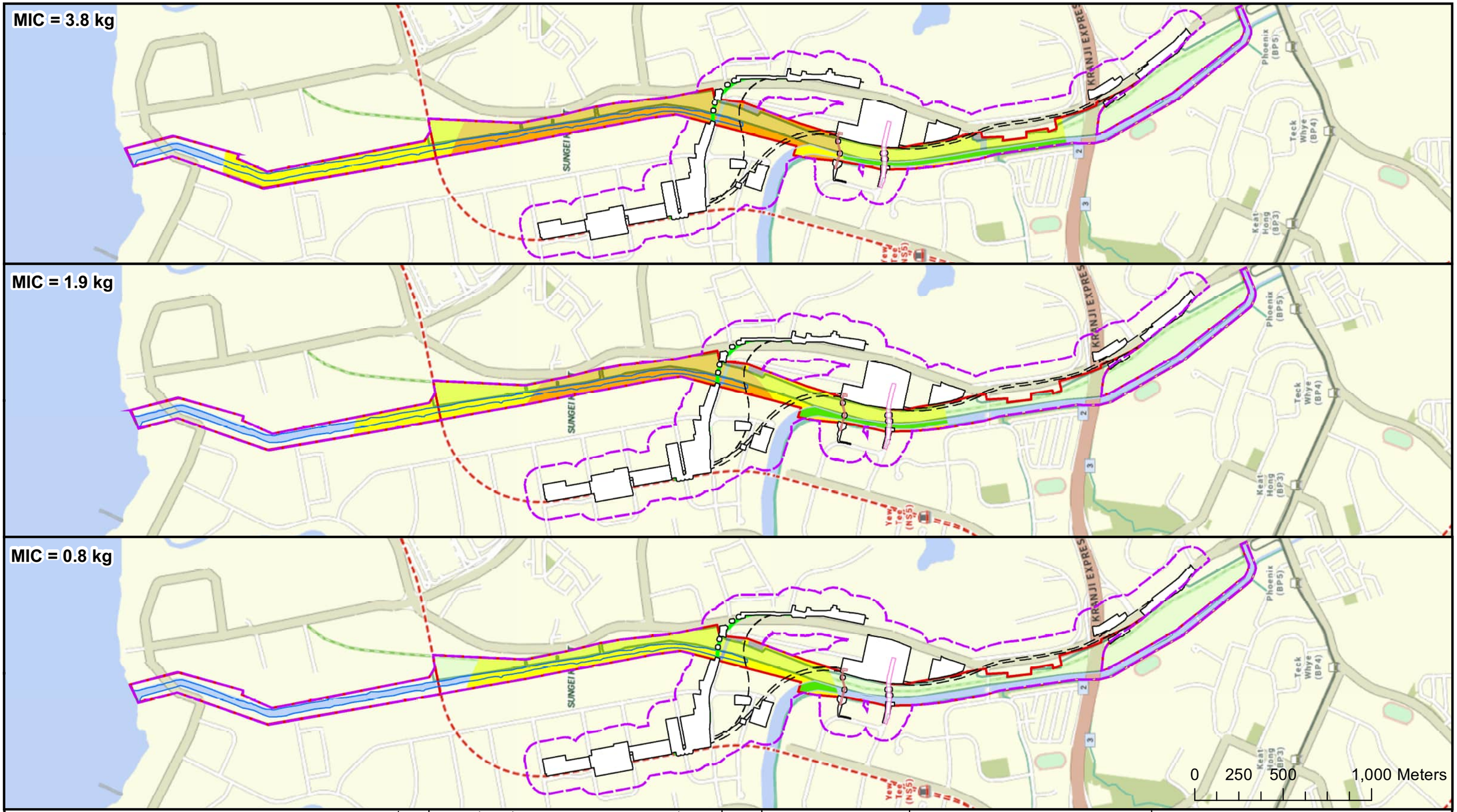
Ground-borne Vibration (human and ecological impacts)

Mitigation measures for tunnel boring are limited. If the project requirements permit, it might be possible to control the vibration levels at the source by altering the tunnelling operation parameters such as cutterhead rotation and driving force, especially if TBM is very close to surface underneath biodiversity sensitive area. If circumstances do not permit the above, other mitigation measures include pipe jacking and developing an engagement community programme shall be considered. Lubricant injection can also help to mitigate vibration by reducing frictional resistance and jacking force.

To reduce the ecological impacts due to rock breaking at Sungei Kadut Station, it is recommended to reduce the MIC. Two more scenarios (MIC 1.9 kg and 0.8 kg) were assessed as seen in Table 11-22, the impact significance for different scenarios are shown in Figure 11-28.

Table 11-22 Reduced MIC Values using BS 6472-2-2008 Equation

Sungei Kadut Station	Vertical Distance (m)	Horizontal Distance (m)	Slant Distance (m)	Maximum Instantaneous Charge, MIC (kg)		
				3.8	1.9	0.8
				PPV, mm/s		
Human Receptor	14.5	37	40	14.0	4.3	2.3
Ecological Receptor	13	534	534	0.3	0.2	0.1



Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

N

Rev.	Date	By	Description	Chk'd	App'd
A	MAY 2023	TTR	Draft Final Report	HHL	JAG

Qualified Person Endorsement :
N/A

LTA Endorsement :
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Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
GROUND-BORNE VIBRATION ASSESSMENT FOR ROCK BREAKING AND EXCAVATION (SUNGEI KADUT STATION) ON ECOLOGICAL RECEPTORS MITIGATED SCENARIOS

Designed	Checked	Approved
TTR	HHL	JAG
	Drawn TTR	Date MAY 2023

Figure No. :	Rev.	Sheet
11 - 28	A	1 of 1

CAD File Name :N/A — A3

Note: Source of basemap - OneMap

Other mitigation measures are listed below:

- The Contractor shall control construction vibration levels using the best available techniques (BAT).
- The Contractor shall also ensure that the vibration levels at Rail Corridor (excluding the worksite area) do not exceed PPV, 8.0 mm/s.
- Mitigation measures such as setting up barriers (see Figure 11-29) using GI pipes and canvas sheets to prevent road kills should be implemented along the road where Moderate impact occurs due to rock breaking.

Figure 11-29 Example of Barriers using GI Pipes and Canvas Sheet

In Table 11-18, behavioural impacts may be identified in different species. Incubating birds of prey may leave their nests due to rock breaking and excavation, resulting in the loss of their chicks or eggs. Accordingly, closely related species, including the red-legged crake, red junglefowl, and long-tailed parakeet, exhibit similar behavioural patterns during the breeding season. Foraging, nesting and roosting are typical bird activities that can be affected. The impacts can be reversed once rock breaking and excavation work has been completed and when high levels of human activity become more manageable. In addition, bird breeding seasons are observed year-round in Singapore, so significant impacts cannot be avoided. Still, avoiding the peak bird breeding season from March to July is suggested.

Ground-borne Noise (human impact)

In general, ground-borne noise level values are relevant only where they are higher than the airborne noise from the construction activities, such as where tunnelling activities are being undertaken. Regenerated noise levels would typically be masked by airborne noise associated with surface construction activities.

Depending on the progress rates and techniques employed, tunnel boring effects can be relatively short-lived. However, they might expose a receptor to high magnitudes of ground-borne noise. Mitigation options for tunnelling activities include providing a comprehensive and informative community relations programme in advance of the works. It might also be possible to control the vibration at the source by altering the tunnelling operation parameters such as cutterhead rotation and driving force if the project requirements permit.

A summary of mitigation measures for both ground-borne noise and the vibration is provided below:

- Schedule high vibration activities (rock breaking and excavation, rotary bored piling, vibratory piling, vibratory compaction) during the daytime;

- Avoid rock breaking and excavation and vibratory piling activities during peak bird breeding season from March to July;
- Restrict vibration-generating activities to below the vibration threshold of PPV, 8.0 mm/s;
- No night works should be conducted after 7 pm for all non-safety critical activities since the site is next to human and ecological receptors;
- The Contractor shall control construction vibration levels using the best available techniques (BAT);
- Set up barriers to prevent roadkills; and
- If there are justified complaints from the construction works, particularly from rock breaking, piling works, and tunnel boring, the operation may need to mitigate vibration to the most practical levels.

11.9.2 Operational Phase

Based on the assessment results in Section 11.8.2.1, 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. Since the potential impact significance is considered to be Minor, no mitigation measures are required during operational phase.

11.10 Residual Impacts

11.10.1 Construction Phase

This section details the residual impacts after the implementation of proposed mitigation measures on ecological receptors due to construction activities.

11.10.1.1 Behavioural Impacts of Fauna (Mitigated Scenario)

Comparisons were made between the base and mitigated impact significances, as seen in Table 11-23. Since the impact significances for some of the construction activities after implementation of mitigation measures are **Major**, additional mitigation measures were introduced, and the resultant impact significance was determined.

Table 11-23 Comparison between Base and Mitigated Impact Significances with Mitigation Measures for Mitigated Scenario on Ecological Receptors

Construction Worksite and Activities	Impact Significance with Minimum Controls	Mitigation Measures (if required)	Residual Impact Significance with Mitigation Measures	Changes in Impact Significance (Increased/Decreased/No Change?)
	Rail Corridor		Rail Corridor	
Rock Breaking and Excavation (Sungei Kadut Station)	Negligible – Moderate Impacted Area (ha) Moderate, 27.5	Reduce MIC to 0.8 kg	Negligible - Minor	Decreased
Rotary Bored Piling	Negligible – Minor	Not required	Negligible – Minor	No Change
Vibratory Piling	Negligible – Moderate Impacted Area (ha) Moderate, 2.3	No night works after 7 pm should be conducted	Negligible – Minor	Decreased
Vibratory Compactor (Low)	Negligible – Minor	Not required	Negligible – Minor	No Change
Vibratory Compactor (High)	Negligible – Minor	Not required	Negligible – Minor	No Change
Tunnel Boring Machine (Hypothetical overall[14])	Negligible – Major Impacted Area, ha Moderate, 17.6 Major, 9.2	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.	Negligible – Major	No Change Since the impact significance is still Moderate/ Major, EMMP measures should be further enhanced, monitored, and applied.
Tunnel Boring Machine at Spot 1 at Reception Track	Negligible – Major Impacted area, ha Moderate, 8.8 Major, 0.5			
Tunnel Boring Machine at Spot 2 at DTLe	Negligible – Major Impacted area, ha Moderate, 8.1 Major, 0.4			

[14] The hypothetical overall TBM was assessed as complete affected alignment. It should be noted that the tunnel boring machine will only bore section by section along the alignment at a rate of 5-7 m/day. Thus, this assessment also identified the critical spots for detailed hotspot analysis of TBM passage impact on fauna at any particular time.

Construction Worksite and Activities	**Impact Significance with Minimum Controls**	**Mitigation Measures (if required)**	**Residual Impact Significance with Mitigation Measures**	**Changes in Impact Significance (Increased/Decreased/No Change?)**
	Rail Corridor		**Rail Corridor**	
Tunnel Boring Machine at Spot 3 at DTLe	Negligible – Moderate		Negligible – Moderate	
	Impacted area, ha			
	Moderate, 0.5			

11.10.1.2 Assessment for Ground-borne Vibration for Human Receptors

After implementing mitigation measures, the results of the ground-borne vibration on human receptors due to construction activities are summarised in Table 11-24.

Table 11-24 Comparison between Ground-borne Vibration Impact Significance and Residual Impact Significance with Mitigation Measures on Human Receptors

Construction Worksite and Activities	Impact Significance with Minimum Controls	Mitigation Measures (if required)	Residual Impact Significance with Mitigation Measures	Changes in Impact Significance (Increased/Decreased/No Change?)
Rock Breaking and Excavation (Sungei Kadut Station)	Negligible	Not required	Negligible	Decreased
Rotary Bored Piling	Negligible – Minor	Not required	Negligible – Minor	No Change
Vibratory Piling	Negligible – Minor	Not required	Negligible – Minor	No Change
Vibratory Compactor (Low)	Negligible – Minor	Not required	Negligible – Minor	No Change
Vibratory Compactor (High)	Negligible – Minor	Not required	Negligible – Minor	No Change
Tunnel Boring Machine (Hypothetical overall)	Negligible – Moderate Number of Receptors with Moderate Impact Significance: 6	Provide a comprehensive and informative community relations programme in advance of the works. It is reasonable to assess the duration of impacts to be transient during the pass-by of a tunnel boring machine in a day.	Negligible – Minor	Decreased

11.10.1.3 Assessment for Ground-borne Noise for Human Receptors

After implementing mitigation measures, the results of the ground-borne noise on human receptors due to construction activities are summarised in Table 11-25. It should be noted that ground-borne noise is reradiated noise from a building structure. Thus, ground-borne noise level values are generally noticeable only in a tranquil environment; hence, they are typically masked by airborne noise associated with surface construction activities.

Table 11-25 Maximum Predicted Ground-borne Noise Levels Due to Construction Activities for Human Receptors

Construction Worksite and Activities	Impact Significance with Minimum Controls	Mitigation Measures (if required)	Residual Impact Significance with Mitigation Measures	Changes in Impact Significance (Increased/Decreased/No Change?)
Rock Breaking and Excavation (Sungei Kadut Station)	Negligible – Moderate	Reduce MIC to 0.8 kg	Negligible - Minor	Decreased
Rotary Bored Piling	Negligible – Moderate	No night work after 7 pm should be conducted	Negligible – Minor	Decreased
Vibratory Piling	Negligible – Moderate	No night work after 7 pm should be conducted	Negligible – Minor	Decreased
Vibratory Compactor (Low)	Negligible – Minor	Not required	Negligible – Minor	No Change
Vibratory Compactor (High)	Negligible – Minor	Not required	Negligible – Minor	No Change
Tunnel Boring Machine	Negligible – Major Number of Receptors with Moderate Impact Significance: 2 Number of Receptors with Major Impact Significance: 4	Provide a comprehensive and informative community relations programme in advance of the works. It is reasonable to assess the duration of impacts to be transient during the pass-by of a tunnel boring machine in a day.	Negligible – Moderate Number of Receptors with Moderate Impact Significance: 4	Decreased
Note: Regenerated ground-borne noise due to construction activities may be masked by airborne noise.				

11.10.2 Operational Phase

Since no mitigated alignment or mitigation measures are required for the track, residual impacts for the operational phase were not assessed.

11.11 Cumulative Impacts with Other Concurrent Projects

Understanding concurrent projects near the Project must be reviewed in parallel with the baseline data collected. Some potential concurrent projects might include:

- HDB CCK N1 Construction
- JTC Woodlands Road Realignment

During this report's writing, there is limited information regarding construction activities to be reviewed; hence, cumulative impacts were not assessed quantitatively.

The construction schedule for the concurrent projects mentioned might overlap with this Project. However, typical construction methods for pipelines and roads are unlikely to cause higher vibration levels than this Project. Hence this Project's worksite activities are the primary source of impact within the vibration and Biodiversity Study Area.

During the operational phase of this Project, the ground-borne vibration levels caused by moving trains are insignificant in the cumulative impact of other significant concurrent developments.

11.12 Summary of Key Findings

The Study assessed the vibration impacts of construction and operational phases on human receptors and the Biodiversity Study Areas (i.e., Rail Corridor).

The Study reviewed several works of literature to gather information on the vibration thresholds of fauna. Research shows that vibration thresholds for fauna are species-specific. There is a limited amount of information in this area for the indicator species for the Study. The Study uses the baseline results along the Rail Corridor to form conservative criteria for the impact assessment. Different standards and guidelines were also used to determine the criteria for human comfort.

Baseline vibration levels were collected and analysed in this Study. The 99th percentile of the baseline ground-borne vibration levels measured across the 15 locations ranged from PPV, 0.03 to 0.23 mm/s. Along the Rail Corridor, it ranged from PPV, 0.03 to 0.09 mm/s. Locations V1 and V3 stood out with PPV, 0.23 and PPV, 0.15 mm/s, respectively. The high baseline vibration levels could be due to the monitoring locations close to factories and roads. The remaining locations, V2, V4 to V9 and VR1 to VR6, had results close to PPV, 0.03 to 0.10 mm/s.

The Study assessed ground-borne vibration impacts from construction and operational phases on the potential of the burrow and mud lobster mounds damage/collapse (i.e., structural impact assessment) and the ecological behaviour of the sensitive receptors. The biodiversity habitats/fauna species classifies in Priorities 1, 2 and 3 as ecologically sensitive receptors based on their ecological values and sensitivity towards vibration. The indicator species include pangolin and mud lobster mounds.

The Study assessed predicted vibration levels from the construction and operational phases of the Project against the impact assessment matrix for impact intensity, consequence, likelihood and impact significance on the ecological behaviours of the ecologically sensitive receptors. The Study also evaluated ground-borne noise and vibration on building receptors due to construction activities. Operational impacts on building receptors were not covered in this Study but in the Contract 9175 NVS Preliminary Report.

11.12.1 Summary of Construction Phase

The Study predicted vibration levels for various construction equipment at the worksites. The vibration levels are assessed according to the impact assessment matrix.

Ecological Receptors

Rotary bored piling and vibratory compactors (low and high) cause **Negligible - Minor** impact significance.

The impact significance caused by vibratory piling was to be **negligible - Moderate. By avoiding night work, it can be reduced to negligible - Minor**.

Rock breaking and excavation at Sungei Kadut Station were predicted to cause **Negligible - Moderate** impact significance; the impact can be reduced to **Negligible - Minor** by reducing the Maximum Instantaneous Charge (MIC) to 0.8 kg. GI pipes and canvas sheets to prevent road kills should be implemented along the road where Moderate impact occurs due to rock breaking.

Tunnel boring produces a **Negligible – Major** impact significance. As it is reasonable to assess the duration of impacts of TBM to be transient during the pass-by of the TBM in a day, mitigation measures are not required for TBM. Thus, the impact of the TBM remains as **Negligible – Major** impact significance. However, EMMP measures should be further enhanced, monitored and applied.

Human Receptors

Rotary bore piling and vibratory piling cause **Negligible - Minor** ground-borne vibration impact significance and **Negligible - Moderate** ground-borne noise impact significance. This can be reduced to **Negligible - Minor** by avoiding construction work at night.

The impact significance caused by vibratory compactors (low and high) was **Negligible – Minor** for both ground-borne vibration and ground-borne noise.

Rock breaking at Sungei Kadut Station causes **Negligible** ground-borne vibration impact and **Negligible - Moderate** impact significance for ground-borne noise. The impact can be reduced to **Negligible - Minor** by reducing the Maximum Instantaneous Charge (MIC) to 0.8 kg. It should be noted that since above-ground construction activities potentially generate a much higher noise, the ground-borne noise may be masked by the airborne noise.

The tunnel boring machine causes **Negligible - Moderate** ground-borne vibration impact and **Negligible – Major** ground-borne noise impact. With community engagement, the impacts on ground-borne vibration and ground-borne noise can be managed through cooperation and communication with the affected community and reduced to **Negligible – Minor,** and **Negligible – Moderate** impact significance, respectively.

11.12.2 Summary of Operational Phase

Operational vibration impact assessment results indicate that standard track forms do not cause exceedances in vibration levels or produce moderate or major impact significances towards ecological receptors. The residual impact significance on ecological behaviour is **Minor** along the Rail Corridor. Thus, no mitigation measures are required. Operational impacts on human receptors were covered in the Contract 9175 NVS Preliminary Report [R-90], no receptor was predicted to experience any exceedances for ground-borne noise and vibration.

11.13 Conclusion

The Study assessed the vibration impacts of construction and operational phases on human receptors and the Biodiversity Study Areas (i.e., Rail Corridor).

The Study reviewed several works of literature to gather information on vibration thresholds of fauna. Research shows that vibration thresholds for fauna are species-specific. There is a limited amount of information in this area for the indicator species for the Study. The Study uses the baseline results along the Rail Corridor to form conservative criteria for the impact assessment. Different standards and guidelines were also used to determine the criteria for human comfort.

Baseline vibration was also monitored in this Study. The 99th percentile of the ground-borne vibration levels measured across the 17 locations for the baseline study ranged from PPV 0.03 to 0.28 mm/s. It ranged from PPV, 0.03 to 0.09 mm/s along the Rail Corridor. Locations V1, V3, V10 and V11 stood out with PPV 0.15 to PPV 0.28 mm/s. This could be due to the locations being close to factories and roads or existing viaduct and could have been affected by the industrial operations and road traffic, leading to a higher recorded vibration level. The remaining locations, V2, V4 to V9 and VR1 to VR6, had results close to PPV, 0.03 to 0.10 mm/s.

The BS 5228-2:2009+A1:2014 guideline was used for the vibration threshold for cosmetic damage, while the BS 6472-2:2008 guideline was used to assess ground-borne vibration induced by rock breaking. The Study assessed ground-borne vibration impacts from construction and operational phases on the potential of burrow and mud lobster mound damage/collapse (i.e. structural impact assessment) and the ecological behaviour of the sensitive receptors. The biodiversity habitats/fauna species are classified in Priorities 1, 2 and 3 as ecologically sensitive receptors based on their ecological values and sensitivity towards vibration. The indicator species selected in this area were pangolin and mud lobster. The Study assessed the predicted vibration levels from the construction and operational phases of the Project and evaluated against the project specific criteria developed for this project. The Study also evaluated ground-borne noise and vibration on building receptors due to construction activities.

Construction Phase

Groundborne vibration - Ecological Receptors

For the ecological receptors, impacts from rock breaking and excavation at Sungei Kadut Station, rotary bore piling, vibratory piling, vibratory compactors and tunnel boring (hypothetical overall and spots) were assessed for ground-borne vibration. The impact significance caused by rotary bored piling and vibratory compactors (low and high) were predicted to be **Negligible - Minor**. Rock breaking and excavation at Sungei Kadut Station, vibratory piling, and tunnel boring at Spot 3 were predicted to cause **Negligible - Moderate** impact significance, while tunnel boring (hypothetical overall, Spot 1 and Spot 2) were predicted to cause **Negligible - Major** impact significance.

Mitigation measures were proposed for construction activities with **Moderate - Major** impact significance. The impact can be reduced to **Negligible** - **Minor** for rock breaking and excavation at Sungei Kadut Station by reducing the Maximum Instantaneous Charge (MIC) to 0.8 kg. By avoiding construction work at night, the impact significance of vibratory piling can be reduced to **Negligible - Minor**. As it is reasonable to assess the duration of impacts of TBM to be transient during the pass-by of the TBM in a day, mitigation measures are not required for TBM. Thus, the impact of the TBM remains as **Negligible – Major** impact significance. However, EMMP measures should be further enhanced, monitored and applied. The Contractor shall control construction vibration levels using the best available techniques (BAT). The Study recommends controlling vibration levels emitted to PPV, 8 mm/s where burrows and mud lobster mounds are sighted to prevent damage/collapse of the burrows and entombing the species.

Ground-borne vibration - Human Receptors

The Study assessed ground-borne vibration impacts from the construction phase on the human receptors. For the human receptors, impacts from rotary bore piling, rock breaking, vibratory piling, vibratory compactors and tunnel boring machines were assessed. The overall impacts for ground-borne vibration were predicted to be **Negligible - Minor** for most activities except for the tunnel boring machine, which was predicted to have **Negligible - Moderate** impact. With community engagement, the impacts can be managed through cooperation and communication with the affected community.

Ground-borne noise – Human Receptors

The Study also assessed ground-borne noise impacts from the construction phase on the human receptors resulting from rotary bore piling, vibratory pile driver, vibratory compactor, rock breaking and tunnel boring machine. The overall unmitigated impacts for ground-borne noise were predicted to be **Negligible - Minor** for vibratory compactions. While for rock breaking and excavation at Sungei Kadut Station, rotary bore piling and vibratory piling, they were predicted to have **Negligible - Moderate** impact. For tunnel boring, it was predicted to have Negligible – Major impact significance.

By reducing the MIC to 0.8 kg, the impact significance of rotary bore piling and rock breaking Sungei Kadut Station was predicted to be **Negligible - Minor** for ground-borne noise. The impacts caused by rotary bore piling and vibratory piling could be reduced by avoiding construction work at night. With community engagement, the impacts on ground-borne noise can be managed through cooperation and communication with the affected community and reduced to **Negligible – Moderate**. It should also be noted that since above-ground construction activities potentially generate a much higher noise, the ground-borne noise may be masked by the airborne noise.

Operational Phase

Operational vibration impact assessment results indicate that standard track forms do not cause exceedances in vibration levels or produce moderate or major impact significances towards ecological receptors. The residual impact significance on ecological behaviour is **Minor** along the Rail Corridor on ecologically sensitive receptors. Operational impacts on human receptors were covered in the Contract 9175 NVS Preliminary Report [R-90]; no receptor was predicted to experience any exceedances for ground-borne noise and vibration. Thus, no mitigation measures are required.

Concurrent construction activities at nearby works are unlikely to cause more impacts on the vibration Biodiversity Study Areas.

A summary of ground-borne noise and vibration can be seen in Table 11-26.

Table 11-26 Summary of Ground-borne Noise and Vibration Impact Assessment

Sensitive Receptors and Phases	Impact Significance with minimum controls		Residual Impact Significance with mitigation measures (if required)	
	Ground-borne Vibration	Ground-borne Noise	Ground-borne Vibration	Ground-borne Noise
Construction Phase				
Ecologically Sensitive Receptors	Negligible - Major	-	Negligible - Major	-
Human Sensitive Receptors	Negligible - Moderate	Negligible - Major	Negligible - Minor	Negligible - Moderate
Operational Phase				
Ecologically Sensitive Receptors	Minor	-	Minor	-
Human Sensitive Receptors	No receptor was predicted to experience any exceedances for ground-borne noise and vibration (Contract 9175 NVS Preliminary Report)			

12 Soil, Groundwater and Waste Management

This section presents the soil and groundwater baseline environment within the study area of the Project (as defined in Section 6.2.1) as well as assessment of impacts due to activities planned for construction and operational phases of the Project.

12.1 Introduction

Activities expected to occur during the construction and operational phase of the Project may cause contamination of soil and groundwater resources, and also cause decrease of groundwater level. Furthermore, during early construction and main construction phase activities, such as site clearance and tunnel boring works there is also a potential to encounter historically contaminated soils. If not managed properly, these contaminated soils may cause variety of adverse impacts on surrounding environment, such as soil, groundwater and downstream watercourses quality degradation as well as direct and/ or indirect impacts on biodiversity and humans. This section presents the assessment undertaken to define the nature and scale of potential impacts that soil and groundwater can have on identified sensitive receptors, associated with the Project's construction and operational phases. This section also outlines appropriate controls and best management practices

12.2 Methodology

This section outlines the methodology adopted for the soil, groundwater and waste baseline study. The baseline conditions within the defined study area (refer to the Section 0 of this report) were based on findings from Historical Land Use Survey (HLUS) report [R-79]. Furthermore, as part of HLUS, collected secondary information regarding current land use and physical settings was verified during site reconnaissance carried out in February 2021. Currently, intrusive soil and groundwater investigations (i.e., Soil and Groundwater Environmental Baseline Study [EBS] and Soil Investigation [SI]) are being conducted by LTA's Term contractor. Relevant data collected so far was shared with AECOM and was used in this Report. Once the full data set is available, AECOM may review the collected data and include it in the report to further refine and update (if required) soil and groundwater baseline analysis and impact assessment depending on overall project's timeline.

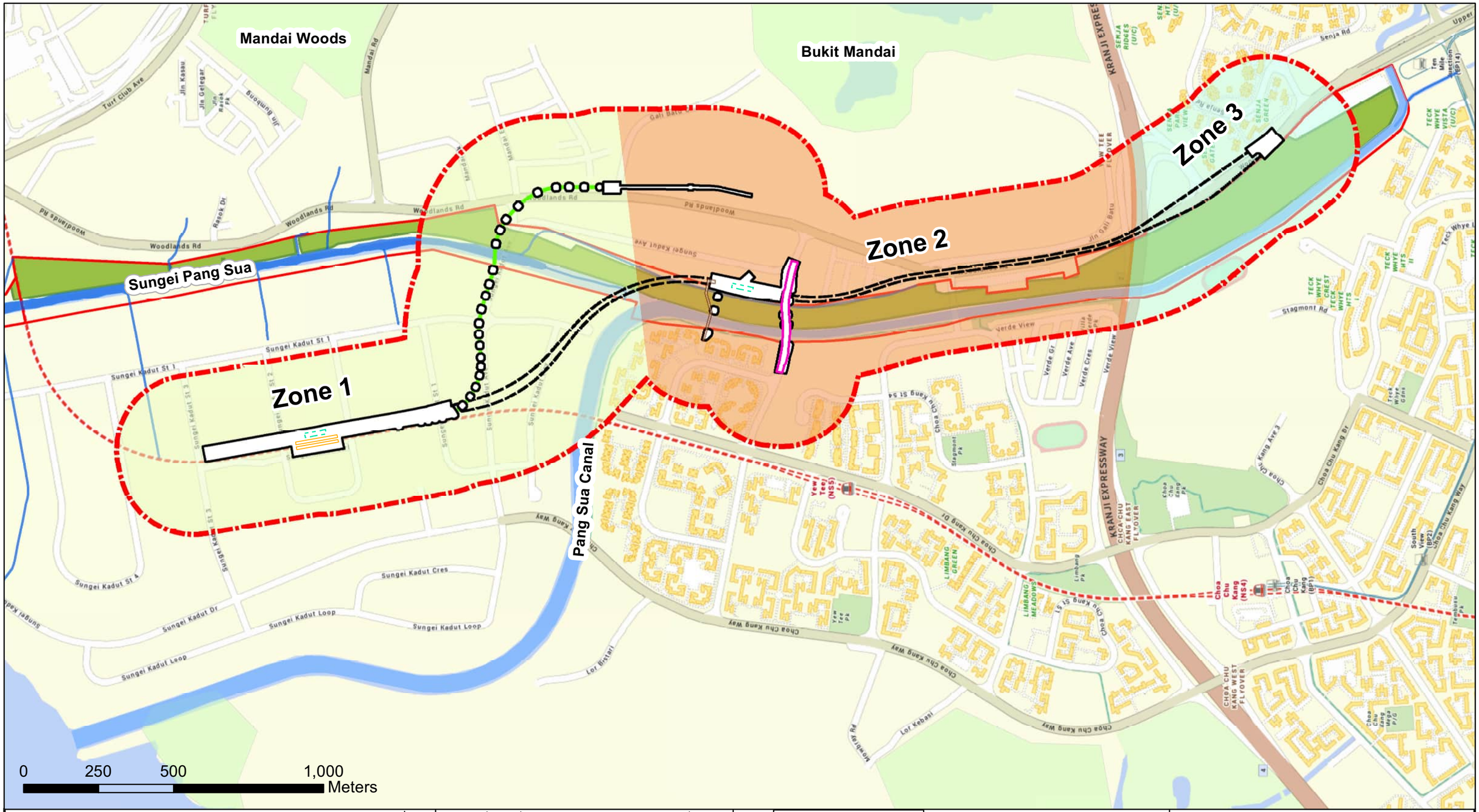
12.2.1 Desktop Assessment (Secondary Data Collection)

The assessment of potential soil and groundwater contamination due to past and existing land uses within the study area is carried out based on the findings of HLUS Report [R-79]. The adopted approach for HLUS was in accordance with an environmental due diligence site assessment and includes a preliminary assessment of potential environmental liabilities arising from past and existing facilities and activities within the study area. For the purposes of HLUS report, the study area has been divided into three zones (i.e., Zone 1, Zone 2 and Zone 3), as shown in the
Figure 12-1. Non-intrusive investigation of potential buried structures, unexploded ordnances (UXO) and potential contamination due to existing and historical land uses was then carried out for each of the Zones.
Furthermore, HLUS Report recommends the methodology and proposes locations for intrusive ground investigations, including advancement of environmental boreholes, installation of monitoring wells, as well as investigation methods for verification of presence of underground buried structures. In total, 18 locations were proposed for intrusive soil and groundwater investigations. Upon discussion with LTA, 11 out of the proposed 18 locations for boreholes have been selected and included in LTA's work order to the term contractors. At the time of writing this report, soil and groundwater quality data was available for 9 boreholes (data still pending for 2 boreholes). Once available this data will be included in the Report.

12.2.2 Field Assessment (Primary Data Collection)

No primary data collection (i.e., intrusive soil and groundwater investigation) was required as per scope of this Study. The secondary data which was collected as a part of HLUS (as explained in the previous section) is considered to be sufficient for determining the potential soil and groundwater contamination arising from past and existing land uses and/ or activities.

It should be noted that a walkover along publicly accessible paths within study area was carried out on 16 February 2021. The purpose was to verify the accuracy of the information collected during the desktop assessment, such as current land use, physical settings as well as to check if any signs of contamination exist (e.g., odour, staining, etc.). Available results from the intrusive soil and groundwater investigation (obtained from EBS and SI carried out by LTA's Term contractor) have been reviewed and included in the soil and groundwater baseline assessment.



Legend

- Proposed DTL2e Stations (Underground)
- Proposed NSL Elevated Station
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Potential Future Infrastructure
- Proposed DTL2e Tunnel Alignment
- Study Area
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Study Zones

- Zone 1
- Zone 2
- Zone 3

N

Rev.	Date	By	Description	Chk'd	App'd
-	AUG 2022	SAG	Draft Final Report	ADP	JAG

Qualified Person Endorsement :
NA

LTA Endorsement :
NA

Consultant : AECOM

Land Transport Authority
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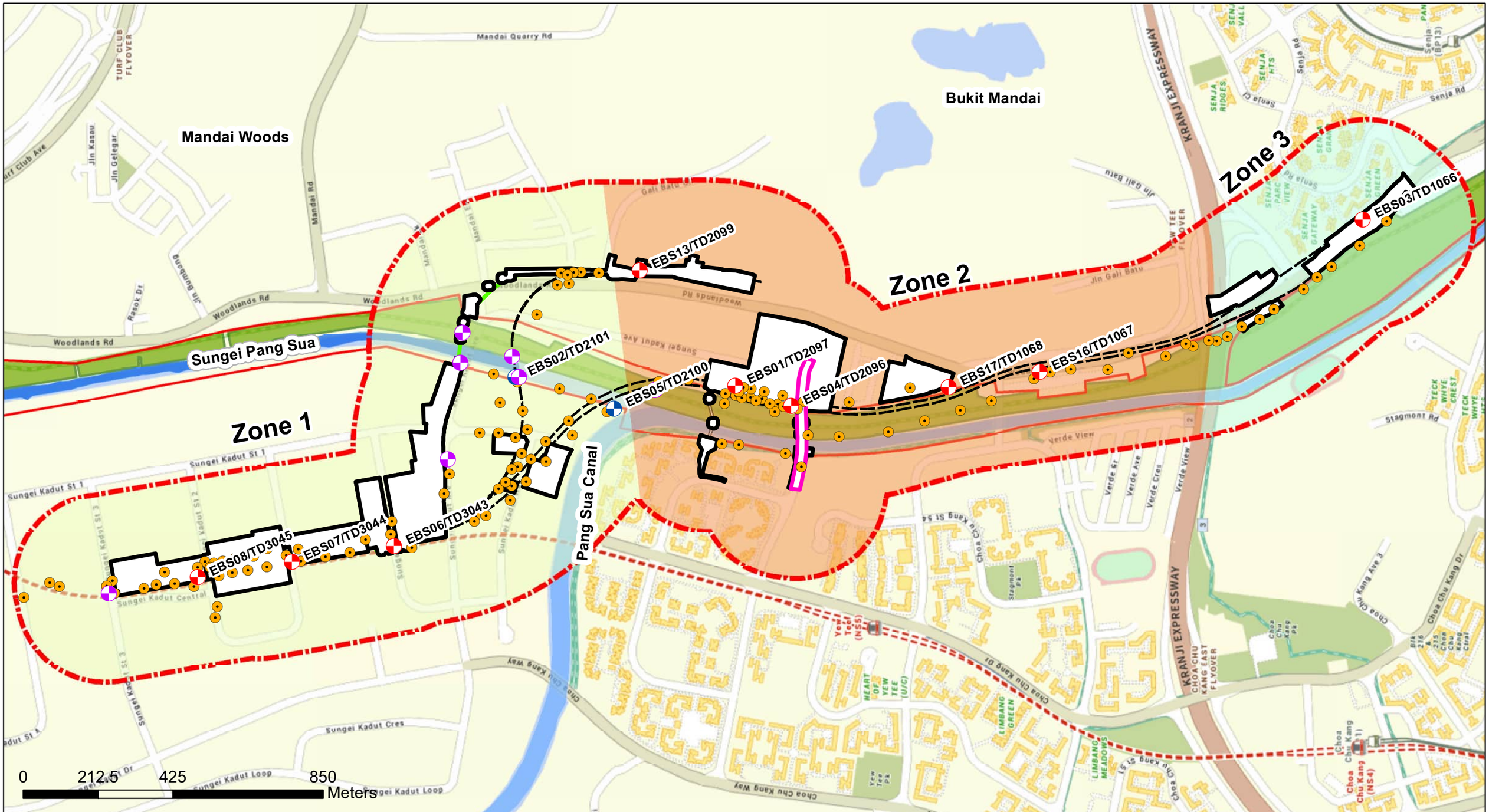
Project Title :
CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
SOIL, GROUNDWATER AND WASTE STUDY AREA AND DEMARCATED STUDY ZONES (AS PER HLUS REPORT)

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

Note: Source of basemap - OneMap



Legend

Boreholes

- Developed Environmental Boreholes
- ENV BHs converted into MWs
- Proposed Environmental Boreholes
- SI Boreholes
- Proposed Vehicle Bridge
- Construction Worksite
- Potential Future Infrastructure
- Proposed Pedestrian Overhead Bridge
- Biodiversity Study Area
- Existing Vegetated Area

- Zone 1
- Zone 2
- Zone 3
- Proposed DTL2e Tunnel Alignment
- Pang Sua Canal
- Sungei Pang Sua
- Study Area

N

Rev.	Date	By	Description	Chk'd	App'd
A	APR 2023	SAG	Draft Final Report	ADP	JAG
-	AUG 2022	SAG	Draft Final Report	ADP	JAG

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Project Title :
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ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
Location of boreholes

Designed	Checked	Approved
SAG	ADP	JAG
	Drawn: SAG	Date: APR 2023

Figure No. : 12 - 2 | Rev. : A | Sheet : 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap

12.3 Potential Sources of Impacts

Activities during both construction and operational phases of the Project may cause contamination of soil and groundwater as well as decrease in groundwater levels. Furthermore, during pre-construction and construction activities such as site clearance and excavation, there is also a potential to encounter historically contaminated soils.

12.3.1 Construction Phase

Soil and groundwater can be potentially exposed to contaminants due to activities during the construction phase of the Project, especially within and around the cut and cover areas. In addition, construction activities which include soil dewatering process (e.g., excavations, foundations works) can cause temporary or permanent decrease in groundwater levels. The activities during construction phase which could affe ct soil and groundwater (both quality and groundwater level) and their associated impacts are listed in the table below.

Table 12-1 Potential Sources of Soil and Groundwater Impacts during Construction Phase

Construction Activity	Potential Sources of Impacts	Potentially Affected Environmental Parameter	Potential Associated Impacts
• Demolition of existing buildings, mainly along Woodlands Road, Sungei Kadut Avenue, Sungei Kadut Way and Sungei Kadut Street 1 and 2 • Site clearance (e.g., vegetation clearance for construction of vehicular bridge and pedestrian linkbridge) and levelling • Earthworks • Construction of station boxes and MRT superstructures (above-ground station, entrances/ exits for stations) • Construction of potential future infrastructure, elevated vehicular bridge, pedestrian linkbridge • Construction of launch/ retrieval shafts, tunnelling works	• Groundwater extraction/ soil dewatering for the activities that require dry soil conditions • Decreased infiltration into the ground due to increase of impervious surfaces within study area	Groundwater Level	• Disturbances in habitats and/ or reduction in size of species' population due to decreased groundwater baseflow feeding into downgradient watercourses • It is understood that currently in Singapore groundwater is not used for any beneficial purposes (i.e., drinking or industrial purposes, irrigation)
• Site clearance (e.g., vegetation clearance	• Seepage of contaminants (if any)	• Soil Quality	• Some contaminants such as metals can

Construction Activity	Potential Sources of Impacts	Potentially Affected Environmental Parameter	Potential Associated Impacts
for construction of vehicular bridge and pedestrian linkbridge) • Earthworks (e.g., excavation of cut and cover areas, civil engineering earthworks) • Stockpiling of excavated soil from cut and cover areas (e.g., intermediate and interchange stations' station boxes) and tunnel boring activities • Management and disposal of excavated soils and groundwater during excavations and tunnel boring activities	from excavated soil into the underlying soil and groundwater • Soil erosion of exposed soil from excavations and stockpiles • Leakage of contaminants (if any) from extracted groundwater into the underlying soil and groundwater • Improper management of wastewater generated from tunnelling activities	• Groundwater Quality	accumulate in the root zone, affecting vegetation growth and long-term viability • Contaminated soil and groundwater can directly or indirectly affect flora and fauna, possibly leading to reduction in size of species' population and long-term viability • Contaminated groundwater may affect the quality of downgradient surface watercourses • Pollution of the adjacent areas within the immediate vicinity of the Project due to migration of groundwater contamination • Adverse impact on human health due to direct or indirect exposure to contaminated soil and groundwater • It is understood that currently in Singapore groundwater is not used for any beneficial purposes (i.e., drinking or industrial purposes, irrigation)
• Handling, transfer and storage of hazardous chemicals/ substances • Handling, transfer and storage of toxic chemical waste (e.g., diesel, bentonite, lubricants, oils, grease, solvents, etc.) generated during construction activities • Maintenance of vehicles, machinery and equipment	• Uncontrolled discharge and leakage of waste and chemicals due to improper management • Inappropriate or inadequate design parameters for storage containers • Discharge or leakage of chemicals used for refuelling and maintenance of vehicles, machinery and equipment		

12.3.2 Operational Phase

Taking into consideration proposed activities during operational phase of the Project, it is anticipated that there will be limited sources of impacts to soil and groundwater during this phase. Use of chemicals and generation of toxic chemical waste are expected to be of limited quantities, while generation of hazardous waste is associated to maintenance works on the alignment, stations and facility buildings. Non-hazardous waste generations are expected to be generated from the site office staff's general waste within the station. However, the permanent land use change (i.e., increase in impervious surfaces) and planned underground developments may lead to

groundwater level decrease. The table below summarizes activities which could affect soil and groundwater during operational phase and their associated impacts.

Table 12-2 Potential Sources of Soil and Groundwater Impacts during Operational Phase

Construction Activity	Potential Sources of Impacts	Potentially Affected Environmental Parameter	Potential Associated Impacts
• Permanent land use change	• Decreased infiltration into the ground due to more areas with impervious surfaces	Groundwater Level	• Disturbances in habitats and/ or reduction in size of species' population due to decreased groundwater baseflow feeding into downgradient watercourses • It is understood that currently in Singapore groundwater is not used for any beneficial purposes (i.e., drinking or industrial purposes, irrigation)
	• Heavy rain and stormwater wash-off pollutants in the new development area and discharge into surrounding soil and groundwater	• Soil Quality • Groundwater Quality	• Some contaminants such as metals can accumulate in the root zone, affecting vegetation growth and long-term viability • Contaminated soil and groundwater can directly or indirectly affect flora and fauna, possibly leading to reduction in size of species' population and long-term viability • Adverse impact on human health due to direct or indirect exposure to contaminated soil and groundwater • It is understood that currently in Singapore groundwater is not used for any beneficial purposes (i.e., drinking or industrial purposes, irrigation)
• Maintenance works on the alignment and stations • Landscaping works	• Small quantities of chemical waste generated during maintenance works and operational phase (e.g.,	• Soil Quality • Groundwater Quality	• Some contaminants such as metals can accumulate in the root zone, affecting vegetation

Construction Activity	Potential Sources of Impacts	Potentially Affected Environmental Parameter	Potential Associated Impacts
	used fluorescent bulbs, used lead-batteries, used chemical containers, etc.) • Operation of trains resulting in diesel oil leakage • Improper handling of hazardous substances during operational phase		growth and long-term viability • Contaminated soil and groundwater can directly or indirectly affect flora and fauna, possibly leading to reduction in size of species' population and long-term viability • Contaminated groundwater may affect the quality of downgradient surface watercourses • Contaminated soil and groundwater can have adverse effects on human health • It is understood that currently in Singapore groundwater is not used for any beneficial purposes (i.e., drinking or industrial purposes, irrigation)

12.4 Identification of Sensitive Receptors

The sensitive receptor screening for soil and groundwater was conducted within the study area (as defined in Section 6.2.1.) and classified based on the methodology outlined in Table 6-2.

12.4.1 Construction Phase

The activities planned for the construction phase of the Project have a potential to cause soil and groundwater contamination which can consequently have adverse effects on identified ecological and human receptors. Additionally, during earthworks there is also a potential to encounter historically contaminated soils. The following table identifies potential soil and groundwater sensitive receptors and summarizes sensitivity of each of the receptors.

Table 12-3 Classification of Receptor Sensitivity for Construction Phase

Sensitive Receptor	Receptor Description	Receptor Classification
Ecological Receptors		

Sensitive Receptor	Receptor Description	Receptor Classification
Urban vegetation	• This habitat occupies the largest area and is mostly located in the southern part of study area. • It comprises mostly exotic trees (e.g., rain tree, Senegal mahogany, trumpet tree) and native species (e.g., sea almond, wild cinnamon). Some areas (mostly located along the Rail Corridor) have little to no trees, comprising grasses. • Pruning and mulching activities as well as short uniform grass height observed during site surveys indicate that this habitat is regularly maintained. • This habitat is assessed to be of low ecological value (refer to the Section 7).	Priority 3
Scrubland	• This is the second largest habitat within study area which mostly occurs along the Rail Corridor, adjacent to exotic-dominated secondary forest and behind the mangrove forest. • It is typically made of shrubs, climbing/ creeping plants and grasses. • This habitat is assessed to be of medium ecological value (refer to the Section 7).	Priority 3
Mangrove forest	• This habitat borders the banks of Sungei Pang Sua and stretches towards the north of the study area. • Great variety of mangrove species can be found in this habitat, owning to its proximity to the sea and varying salinity along the Sungei Pang Sua. • Most of the identified floral species of conservation significance can be found in this habitat. • This habitat is assessed to be of high ecological value (refer to the Section 7).	Priority 2
Exotic-Dominated Secondary forest	• This habitat is mostly located in the east of the study area with some patches along the Rail Corridor. • It mostly comprises exotic-dominated species. • This habitat is assessed to be of medium ecological value (refer to the Section 7).	Priority 3
Pang Sua Canal	• It is the largest aquatic habitat found within the study area. • Man-made canal with surface water runoff mostly originating from upstream drainage network. • Poor water quality for survival of aquatic life (i.e., relatively high pH, TSS and nutrients) which is aligned with biodiversity findings which indicated that the canal is poor in aquatic life. • It may provide connectivity for some aquatic species such as the otters and birds.	Priority 3

Sensitive Receptor	Receptor Description	Receptor Classification
Sungei Pang Sua	• It is the second largest aquatic habitat located within study area, stretching from the south of Sungei Kadut Avenue into the open sea at the north. • Tidal-influenced stream with low water flow (possibly stagnant conditions in certain areas). • Brackish water found in Pang Sua Canal is highly influenced by tidal cycle while hydrological findings suggest that the majority of water inflows from surrounding areas while groundwater only partly supports and maintains surface water level. • Habitat for mangrove and mudflat-associated species and home to nationally Endangered mud lobsters.	Priority 2
Human Receptors		
On-site construction workers and permanent off-site residents downgradient of the study area	• On-site construction workers may come in direct contact with soil and groundwater during various construction phase activities (i.e., activities that require soil excavation, soil dewatering and management of soil and extracted groundwater). Possible pathways of exposure of on-site construction workers might be dermal contact and incidental ingestion of soils and/ or groundwater and inhalation of fugitive dust and vapours derived from soil • Off-site permanent residents may be exposed to soil and/ or groundwater during the soil excavation and handling activities via incidental ingestion of soil and/ or groundwater particulates, inhalation of fugitive dust and vapours and less likely by dermal contact. • Based on HLUS findings, there is a potential of Chemicals of Concern (COC) such as aromatic compounds, phenols, metals, PAHs and TPHs to be found in underlying soil due to the past and current land uses. • It is assumed that groundwater will not be extracted and used for any beneficial purposes (i.e., drinking and industrial purposes, irrigation).	Priority 1
Off-site visitors	• Off-site visitors might be exposed short-term to soil and groundwater, with possible exposure pathways being incidental ingestion of soil and groundwater as well as inhalation of fugitive dust and vapours • Based on HLUS findings, there is a potential of Chemicals of Concern (COC) such as aromatic compounds, phenols, metals, PAHs and TPHs to be found in underlying soil due to the past and current land uses.	Priority 1

12.4.2 Operational Phase

As the proposed development becomes operational, it is expected that the human activities will increase within the study area. Activities planned for the operational phase of the Project, such as landscaping and maintenance may potentially cause soil and groundwater pollution and subsequently have adverse impact on human and ecological receptors. The following table identifies potential soil and groundwater sensitive receptors and summarizes sensitivity of each of the receptors.

Table 12-4 Classification of Receptor Sensitivity for Operational Phase

Sensitive Receptor	Receptor Description	Receptor Classification
Ecological Receptors		
Ecological receptors that could potentially be affected by operational activities are expected to be the same as the ones for construction phase. Refer to Table 12-3 for more details on each of the identified ecological receptors.		
Human Receptors		
Maintenance workers	• Maintenance workers may come in contact with soil and groundwater during operational phase (e.g., during landscaping activities). Possible pathways of exposure of might be dermal contact and incidental ingestion of soils and/ or groundwater and inhalation of fugitive dust and vapours derived from soil.	Priority 1
Visitors	• Visitors of future developments may come in contact with soil and groundwater particles during operational phase via inhalation of fugitive dust and vapours derived from the soil during maintenance activities within the development.	Priority 1

12.5 Soil, Groundwater and Waste Management Baseline Findings

The historical and existing land use within the study area (i.e., 250 m from both sides of the centerline of the alignment and potential future infrastructure) was reviewed in detail in the HLUS report [R-79]. A soil and groundwater baseline study was carried out to determine the soil profile and hydrogeological conditions of the Study Area, and also to ascertain the presence of possible pollutants in the underlying soil and groundwater that may impact the from the latest SI investigations were used for the analysis of the soil and groundwater baseline conditions.

12.5.1 Underground Buried Structures and Unexploded Ordinance (UXO)

Based on the findings from HLUS report, there is a potential for existence of underground buried structures within study area. Potential underground buried structures include:

- Demolished buildings along Sungei Kadut Street 2 (refer to the Figure 4-2); and
- Remnants of the railway tracks left along the current Rail Corridor.

The HLUS found that there were bombing incidences at Yew Tee Village during World War II. However, as that area has been redeveloped and currently is a residential area, the presence of UXOs was found to be unlikely.

12.5.2 Potential Contamination from Historical and Existing Land Use

Potentially contaminating activities can be deducted to have occurred based on the land use at the site, noting possible contamination at some point during the history of the land usage. The identified potential sources of contamination and Chemicals of Concern (CoC), based on historical and existing land use have been summarized in the table below.

Table 12-5 Summarized Potential Sources of Contamination and CoCs per Study Zones

Study Zone	1	2	3
Historical Land Uses and Activities	• Completion of the Singapore-Kranji Railway; • Rubber and sundry tree plantations; • Industrial facilities; • Establishment of Sungei Kadut Industrial Estate and Mandai Estate; • Woodlands extension of North-South MRT line; • Residential Developments; • Widening of watercourses near Rail Corridor to form Pang Sua Canal; • Demolition of some buildings; and • Removal of Singapore-Kranji Railway tracks and conversion to Rail Corridor	• Completion of the Singapore-Kranji Railway; • Storage of oil (at Yew Tee Village) • Singapore Granite Quarries Mill; • Establishment of Yew Tee Industrial Estate; • Residential and educational developments; • Widening of watercourses near Rail Corridor to form Pang Sua Canal; and • Construction and development of Gali Batu MRT Depot, Gali Batu Bus Terminal, expansion of Gali Batu MRT Depot and Gali Batu Bus Terminal (not finished)	• Completion of the Singapore-Kranji Railway; • Establishment of Bukit Panjang Estate; • Establishment of Kampong Bukit Panjang; • Construction of Kranji Expressway; and • Residential and educational developments •
Current Land Use[1]	• Residential; • Business 2; • Business Park; • Reserve Site; • Civic and Community Institution; • Park; • Waterbody; and • Place of Worship	• Residential; • Park; • Reserve Site; • Health and Medical Care; • Waterbody; • Educational Institution; and • Transport Facilities •	• Residential; • Special Use (Military Base); • Educational Institution; • Waterbody; and • Park •
Potential Sources of Contamination	• Discharge/ release of chemicals, oil products or other hazardous material due to accidental spills, leaks, and releases in storage, transport, and utility equipment areas; • Land previously used for storing or handling chemicals, oil products, or other hazardous material; • Manufacture of furniture and woodworks; and • Repair of vehicles		

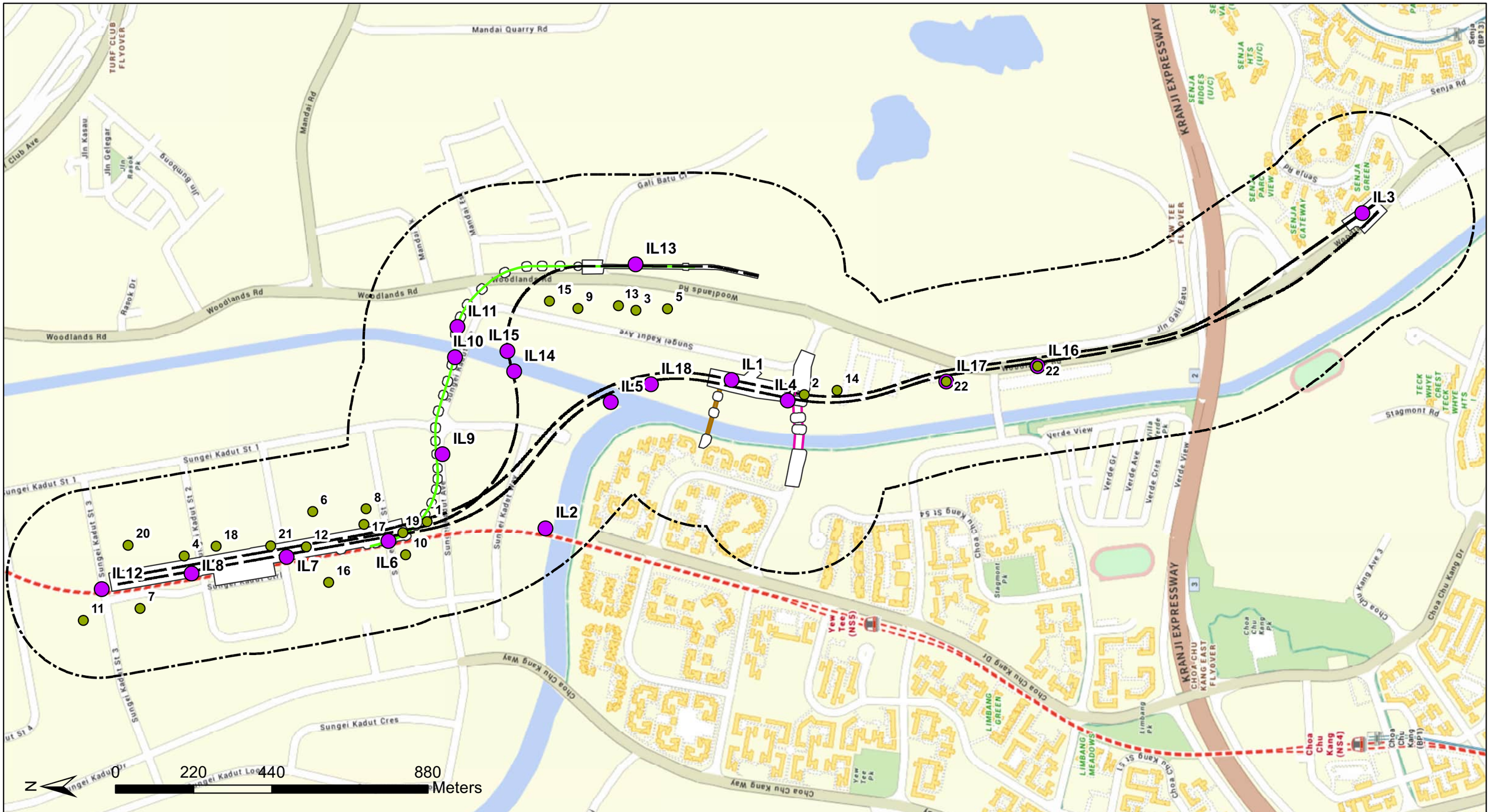
Study Zone	1	2	3
Potential Chemicals of Concern (CoC)	Aromatic compounds, phenols, PAHs, metals, TPHs, VOCs, chlorinated hydrocarbons, dioxins/furans	Aromatic compounds, phenols, PAHs, metals, TPHs, VOCs, SVOCs, dioxins/furans, chlorinated hydrocarbons, organotin, cyanides	N/A[2]
Note: 1- Current Land Use categories are based on URA's Master Plan Zoning Interpretation. Detailed current land uses are described in Section 4.1 of this report. 2- As this zone comprises of residential buildings, educational institutes and military base with no industries, it is assumed that Zone 3 does not have potential contamination sources.			

12.5.3 Findings From Latest EBS Investigations

Intrusive soil and groundwater investigation was recommended in HLUS in order to assess potential historical contamination of underlying soil and groundwater. The locations of proposed boreholes were proposed based on the historical land use and identified potential contamination hotspots. Upon discussion with LTA, 11 out of 18 proposed locations for soil and groundwater investigations have been selected. At the time of writing this report, soil and groundwater analytical results are still pending for two (2) boreholes (including one [1] monitoring well) and these results will be included in the subsequent submission, once the results become available. The naming convention for the proposed boreholes (as per this HLUS) and developed boreholes/ monitoring wells (as used by LTA's contractor) is summarised below for easier reference.

Table 12-6 Adopted Borehole/ Monitoring Well Naming Convention

HLUS ID	LTA's Contractor ID	Note(s)
IL1/EBS01	TD/2097/EBS	Developed
IL2/EBS02	TD/2101/EBS	Excluded
IL3/EBS03	TD/1066/EBS	Pending development
IL4/EBS04	TD/2096/EBS	Developed
IL5/EBS05	TD/2100/EBS	Developed
IL6/EBS06	TD/3043/EBS	Developed
IL7/EBS07	TD/3044/EBS	Developed
IL8/EBS08	TD/3045/EBS	Developed
IL9/EBS09	TD/2106/EBS	Excluded
IL10/EBS10	TD/2104/EBS	Excluded
IL11/EBS11	TD/2105/EBS	Excluded
IL12/EBS12	TD/3046/EBS	Excluded
IL13/EBS13	TD/2099/EBS	Pending development
IL14/EBS14	TD/2102/EBS	Developed
IL15/EBS15	TD/2103/EBS	Excluded
IL16/EBS16	TD/1067/EBS	Developed
IL17/EBS17	TD/1068/EBS	Developed
IL18/EBS18	TD/2098/EBS	Excluded



Legend

- Proposed Location for Intrusive Investigation
- Potential Contamination Site
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Proposed Cut and Cover Areas
- Proposed Vehicle Bridge
- Proposed Pedestrian Overhead Bridge
- Project Corridor (250 m)

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A	APR 2023	HHL	Concept Stage	ADP	JAG
-	DEC 2021	HHL	Concept Stage	ADP	JAG

Qualified Person Endorsement :
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Project Title :
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ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
PROPOSED LOCATIONS FOR INTRUSIVE INVESTIGATION BASED ON POTENTIAL CONTAMINATION SITES

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
HHL	ADP	JAG	12-3	-	1 of 1
	Drawn HHL	Date APR 2023	CAD File Name : NA		A3

Note: Source of basemap - OneMap (www.onemap.sg)

12.5.3.1 Soil Profile

Based on the information obtained during the soil investigation study, the soil profile encountered at the study are generally consisted of clay. Layers of sandy clay were observed at TD/3034/EBS (down to 1.0 m bgl) TD/3044/EBS (down to 3.5 m bgl), TD/3045/EBS (from 2.5 m bgl to 6.0 m bgl), TD/2100/EBS (from 3.5 m bgl to 6.0 m bgl) and depths down to 1.0 m bgl at borehole TD/2101/EBS. Layers of silty clay were observed in depths 1.0 m bgl – 4.0 m bgl at borehole TD/3043/EBS, down to 3.5 m bgl at borehole TD/2100/EBS, and from 1.0 m bgl to 6.0 m bgl at borehole TD/2101/EBS. Layer of clayey sand was observed in at TD/3045/EBS, down to the depth of 3.5 m bgl. During the borehole drilling and soil sampling, no staining was reported in soil samples.

12.5.3.2 Soil Baseline Results

In total, twenty-seven (27) soil samples were collected from the nine (9) boreholes - three (3) soil samples were collected from each borehole as shown in Figure 12-4. Based on the available information collected during the field works, the samples collected from the subsurface (i.e. from 0.5 m bgs down to the termination depth of the boreholes) did not exhibit signs of visual or olfactory contamination.

From each of the boreholes, three (3) samples were sent for ex-situ laboratory analysis. A summary of the reported constituents in soil and a comparison of the soil analytical results with the DIVs for soil is shown in Table 7 - 4. A copy of the full laboratory report for the soil samples is included in Appendix

Table 12-7 Soil Analytical Results

Test Parameters	Units	DIV	TD/3043/EBS			TD/3044/EBS			TD/3045/EBS			TD/2100/EBS		
			S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)
Metals														
Arsenic	mg/kg	76	4.70	N.D.	N.D.	4.68	N.D.	N.D.	9.87	3.92	5.41	19.14	N.D.	2.19
Antimony	mg/kg	22	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Barium	mg/kg	- [a]	N.D.	N.D.	N.D.	3.63	N.D.	N.D.	N.D.	N.D.	N.D.	3.79	3.04	10.23
Cadmium	mg/kg	13	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Chromium	mg/kg	180 / 78 [b]	22.76	50.77	44.27	19.47	39.59	34.37	32.25	59.07	18.65	20.33	N.D.	N.D.
Cobalt	mg/kg	190	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Copper	mg/kg	190	6.31	2.47	4.83	7.74	N.D.	4.54	86.52	20.31	37.59	11.06	N.D.	2.37
Mercury	mg/kg	36 / 4 [c]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Lead	mg/kg	530	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	7.98	N.D.	11.96	N.D.	12.77
Zinc	mg/kg	720	2.05	N.D.	N.D.	14.38	N.D.	N.D.	N.D.	N.D.	N.D.	39.85	N.D.	N.D.
2 others	mg/kg	100 – 190	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cyanide														
Cyanide (Total)	mg/kg	20 / 50 [d]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Aromatic Compounds														
10 Compounds	mg/kg	*various*[e]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Polynuclear Aromatic Hydrocarbons (PAHs)														
Phenanthrene	mg/kg	*NA*	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
10 Compounds	mg/kg	*various*[e]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Total Petroleum Hydrocarbons (TPH)														
C_6 – C_{36} (Total)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Chlorinated Hydrocarbons														
29 Compounds	mg/kg	*various*[e]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Pesticides														

Test Parameters	Units	DIV	TD/3043/EBS			TD/3044/EBS			TD/3045/EBS			TD/2100/EBS		
			S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)
20 Compounds	mg/kg	*various*[e]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Other Pollutants														
Phthalates	mg/kg	*NA*	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Pyridine	mg/kg	11.0	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
MCPA	mg/kg	4.0	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
4 Others		*various*[e]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Asbestos	mg/kg	100	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Miscellaneous Parameters														
pH	-	Not Available	7.8	7.0	7.7	8.0	7.0	7.4	8.1	4.6	4.7	7.0	4.1	4.7
Organic Content	%	Not Available	3.28	5.81	4.05	2.17	6.74	7.92	2.65	2.40	0.53	6.33	2.64	2.39
Moisture Content	%	Not Available	24.32	45.03	45.95	26.36	42.17	47.75	43.38	37.29	34.22	41.70	19.17	18.96

Notes:
Not Available - value not specified in standard
N.D. – Not Detected above the limit of reporting (LOR)
a - The barium standard has been repealed because the intervention value for barium proved to be lower than the concentration naturally occurring in the soil.
b - Intervention value for Chromium (III) = 180 mg/kg; Chromium (IV) = 78 mg/kg
c - Intervention value for Inorganic Mercury = 36 mg/kg; Organic Mercury = 4 mg/kg
d - Intervention value for free cyanide = 20 mg/kg; complex cyanide = 50 mg/kg
e - Intervention value for mineral oil; This applies to contamination due to mixtures (e.g. gasoline or domestic heating oil), then not only the alkane content but also the content of aromatic and/or polycyclic aromatic hydrocarbons must be determined. This aggregate parameter has been adopted for practical reasons. Further toxicological and chemical disaggregation is under study.

Test Parameters	Units	DIV	TD/2101/EBS			TD/2096/EBS			TD/2097/EBS			TD/1067/EBS		
			S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)
Metals														
Arsenic	mg/kg	76	29.60	2.85	N.D.	13.08	20.41	2.70	19.25	17.15	N.D.	43.49	N.D.	N.D.
Antimony	mg/kg	22	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Barium	mg/kg	- [a]	N.D.	N.D.	N.D.	11.94	21.49	N.D.	17.17	20.57	N.D.	13.97	N.D.	N.D.
Cadmium	mg/kg	13	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Chromium	mg/kg	180 / 78 [b]	2.55	N.D.	2.23	14.43	15.16	N.D.	12.07	20.98	N.D.	12.41	2.25	N.D.
Cobalt	mg/kg	190	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Copper	mg/kg	190	N.D.	N.D.	N.D.	33.04	21.97	N.D.	22.43	5.68	N.D.	4.67	N.D.	N.D.
Mercury	mg/kg	36 / 4 [c]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Lead	mg/kg	530	N.D.	N.D.	9.84	8.97	35.07	2.23	31.87	34.20	N.D.	24.82	N.D.	8.47
Molybdenum	mg/kg	190	14.08	N.D.	N.D.	10.61	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Nickel	mg/kg	100	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Zinc	mg/kg	720	N.D.	N.D.	N.D.	70.73	101.92	N.D.	53.08	19.83	N.D.	129.32	N.D.	N.D.
Cyanide														
Cyanide (Total)	mg/kg	20 / 50 [d]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Aromatic Compounds														
10 Compounds	mg/kg	*various*[e]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Polynuclear Aromatic Hydrocarbons (PAHs)														

Test Parameters	Units	DIV	TD/2101/EBS			TD/2096/EBS			TD/2097/EBS			TD/1067/EBS		
			S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)
Phenanthrene	mg/kg	*NA*	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
10 Compounds	mg/kg	*various*[e]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Total Petroleum Hydrocarbons (TPH)														
$C_6 – C_9$	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
$C_{10} – C_{14}$	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
$C_{15} – C_{28}$	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	14.6	31.7	N.D.	26.0	N.D.	N.D.	N.D.
$C_{29} – C_{36}$	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	25.00	14.80	N.D.	21.90	N.D.	N.D.	N.D.
$C_{10} – C_{36}$	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	39.60	46.50	N.D.	48.00	N.D.	N.D.	N.D.
$C_6 – C_{36}$ (Total)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	46.50	N.D.	48.00	N.D.	N.D.	N.D.

Test Parameters	Units	DIV	TD/2101/EBS			TD/2096/EBS			TD/2097/EBS			TD/1067/EBS		
			S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)
Chlorinated Hydrocarbons														
29 Compounds	mg/kg	*various*[e]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Pesticides														
20 Compounds	mg/kg	*various*[e]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Other Pollutants														
Phthalates	mg/kg	*NA*	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Pyridine	mg/kg	11.0	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
MCPA	mg/kg	4.0	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
4 Others	mg/kg	*various*[e]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Asbestos	mg/kg	100	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Miscellaneous Parameters														
pH	-	Not Available	6.5	8.1	7.8	8.2	6.3	5.8	8.5	6.8	6.1	7.5	7.0	5.5

Test Parameters	Units	DIV	TD/2101/EBS			TD/2096/EBS			TD/2097/EBS			TD/1067/EBS		
			S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)
Organic Content	%	Not Available	3.53	1.19	10.78	1.50	2.61	5.66	3.18	7.61	2.91	3.46	3.48	4.76
Moisture Content	%	Not Available	15.06	13.59	34.67	27.10	18.12	30.65	12.74	31.96	27.18	25.28	33.39	48.50

Notes:
Not Available - value not specified in standard
N.D. – Not Detected above the limit of reporting (LOR)
a - The barium standard has been repealed because the intervention value for barium proved to be lower than the concentration naturally occurring in the soil.
b - Intervention value for Chromium (III) = 180 mg/kg; Chromium (IV) = 78 mg/kg
c - Intervention value for Inorganic Mercury = 36 mg/kg; Organic Mercury = 4 mg/kg
d - Intervention value for free cyanide = 20 mg/kg; complex cyanide = 50 mg/kg
e - Intervention value for mineral oil; This applies to contamination due to mixtures (e.g. gasoline or domestic heating oil), then not only the alkane content but also the content of aromatic and/or polycyclic aromatic hydrocarbons must be determined. This aggregate parameter has been adopted for practical reasons. Further toxicological and chemical disaggregation is under study.

Test Parameters	Units	DIV	TD/1068/EBS			TD/1066/EBS			TD/2099/EBS		
			S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)
Metals											
Arsenic	mg/kg	76	43.49	N.D.	N.D.	P.R.	P.R	P.R	P.R	P.R	P.R
Antimony	mg/kg	22	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Barium	mg/kg	- [a]	13.97	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Cadmium	mg/kg	13	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Chromium	mg/kg	180 / 78 [b]	12.41	2.25	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Cobalt	mg/kg	190	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Copper	mg/kg	190	4.67	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Mercury	mg/kg	36 / 4 [c]	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Lead	mg/kg	530	24.82	N.D.	8.47	P.R	P.R	P.R	P.R	P.R	P.R
Molybdenum	mg/kg	190	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Nickel	mg/kg	100	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Zinc	mg/kg	720	129.32	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Cyanide											
Cyanide (Total)	mg/kg	20 / 50 [d]	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Aromatic Compounds											
10 Compounds	mg/kg	*various*[e]	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Polynuclear Aromatic Hydrocarbons (PAHs)											
Phenanthrene	mg/kg	*NA*	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
10 Compounds	mg/kg	*various*[e]	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Total Petroleum Hydrocarbons (TPH)											
C_6 – C_{36} (Total)	N.D.	N.D.	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Chlorinated Hydrocarbons											
29 Compounds	mg/kg	*various*[e]	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Pesticides											
20 Compounds	mg/kg	*various*[e]	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R

Test Parameters	Units	DIV	TD/1068/EBS			TD/1066/EBS			TD/2099/EBS		
			S1 (0.5-0.7)	S1 (0.5-0.7)	S3 (3-3.2)	S1 (0.5-0.7)	S3 (3-3.2)	S1 (0.5-0.7)	S3 (3-3.2)	S3 (3-3.2)	S4 (4.5-4.7)
Other Pollutants											
Phthalates	mg/kg	*NA*	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Pyridine	mg/kg	11.0	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
MCPA	mg/kg	4.0	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
4 Others	mg/kg	*various*[e]	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Asbestos	mg/kg	100	N.D.	N.D.	N.D.	P.R	P.R	P.R	P.R	P.R	P.R
Miscellaneous Parameters											
pH	-	Not Available	7.6	8.1	6.0	P.R	P.R	P.R	P.R	P.R	P.R
Organic Content	%	Not Available	3.82	0.78	1.00	P.R	P.R	P.R	P.R	P.R	P.R
Moisture Content	%	Not Available	21.54	15.70	13.92	P.R	P.R	P.R	P.R	P.R	P.R

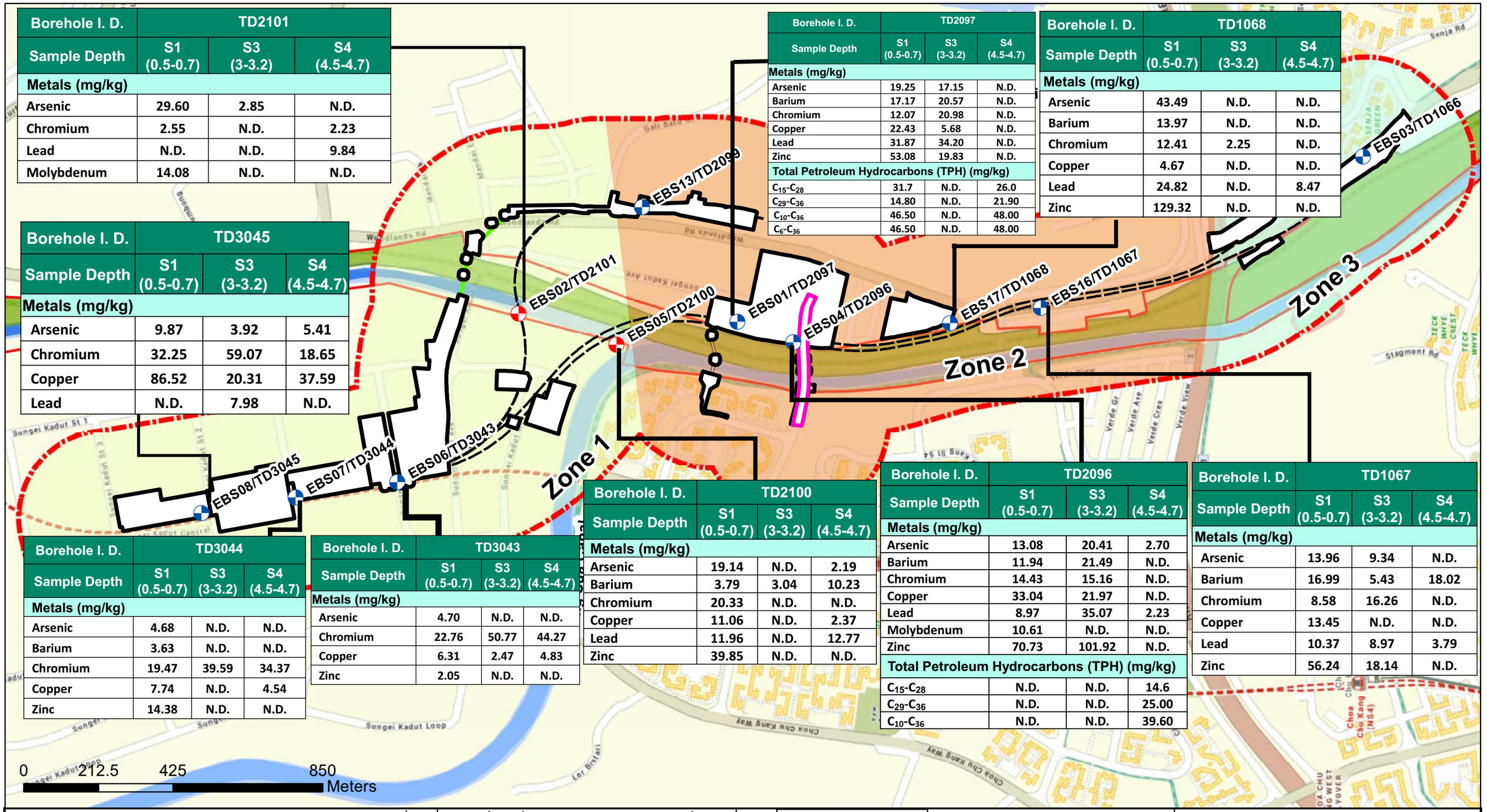
Notes:
Not Available - value not specified in standard
N.D. – Not Detected above the limit of reporting (LOR)
P.R. – Pending Results
a - The barium standard has been repealed because the intervention value for barium proved to be lower than the concentration naturally occurring in the soil.
b - Intervention value for Chromium (III) = 180 mg/kg; Chromium (IV) = 78 mg/kg
c - Intervention value for Inorganic Mercury = 36 mg/kg; Organic Mercury = 4 mg/kg
d - Intervention value for free cyanide = 20 mg/kg; complex cyanide = 50 mg/kg
e - Intervention value for mineral oil; This applies to contamination due to mixtures (e.g. gasoline or domestic heating oil), then not only the alkane content but also the content of aromatic and/or polycyclic aromatic hydrocarbons must be determined. This aggregate parameter has been adopted for practical reasons. Further toxicological and chemical disaggregation is under study.

Metals including arsenic, barium, chromium, copper, nickel and zinc were reported in most soil samples at concentrations above their respective levels of reporting (LOR). All of the detections were below their respective DIVs.

Total Petroleum Hydrocarbons (TPH) were reported at soil samples collected from TD/2096/EBS S4 (4.5 m - 4.7 m) and TD/2097/EBS S1 (0.5 m – 0.7 m) and S4 (4.5 m - 4.7 m). All of the detections were below their respective DIVs.

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

The source(s) of parameters reported above their respective LORs in collected soil samples could not be conclusively ascertained. As analysed in this Report, this area has been historically used for various industrial purposes which could have lead to potential spillages and/ or leakages into the environment. Therefore, it is possible that these anthropogenic activities have potentially caused the changes in chemical composition of soil (i.e. detections of metals and limited detection of TPH in analysed samples). However, it should be noted that some of the reported detections, such as metals, are also naturally occurring elements in the environment and their presence may be due to soil weathering presence. This claim cannot be confirmed nor disproved as currently there are no comprehensive studies that provide the information on the background concentrations of these parameters in soil in Singapore.



Borehole I. D.	TD2101		
Sample Depth	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)
Metals (mg/kg)			
Arsenic	29.60	2.85	N.D.
Chromium	2.55	N.D.	2.23
Lead	N.D.	N.D.	9.84
Molybdenum	14.08	N.D.	N.D.

Borehole I. D.	TD3045		
Sample Depth	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)
Metals (mg/kg)			
Arsenic	9.87	3.92	5.41
Chromium	32.25	59.07	18.65
Copper	86.52	20.31	37.59
Lead	N.D.	7.98	N.D.

Borehole I. D.	TD3044		
Sample Depth	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)
Metals (mg/kg)			
Arsenic	4.68	N.D.	N.D.
Barium	3.63	N.D.	N.D.
Chromium	19.47	39.59	34.37
Copper	7.74	N.D.	4.54
Zinc	14.38	N.D.	N.D.

Borehole I. D.	TD3043		
Sample Depth	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)
Metals (mg/kg)			
Arsenic	4.70	N.D.	N.D.
Chromium	22.76	50.77	44.27
Copper	6.31	2.47	4.83
Zinc	2.05	N.D.	N.D.

Borehole I. D.	TD2100		
Sample Depth	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)
Metals (mg/kg)			
Arsenic	19.14	N.D.	2.19
Barium	3.79	3.04	10.23
Chromium	20.33	N.D.	N.D.
Copper	11.06	N.D.	2.37
Lead	11.96	N.D.	12.77
Zinc	39.85	N.D.	N.D.

Borehole I. D.	TD2097		
Sample Depth	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)
Metals (mg/kg)			
Arsenic	19.25	17.15	N.D.
Barium	17.17	20.57	N.D.
Chromium	12.07	20.98	N.D.
Copper	22.43	5.68	N.D.
Lead	31.87	34.20	N.D.
Zinc	53.08	19.83	N.D.
Total Petroleum Hydrocarbons (TPH) (mg/kg)			
C_{15}-C_{28}	31.7	N.D.	26.0
C_{29}-C_{36}	14.80	N.D.	21.90
C_{10}-C_{36}	46.50	N.D.	48.00
C_{6}-C_{36}	46.50	N.D.	48.00

Borehole I. D.	TD2096		
Sample Depth	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)
Metals (mg/kg)			
Arsenic	13.08	20.41	2.70
Barium	11.94	21.49	N.D.
Chromium	14.43	15.16	N.D.
Copper	33.04	21.97	N.D.
Lead	8.97	35.07	2.23
Molybdenum	10.61	N.D.	N.D.
Zinc	70.73	101.92	N.D.
Total Petroleum Hydrocarbons (TPH) (mg/kg)			
C_{15}-C_{28}	N.D.	N.D.	14.6
C_{29}-C_{36}	N.D.	N.D.	25.00
C_{10}-C_{36}	N.D.	N.D.	39.60

Borehole I. D.	TD1068		
Sample Depth	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)
Metals (mg/kg)			
Arsenic	43.49	N.D.	N.D.
Barium	13.97	N.D.	N.D.
Chromium	12.41	2.25	N.D.
Copper	4.67	N.D.	N.D.
Lead	24.82	N.D.	8.47
Zinc	129.32	N.D.	N.D.

Borehole I. D.	TD1067		
Sample Depth	S1 (0.5-0.7)	S3 (3-3.2)	S4 (4.5-4.7)
Metals (mg/kg)			
Arsenic	13.96	9.34	N.D.
Barium	16.99	5.43	18.02
Chromium	8.58	16.26	N.D.
Copper	13.45	N.D.	N.D.
Lead	10.37	8.97	3.79
Zinc	56.24	18.14	N.D.

Legend

Boreholes

- Actual Environmental Boreholes
- Monitoring Well
- Proposed Environmental Boreholes
- Proposed Vehicle Bridge
- Construction Worksite
- Potential Future Infrastructure
- Proposed Pedestrian Overhead Bridge
- Proposed DTL2e Tunnel Alignment
- Study Area
- Zone 1
- Zone 2
- Zone 3
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area

Rev.	Date	By	Description	Chk'd	App'd
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Figure Title :

Soil analytical results

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
SAG	ADP	JAG	12 - 4	A	1 of 1
	Drawn SAG	Date APR 2023	CAD File Name : NA		A3

Note: Source of basemap - OneMap

12.5.3.3 Groundwater Elevation

Based on the gauging records of two (2) environmental boreholes (i.e. TD/2100/EB and TD/2101/EBS) developed within Study Area and measured on 24th August 2022 and 7th November 2022 respectively, the average stabilized water level (SWL) ranged from 101.3 m reduced level (mRL) in TD/2101/EBS to 102 mRL in TD/2100/EBS. The summary of the groundwater level measurements is presented in Table 12-8 Groundwater Elevation Data (m RL).

Table 12-8 Groundwater Elevation Data (m RL)

Borehole Number	Assumed Level and Top of Standpipe	Static Water Table		Water Table Reduced Level (m) RL	Groundwater Elevation (mSHD)
		Depth (m TOC)	Date of measurement		
TD/2100/EBS	104	2.0	24/9/2022	102	2.00
TD/2101/EBS	104	2.7	7/11/2022	101.3	1.30

Besides the environmental boreholes, geotechnical boreholes were also advanced as part of SI works for this Project. Table 12-11 below summarises the groundwater levels measured during the SI works and have also been taken into consideration during the groundwater elevation assessment.

Table 12-9 Groundwater Elevation Data (m SHD)

Borehole ID	Highest Observed Level (mSHD)	Lowest Observed Level (mSHD)	Average Observed Groundwater Levels (mSHD)
TD/1001	8.47	7.39	7.93
TD/1002	8.26	7.03	7.65
TD/1004	7.47	6.45	6.96
TD/1005	7.22	6.23	6.73
TD/1008	7.06	6.09	6.58
TD/1009	7.17	5.85	6.51
TD/1012	6.43	5.72	6.08
TD/1013	6.62	6.02	6.32
TD/1015	5.02	4.22	4.62
TD/1016	5.13	4.03	4.58
TD/1023	2.91	2.39	2.65
TD/2001	6.30	5.41	5.86
TD/2003	4.14	3.65	3.90
TD/2010	3.98	2.77	3.38
TD/2016	3.24	2.36	2.80
TD/2011	5.06	4.71	4.89
TD/3001	5.22	4.76	4.99
TD/3002	4.97	4.68	4.83

Borehole ID	Highest Observed Level (mSHD)	Lowest Observed Level (mSHD)	Average Observed Groundwater Levels (mSHD)
TD/3005	3.81	3.40	3.61
TD/3007	2.95	2.8	2.88
TD/3008	4.55	4.02	4.29
TD/3009	4.28	4.09	4.19
TD/3011	2.98	2.31	2.65
TD/3012	3.16	2.85	3.01
TD/3014	3.98	3.64	3.81
TD/3015	4.74	4.22	4.48
TD/3016	4.86	4.20	4.53
TD/3018	4.56	3.78	4.17
TD/3020	4.12	3.24	3.68
TD/3021	4.45	4.15	4.30
TD/3022	3.97	3.65	3.81
TD/3024	3.29	3.11	3.20
TD/3025	5.06	3.81	4.44
TD/1044	7.65	7.03	7.34
TD/1049	9.80	8.76	9.28
TD/2019	4.54	4.21	4.38
TD/2020	3.76	3.33	3.55
TD/2021	6.28	5.64	5.96
TD/2024	7.08	6.49	6.79
TD/2025	4.11	3.68	3.90
TD/2029	4.28	3.64	3.96
TD/2031	1.97	1.73	1.85
TD/2033	4.67	3.14	3.91
TD/2034	3.13	2.36	2.75
TD/2037	4.44	3.1	3.77
TD/2042	6.13	5.74	5.94
TD/2056	2.54	2.23	2.39
TD/2059	2.28	1.95	2.12
TD/2113	6.00	5.70	5.85

12.5.3.4 Groundwater Flow Direction and Velocity

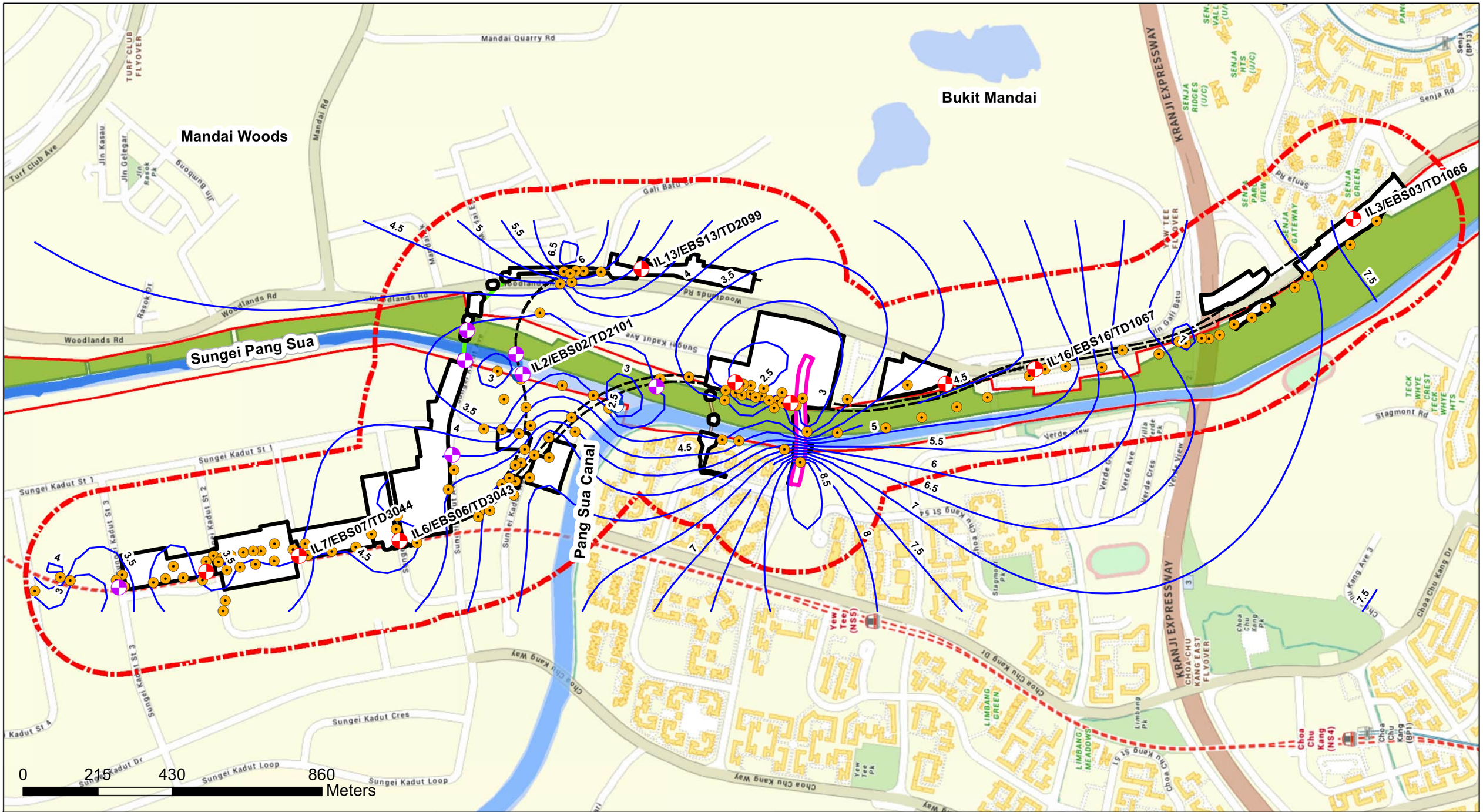
The hydraulic gradient calculated using the EPA On-Line Tools for Site Assessment is 0.003444 meter/meter (m/m). The linear velocity of the groundwater flow was calculated based on the Darcy's Equation as follows:

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

Where
V = Groundwater flow velocity;
K = Theoretical Hydraulic Conductivity;
n = Effective porosity: 0.36 for silty clay, 0.38 for sandy clay and 0.41 for sand; and
i = Hydraulic gradient: 0.003444 m/m.

The average hydraulic gradient of groundwater in the Study Area (based on the environmental boreholes data) was calculated to be 0.003444 m/m. Based on the hydraulic conductivity and effective porosity of the soil types encountered during soil boring, the calculated velocity of groundwater ranges from $3x10^{-4}$ m/year (silty clay) and $2.9x10^{-3}$ m/year (sandy clay). 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 the groundwater elevation contour maps (Figure 12-5), the inferred groundwater flow direction within Study Area follows the topography of the site and generally flows towards major watercourses within the Study Area (Sg Pang Sua and Pang Sua Canal) and flows towards the sea.



Legend

Boreholes

- ENV BHs converted into MWs
- Developed Environmental Boreholes
- Proposed Environmental Boreholes
- SI Boreholes
- Proposed Vehicle Bridge
- Construction Worksite
- Potential Future Infrastructure
- Proposed Pedestrian Overhead Bridge
- Isocontours
- Proposed DTL2e Tunnel Alignment
- Pang Sua Canal
- Sungei Pang Sua
- Study Area

N

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Figure Title :
Groundwater Elevation Contour Map

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	Drawn	Date
	SAG	APR 2023

Figure No. : 12-5 | Rev. : - | Sheet : 1 of 1

CAD File Name : NA | A3

Note: Source of basemap - OneMap

12.5.3.5 Groundwater Baseline Results

The assessed groundwater physicochemical parameters are presented in the table below and based on the in-situ measurements during groundwater sampling events at environmental boreholes (TD/2100/EBS and TD/2101/EBS).

Table 12-10 Physicochemical parameters of groundwater

Purged (L)	pH	Temperature (°C)	Actual Conductivity (µS/cm)	ORP (mV)	Dissolved Oxygen (mg/L)
Acceptance Criteria	+/- 0.2%	+/- 3%	+/- 3%	+/- 10%	+/- 10%
TD/2100/EBS: One well volume = 6.203 L					
6	4.57	25.34	117.18	+261.1	6.23
6	4.55	25.19	117.02	+261.3	6.27
6	4.55	25.41	116.97	+261.4	6.29
TD/2101/EBS: One well volume = 6.203 L					
6	7.23	26.91	130.87	+106.2	5.75
6	7.25	26.90	131.86	+105.5	5.76
6	7.29	26.83	130.90	+105.8	5.77

Based on the physicochemical parameters assessed, the following can be observed:

- The groundwater beneath TD/2101/EBS can be described as slightly acidic, while the groundwater beneath TD/2100/EBS can be described as basic, based on measured pH values;
- Conductivity in both TD/2100/ EBS and TD/2101/EBS is indicative of freshwater; and
- Measured redox potential shows that groundwater underlying on both TD/2100/EBS and TD/2101/EBS has oxidising condition.

In addition to in-situ measurements, one (1) groundwater sample was collected from both monitoring wells and was tested ex-situ. A summary of the reported constituents in groundwater and a comparison of the groundwater analytical results with the DIVs for groundwater is shown in Table 12-11 and Figure 12-6. A copy of the full laboratory report for the soil samples is included in Appendix K.

Table 12-11 Groundwater Analytical Results

Test Parameters	Units	DIV	ANZGFMWQ (2000)	TD/2100/EBS	TD/2101/EBS
Arsenic	µg/L	60	13/24[a]	13.8	N.D.
Antimony	µg/L	20	I.D	N.D.	N.D.
Barium	µg/L	625	NA	33.2	4.0
Cadmium	µg/L	6	0.2	N.D.	N.D.
Chromium	µg/L	30	*1*[b]	4	21.7
Cobalt	µg/L	100	I.D	N.D.	N.D.
Copper	µg/L	75	1.4	5.9	N.D.
Mercury	µg/L	0.3	0.6	N.D.	N.D.
Lead	µg/L	75	3.4	N.D.	N.D.
Molybdenum	µg/L	300	I.D	N.D.	N.D.
Nickel	µg/L	75	11	2.6	10.4
Zinc	µg/L	800	8.0[d]	19.7	28.6
Cyanide					
Cyanide (Total)	µg/L	1,500[a]	NA	N.D.	N.D.
Aromatic Compounds					
10 Compounds	µg/L	*Various*[e]	*Various*[e]	N.D.	N.D.
Polynuclear Aromatic Hydrocarbons (PAHs)					
Naphthalene	µg/L	70	16	1	1
10 Compounds	µg/L	*Various*[e]	*Various*[e]	N.D.	N.D.
Total Petroleum Hydrocarbons (TPH)					
$C_6 – C_9$	µg/L	NA	NA	N.D.	N.D.
$C_{10} – C_{14}$	µg/L		NA	N.D.	N.D.
$C_{15} – C_{28}$	µg/L		NA	66	138
$C_{29} – C_{36}$	µg/L		NA	N.D.	N.D.
$C_{10} – C_{36}$	µg/L		NA	N.D.	N.D.
$C_6 – C_{36}$	µg/L	600[c]	NA	N.D.	N.D.
Chlorinated Hydrocarbon					
29 Compounds	µg/L	*Various*[e]	*Various*[e]	N.D.	N.D.

Test Parameters	Units	DIV	ANZGFMWQ (2000)	TD/2100/EBS	TD/2101/EBS
Pesticides					
20 Compounds	µg/L	*Various*[e]	NA	N.D.	N.D.
Other Pollutants					
7 Others	µg/L	*Various*[e]	*Various*[e]	N.D.	N.D.
Miscellaneous Parameters					
BOD	mg/L	NA	NA	9	2
COD	mg/L	NA	NA	N.D.	N.D.
TOC	mg/L	NA	NA	24.3	2.3
Fluoride	mg/L	NA	NA	N.D.	N.D.
Chloride	mg/L	NA	NA	58.5	3.0
Bromide	mg/L	NA	NA	1.3	N.D.
Phosphate	mg/L	NA	NA	N.D.	N.D.
Sulfate	mg/L	NA	NA	159.7	289.3
Total Ammonical Nitrogen	mg/L	NA	NA	3.07	2.56

Notes:
Not Available - value not specified in standard
N.D. – Not Reported above the limit of reporting (LOR)
ID- Insufficient data to derive a reliable triger value
ANZGFMWQ – Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Trigger Value for Fresh Water, Level of Protection 95%
DIV- Dutch Intervention Value
a – Trigger value for Arsenic (as III) = 24 µg/L; trigger value for Arsenic (as V) = 13 µg/L
b - Intervention value for Chromium (VI)
c - Intervention value for Inorganic Mercury = 36 mg/kg; Organic Mercury = 4 mg/kg
d – Figure may not protect key test species from chronic toxicity
e - Intervention value for mineral oil; This applies to contamination due to mixtures (e.g. gasoline or domestic heating oil), then not only the alkane content but also the content of aromatic and/or polycyclic aromatic hydrocarbons must be determined. This aggregate parameter has been adopted for practical reasons. Further toxicological and chemical disaggregation is under study.

Metals including arsenic, barium, cadmium, chromium, cobalt, copper, lead, molybdenum and zinc were reported in all groundwater samples at concentrations above their respective levels of reporting (LOR). All of the detections were below their respective DIVs.

Polynuclear Aromatic Hydrocarbons (PAHs) were reported at TD/2100/EBS (i.e. Naphthalene) with concentrations of 1 µg/L. Sum of PAHs at each of the groundwater samples with PAH detections was below the DIV.

Total Petroleum Hydrocarbons (TPH) were reported at groundwater samples collected from TD/2100/EBS and TD/2101/EBS (i.e. $C_{15} – C_{28}$) with concentrations of 66 µg/L and 138 µg/L respectively. All of the detections were below their respective DIVs.

Conventional Parameters (i.e. BOD, TOC, chloride, bromide, sulfate and total ammonical nitrogen) were reported in all groundwater samples at concentrations above their respective levels of reporting (LOR) and did not indicate groundwater degradation.

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

Borehole I. D.	TD2101
Metals (µg/L)	
Barium	4.0
Chromium	21.7
Nickel	10.4
Zinc	28.6
Total Petroleum Hydrocarbons (TPH) (µg/L)	
C_{15}-C_{28}	66
Polynuclear Aromatic Hydrocarbons (PAHs) (µg/L)	
Naphthalene	1
Conventional Parameters	
BOD	9
TOC	24.3
Chloride	58.5
Bromide	1.3
Sulphate	159.7
TAN	3.07

Borehole I. D.	TD2100
Metals (µg/L)	
Arsenic	13.8
Barium	33.2
Chromium	4
Copper	5.9
Nickel	2.6
Zinc	19.7
Total Petroleum Hydrocarbons (TPH) (µg/L)	
C_{15}-C_{28}	66
Polynuclear Aromatic Hydrocarbons (PAHs) (µg/L)	
Naphthalene	1
Conventional Parameters	
BOD	9
COD	N.D.
TOC	24.3
Fluoride	N.D.
Chloride	58.5
Bromide	1.3
Phosphate	N.D.
Sulphate	159.7
TAN	3.07

Zone 1
Zone 2
Zone 3
Bukit Mandai
Sungei Pang Sua
Pang Sua Canal
EBS02/TD2101
EBS05/TD2100
KRANJI EXPRESSWAY
Mandai Quarry Rd
Woodlands Rd
Woodlands Rd
Sungei Kadut St 1
Sungei Kadut Cres
Sungei Kadut Loop
Choa Chu Kang Way
Choa Chu Kang Dr
Yew Tee (NS5)
Stagmont Rd
Verde View
Senja Rd
Jln Gali Batu
Gali Batu
Sungei Kadut Ave
Sungei Kadut St 2
Sungei Kadut St 3
Sungei Kadut Dr
Sungei Kadut Loop
Yew Tee Pk
Stagmont Pk
SENJA RIDGES (U/C)
SENJA HTS (U/C)
SENJA GATEWAY
SENJA GREEN
LIMBANG GREEN
LIMBANG MEADOWS
TECK WHYE CREST
TECK WHYE HTS

0 212.5 425 850 Meters

Legend

- Boreholes Converted Into Monitoring Wells
- Proposed Vehicle Bridge
- Construction Worksite
- Potential Future Infrastructure
- Proposed Pedestrian Overhead Bridge
- Zone 1
- Zone 2
- Zone 3
- Proposed DTL2e Tunnel Alignment
- Pang Sua Canal
- Sungei Pang Sua
- Study Area

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Figure Title :
Groundwater analytical results

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CAD File Name : NA | A3

Note: Source of basemap - OneMap

Table 12-12 Groundwater Analytical Results

Test Parameters	Units	Limit of Trade Effluent into Public Sewers[a]	TD/2096	TD/2097
BOD_5	mg/L	400	6	N.D
COD	mg/L	600	N.D	N.D
TOC	mg/L	400	19110	3304
TDS	mg/L	3000	260	372
Chloride (as Chlorine Ion)	mg/L	1000	62.9	53.9
Sulphate (as SO_4)	mg/L	1000	54.6	66.2
Sulphide (as Sulphur)		1	N.D	N.D
Cyanide (as CN)	mg/L	2	N.D	N.D
Detergents (linear alkylate sulphonate as methlyene blue active substances)	mg/L	30	N.D	N.D
Grease and Oil (Hydrocarbon)	mg/L	60	N.D	N.D
Grease and Oil (Non- hydrocarbon)	mg/L	100	N.D	N.D
Arsenic (As)	mg/L	5	0.27	0.03
Barium (Ba)	mg/L	10	1.01	0.09
Tin (Sn)	mg/L	10	0.01	N.D
Iron (Fe)	mg/L	50	3.31	0.42
Beryllium (Be)	mg/L	5	0.03	N.D
Boron (B)	mg/L	5	0.05	0.03
Manganese (Mn)	mg/L	10	2.02	0.11
Phenolic Compounds (expressed as phenols)	mg/L	0.5	N.D	N.D
Fluoride (expressed as fluoride ion)	mg/L	15	0.1	0.4
Cadmium (Cd)	mg/L	1	N.D	N.D
Chromium (Trivalent and Hexavalent)	mg/L	5	0.46	0.03
Copper (Cu)	mg/L	5	0.36	0.12
Lead (Pb)	mg/L	5	0.97	0.08

Test Parameters	Units	Limit of Trade Effluent into Public Sewers[a]	TD/2096	TD/2097
Mercury (Hg)	mg/L	0.5	N.D	N.D
Nickel (Ni)	mg/L	10	0.05	N.D
Selenium (Se)	mg/L	10	0.05	N.D
Silver (Ag)	mg/L	5	N.D	N.D
Zinc (Zn)	mg/L	10	1.49	0.27

Notes:
Not Available - value not specified in standard
N.D. – Not Reported above the limit of reporting (LOR)
a. – NEA Allowable Limits for Trade Effluent into Public Sewers

Mandai Woods

Sungei Pang Sua

Zone 1

Zone 2

Zone 3

EBS13/TD2099

EBS02/TD2101

EBS05/TD2100

EBS01/TD2097

EBS04/TD2096

EBS17/TD1068

EBS16/TD1067

EBS03/TD1066

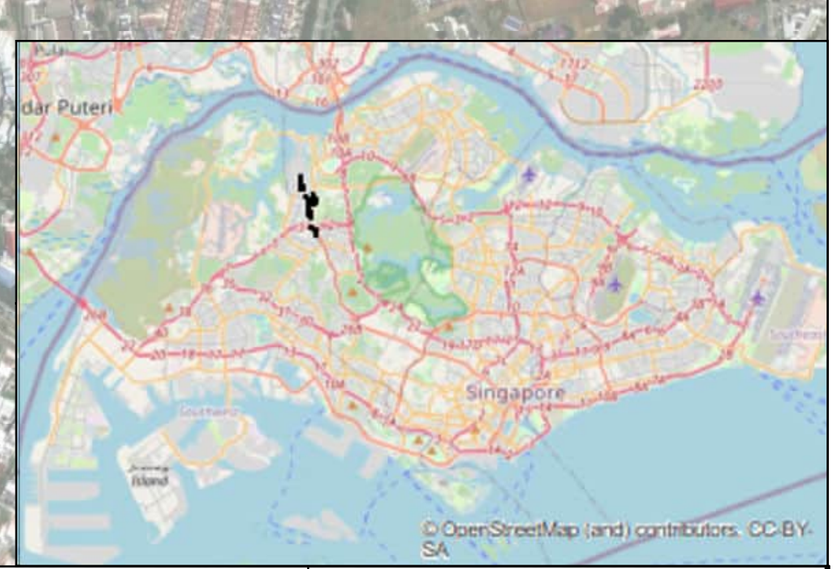
EBS08/TD3045

EBS07/TD3044

EBS06/TD3043

Pang Sua Canal

0 212.5 425 850 Meters



Legend

Boreholes

- Developed Environmental Boreholes
- ENV BHs converted into MWs
- Proposed Environmental Boreholes
- SI Boreholes
- Proposed Vehicle Bridge
- Construction Worksite
- Potential Future Infrastructure
- Proposed Pedestrian Overhead Bridge

- Zone 1
- Zone 2
- Zone 3
- Proposed DTL2e Tunnel Alignment
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area
- Study Area

N

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Figure Title :
Location of soil boreholes

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Note: Source of basemap - Google Earth Map

12.6 Minimum Control Measures

This section presents minimum controls or standard practices commonly implemented in Singapore for similar developments that have been assumed to be implemented for the purposes of impact assessment during construction and operational phases of the Project. Generally, the minimum control has also considered design optimization detailed in Section 3.2.1.

12.6.1 Construction Phase

Table 12-13 sets out the minimum controls that have been identified for the Project during the construction phase. Regular inspections and workers' training must be conducted to ensure that these measures are inculcated in the behavior and practice of all the staff on site.

Table 12-13 Minimum Controls During Construction Phase (Soil and Groundwater)

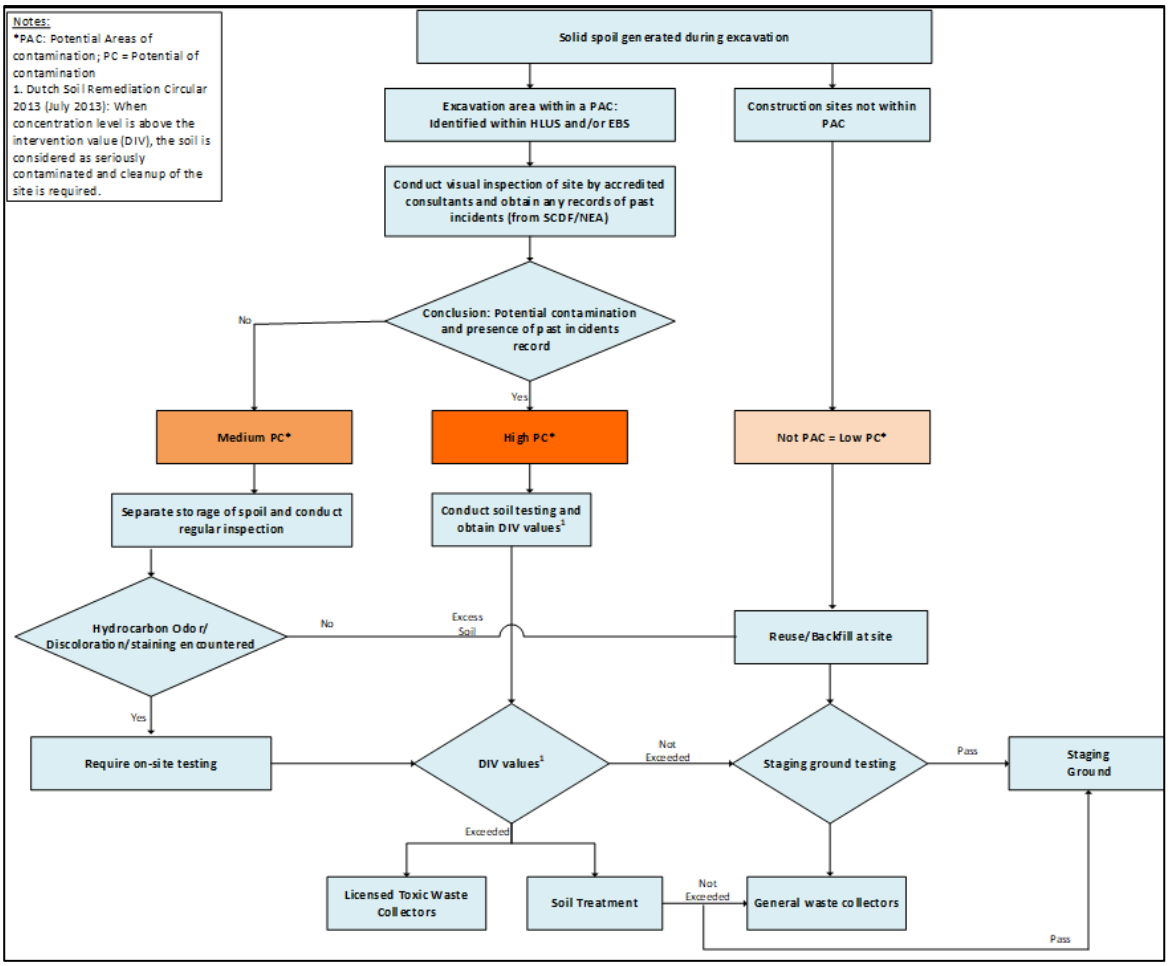
Potentially Affected Environmental Parameter	Potential Sources of Impacts	Minimum Control Measures
• Soil quality • Groundwater quality	• Seepage of contaminants (if any) from excavated soil into the underlying soil and groundwater. • Soil erosion of exposed soil from excavations and stockpiles. • Leakage of contaminants (if any) from extracted groundwater into the underlying soil and groundwater. • Improper management of wastewater generated from tunnelling activities.	• Identify all types of solid 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 will be free of debris, and of good material soil. • Handle and dispose excavated soil following the procedure shown in Figure 12-8. 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

Potentially Affected Environmental Parameter	Potential Sources of Impacts	Minimum Control Measures
		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 12-8. • Discharge of extracted groundwater will be to an area approved for such disposal by the NEA and PUB and the proposed location as identified in Figure 12-8 and following the process set out in Figure 12-9. Based on the HLUS findings, there is a possibility of encountering historically contaminated soil due to the historical activities in the area. Therefore, it is recommended that the construction Contractor 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 will 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 will follow the procedure in Figure 12-8. • The wastewater from tunnelling activities should be stored and removed for treatment and disposal off-site by an approved Waste Management Contractor.
	• Uncontrolled discharge and leakage of waste and chemicals due to improper management	• 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.

Potentially Affected Environmental Parameter	Potential Sources of Impacts	Minimum Control Measures
	• Inappropriate or inadequate design parameters for storage of containers • Discharge or leakage of chemicals used for refuelling and maintenance of vehicles, machinery and equipment	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 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 will be provided for all waste containers Spill trays will 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 will be treated to comply with the requirements under prevailing legislation. • 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 and PUB will be discharged into any watercourse or land. • Ensure all activities involving repair, servicing, engine overhaul works, etc. will be carried out on an area which is appropriately contained (e.g., concreted area and with proper containment/sumps) and all wastes are channeled for appropriate treatment or disposal to meet the regulations. • Provide emergency spill kits on site in the event of any chemical spillages. Identify all types of toxic

Potentially Affected Environmental Parameter	Potential Sources of Impacts	Minimum Control Measures
		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 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 will be provided for all waste containers Spill trays will 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 will be treated to comply with the requirements under prevailing legislation. • 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 and PUB will be discharged into any watercourse or land. • Ensure all activities involving repair, servicing, engine overhaul works, etc. will be carried out on an area which is appropriately contained (e.g., concreted area and with proper containment/sumps) and all wastes are channeled

Potentially Affected Environmental Parameter	Potential Sources of Impacts	Minimum Control Measures
		for appropriate treatment or disposal to meet the regulations. • Provide emergency spill kits on site in the event of any chemical spillages.
Groundwater level	• Groundwater extraction/ soil dewatering for the activities that require dry soil conditions • Decreased infiltration into the ground due to increase of impervious surfaces within study area.	• Install piezometers to monitor the changes in groundwater level in compliance with Building Control Regulations 2003 as part of its instrumentation and monitoring plan to be endorsed by the Qualified Professional (QP). • Proper Earth Retaining Stabilisation Structures (ERSS) should be selected and designed to limit groundwater settlement. • Plan soil dewatering in phases to avoid as much as practicably possible groundwater drawdown.



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 12-8 Screening and disposal of excavated soil

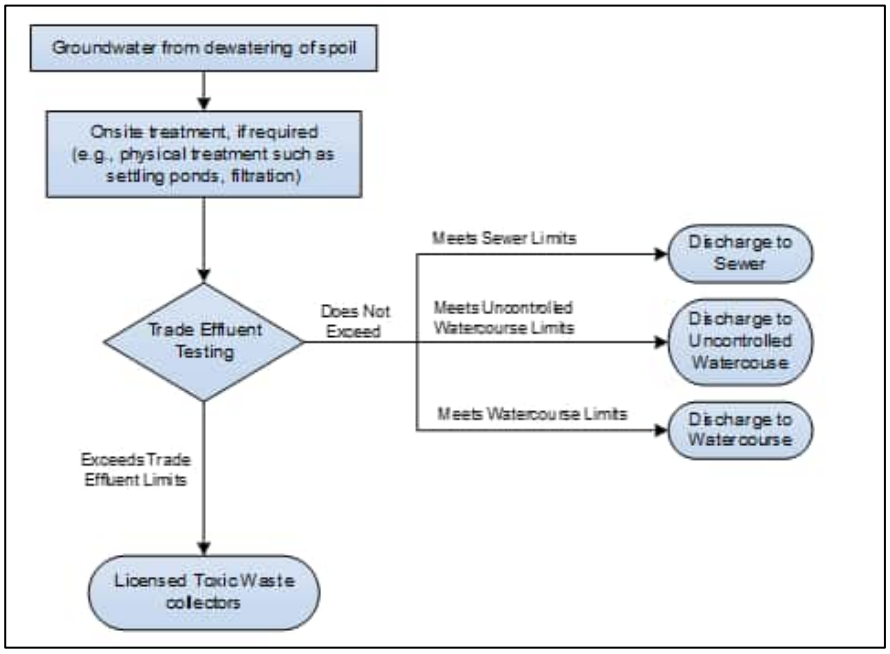


Figure 12-9 Disposal of the groundwater generated through dewatering or inflow into excavation

12.6.2 Operational Phase

Table 12-14 sets out the minimum controls that have been identified for the Project during operational phase.

Table 12-14 Minimum Controls During Operational Phase (Soil and Groundwater)

Potentially Affected Environmental Parameter	Potential Sources of Impacts	Minimum Control Measures
• Soil quality • Groundwater quality	• Heavy rain and stormwater wash-off pollutants in the new development area and discharge into surrounding soil and groundwater	• Ensure no trade effluent other than that of a nature or type approved by NEA and PUB will be discharged into any watercourse or land.

Potentially Affected Environmental Parameter	Potential Sources of Impacts	Minimum Control Measures
	• Small quantities of chemical waste generated during maintenance works and operational phase (e.g., used fluorescent bulbs, used lead-batteries, used chemical containers, etc.) • Operation of trains resulting in diesel oil leakage • Improper handling of hazardous substances during operational phase	• 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 will be provided for all chemical drum and potentially pollutive substances. Spill trays will be regularly maintained to prevent rain from washing out the pollutive substances. • Dispose all toxic waste chemicals to licensed TIW collectors for treatment • Ensure all hazardous chemicals/substances are labelled its movement is recorded and returned to the designated storage areas when not in use. • Conduct regular inspections on waste storage systems to prevent system's clogging and leachate entering the underlying soil, groundwater or surrounding watercourses. • 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 will also be competent in the use of these spill kits.
Groundwater level	• Decreased infiltration into the ground due to more areas with impervious surfaces	• Incorporate more pervious surfaces in the development plan • Installation of recharge wells, if necessary.

12.7 Prediction and Evaluation of Soil, Groundwater and Waste Impacts

This section details prediction and evaluation of soil and groundwater impacts identified to arise from construction and operational phase of the Project.

12.7.1 Construction Phase

Construction phase of the Project is expected to last approximately 9 years during which the study area will go through changes. In the early stage of the construction phase, as part of site preparations, site clearance, road and utilities diversion and construction of temporary worksites will be carried out. Construction worksite areas will include designated areas for construction, site office, area for equipment and material storage, worker's canteens as well as waste disposal area. The main construction activities will include ground improvement works, tunnel boring works, station and superstructure construction. Landscaping and finishing works will be undertaken during the final stages of the construction phase to reinstate the designated work areas to their original condition.

Beforementioned activities could have potential impacts on soil and groundwater quality and groundwater level. Consequently, these potential changes might have adverse impacts on identified sensitive receptors. The

following sub-sections provide qualitative assessment and evaluation of soil and groundwater impacts expected to occur during the construction phase of the Project.

12.7.1.1 Impacts due to Soil and Groundwater Contamination

Based on the findings from HLUS, historical and current land uses and activities indicate that there is a potential for possible contamination of underlying soil and groundwater at some point during historical land usage, primarily in Zone 1 and Zone 2 (refer to
Figure 12-1). Potential CoC include aromatic compounds, phenols, PAHs, metals, TPHs, VOCs, SVOCs, dioxins/ furans, chlorinated hydrocarbons, organotin and cyanides. Intrusive soil and groundwater investigation is currently being carried out by LTA's Term contractor. Data available at the time of writing this report was included in impact assessment analysis.

The activities planned for construction phase of the Project are 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 licensed general and toxic waste contractors as part of minimal controls (as shown in Section 12.6). Handling and storing of soil may expose workers to historically contaminated soil, if any. In the event that contaminated soil and groundwater are encountered during the excavations, implementation of measured details in Figure 12-8 and Figure 12-9 will ensure that the contaminated soil and/ or groundwater is properly managed and disposed.

Another potential mechanism to soil and groundwater contamination, which could consequently have adverse impacts on identified sensitive receptors, is through leakage and seepage of contaminants due to improper management (e.g., handling, transfer, storage) of generated toxic chemical waste and hazardous chemicals. The quantity of toxic chemical waste stored on site is expected to be limited, with the assumption that generated waste will be periodically removed and disposed off-site by licensed Toxic Industrial Waste (TIW) contractors during the construction phase. Chemicals used during the construction phase will be stored at designated sheltered area(s) provided with access-controlled entrance and concrete bund walls or in storage containers with good ventilation or on spill pallets. Furthermore, spill kits will be available on the site to be operated by an emergency response team (competent in their use) in the event of chemical spillage. During maintenance activities of vehicles, machinery and equipment leakage of used chemicals might contaminate the underlying soil and groundwater, if not managed properly.

Assuming that the proposed minimum controls are successfully implemented (and approved by the relevant Agencies, where applicable) it is **unlikely** that discharge, spillage or leakage from spoil, toxic chemical waste and hazardous chemicals will be in quantities that may adversely impact soil and groundwater. Additionally, it the potential contamination occurs, it will most likely cause only localized impacts to soil and groundwater quality which are unlikely to extend beyond the study area and which will be possible to remediate. Furthermore, available soil and groundwater quality baseline data does not indicate presence of historical contamination of underlying soil and groundwater. Therefore, the impact intensity was assessed to be **Low** during the construction phase.

12.7.1.1.1 Assessment of Impacts on Ecological Receptors

Identified ecological receptors include urban vegetation, scrubland, mangrove forest, exotic-dominated secondary forest as well as two major waterbodies – Pang Sua Canal and Sungei Pang Sua. Their sensitivity categorization (as detailed in Table 12-3) was based on their assessed ecological significance (refer to Section 7 of this Report) as well as their dependence on groundwater resources.

As per receptor sensitivity classification (refer to Table 6-2), all ecological receptors that are not of high ecological value have been categorized as **Priority 3** receptors (i.e., urban vegetation, scrubland and exotic-dominated secondary forest). Similarly, due to poor water quality (refer to Section 8 of this report for more detailed analysis), Pang Sua Canal is also found to be poor in aquatic life and was therefore categorized as **Priority 3** ecological receptor.

Based on biodiversity baseline study findings, mangrove forest and adjacent Sungei Pang Sua are home to variety of species of conservation significance. Mangrove forests are habitats that can be found in intertidal zones with usually slow-moving water conditions (which allow fine sediments to accumulate) and low-oxygen soil conditions. It comprises plants and trees which are adapted to high variation of environmental conditions such as fluctuating water levels, salinity and sedimentation. Soils which support mangrove forests usually have high capacity to retain nutrients and metals, which bioaccumulate overtime, within mangrove trees, potentially affecting their livelihood. Furthermore, other COC (e.g., PAHs) could also be present in these habitats and could have adverse impacts on them. It should be noted that any potential pollution may also impact not only mangroves but also other flora and fauna species in this habitat such as mud lobsters, molluscs, etc and eventually humans if these are gathered for commercial purposes. Due to the complex interdependencies between mangrove species and to their surrounding environment (e.g., soil/ sediment, water, biota), remediation of mangrove habitat pollution (if occurs) would be very difficult. This is because the survival and growth of mangrove trees and the forests they comprise, depend on the variety of conditions which could be altered during the process (e.g., destabilization of soil) and/ or accessibility of such habitats (usually dense intertwined roots).

Based on the location, current land use of the surrounding area (i.e., highly urbanized, especially on the left bank side of Sungei Pang Sua) and hydrological conditions (i.e., tidal-influenced stream with brackish water which is mostly fed from surrounding area and sea) of Sungei Pang Sua, both the stream and mangrove forest are likely only partly influenced by groundwater conditions. Therefore, they were categorized as **Priority 2** sensitive receptors. It is worth mentioning that during biodiversity surveys, no observation of deterioration of habitats was noted. This suggests that, even if the historical contamination of soil exists within the study area, the species recorded are already adopted to those baseline concentrations.

Impact intensity was assessed to be **Low** (i.e., small scale, localized contamination, unlikely to spread beyond the study area and is possible to remediate) and therefore impact consequence on ecological receptors was assessed to be **Very Low** for Priority 3 receptors (i.e., urban vegetation, scrubland, exotic-dominated secondary forest and Pang Sua Canal) and for Priority 2 receptors (i.e., mangrove forest and Sungei Pang Sua) (as per Table 6-7).

Available groundwater elevation, topography data and location of the major waterbodies in the area suggest that the groundwater most likely generally flows in north-northwest direction and towards natural waterbodies while the groundwater levels are probably influenced by tidal cycle and sea level. Contamination of groundwater (either directly or indirectly) due to accidental spills and leaks of contaminants into the underlying soil and/ or groundwater during the construction phase may propagate downgradient, potentially impacting ecological receptors. By comparing the location of proposed construction sites with the location of identified ecological receptors, likelihood was assessed to be **Possible/ Occasional**. Based on the Impact Significance Matrix (as shown in Table 6-9), the overall impact on ecological receptors due to soil and groundwater contamination was assessed to be **Minor** and no further mitigation measures were required.

12.7.1.1.2 Assessment of Impacts on Human Receptors

As detailed in Section 12.4.1, identified human receptors include future on-site construction workers, permanent off-site residents downgradient of the study area and off-site visitors. As historical contamination of underlying soil is possible, beforementioned human receptors might be exposed to potentially contaminated medium which may have adverse effect to their health. Possible pathways of exposure include dermal contact, incidental ingestion and inhalation of fugitive dust and vapours. Therefore, identified human receptors were categorized as **Priority 1** (as defined in Table 6-2).

As the impact intensity was assessed to be **Low** (i.e., small scale, localized contamination, unlikely to spread beyond the study area and is possible to remediate), impact consequence on human receptors was assessed to be **Low** (as per Table 6-7). Likelihood of on-site construction workers and permanent off-site residents downgradient of the study area to be exposed to contaminated soil and/ or groundwater was assessed to be **Possible/ Occasional**, while off-site visitors are **Less Likely** to be exposed. Based upon the assessment of the consequence and likelihoods, and considering the routine, standard industry practices implemented during the construction phase of the Project, the overall impact on human receptors due to soil and groundwater

contamination during the construction phase was assessed to be **Minor**. Therefore, no further mitigation measures were required.

12.7.1.2 Impacts due to Groundwater Level Decrease

Certain pre-construction (e.g., earthworks) and construction activities that are planned to be carried out as part of this development will require extraction of groundwater from soil. This is to enable dry ground conditions of the excavation areas which is a pre-requisite for safe and successful works. Based on the available groundwater elevation data, average groundwater depth at proposed cut and cover areas (i.e., at intermediate station and retrieval shaft worksites) ranges from 0.45 m bgl to 1.71 m bgl, which indicates that the soil dewatering will be required. This might have an impact on current groundwater levels by lowering the water table to required depths. Furthermore, as the construction work progress, the current land use may change, reducing the infiltration of surface water and rainfall into the soil, potentially reducing the current groundwater level. Along the future MRT alignment observed groundwater depth was from 1.14 m bgl to 5.19 m bgl, indicating that the tunnel boring will be carried out below the current groundwater table. However, upon successful implementation of minimum controls and by planning the works in phases, it is expected that the groundwater level drop will be mostly localized. Furthermore, after the construction phase has been completed groundwater will most likely find new equilibrium. Therefore, impact intensity was assessed to be **Medium**.

12.7.1.2.1 Assessment of Impacts on Ecological Receptors

The potential importance of groundwater level to ecological receptors is twofold – it may feed the surface watercourses and hence support natural habitats and it also may be the main source of water for various plant species and habitats due to the lack of surface water resources.

As biodiversity findings have found that Pang Sua Canal supports poor aquatic life, it was categorized as **Priority 3** sensitive receptor. With impact intensity assessed to be **Medium**, impact consequence was **Very Low** (as per Table 6-7). Being a concrete canal, it is unlikely that water quantities in Pang Sua Canal are highly dependent on groundwater resources. Furthermore, hydrological baseline study (refer to Section 8 of this Report) has found that the Canal is mostly fed by stormwater and surface water drainage, originating from the upstream urbanized areas. Therefore, it is **Less Likely** that the potential groundwater decrease will impact Pang Sua Canal and the overall impact was assessed to be **Negligible**.

Sungei Pang Sua is the second largest aquatic habitat within the study area, mostly surrounded by mangrove forest. Available groundwater elevation data indicate that at the upstream area of Sungei Pang Sua groundwater depth ranges from 4.85 m bgl (i.e., 3.24 mRL) to 5.73 m bgl (i.e., 2.36 mRL) (i.e., at TD/2016). Based on the topographic data and observed water levels during hydrological surveys it is estimated that the water levels at the upstream of Sungei Pang Sua are around 1.1 mRL. This indicates that the groundwater might be feeding into the stream (i.e., flowing downgradient), at least in the upstream area. However, based on the water quality baseline study (refer to Section 8.4.2 of this Report) Sungei Pang Sua is characterized by brackish water, heavily influenced by tidal cycle of the sea which was shown in the results as a significant variation of salinity, conductivity and TDS in water samples collected during dry and wet weather conditions. This suggests that the quantity and quality of Sungei Pang Sua is mostly governed by the marine water with partial influx of surface water from surrounding area and groundwater. Therefore, although Sungei Pang Sua has high ecological value (refer to the Section 7 of this Report) it has been categorized as **Priority 2** sensitive receptor (i.e., partly supported by groundwater). Because impact intensity was assessed to be **Medium**, impact consequence was **Low** as per Table 6-7, As the construction is expected to progress in phases, likelihood of groundwater level drop was assessed to be **Occasional** with the overall impact significance being **Minor**.

As per definitions set out in Section 6.2.2 of this Report, all of the identified habitats that are not of high ecological value (refer to Section 7 for biodiversity impact assessment) have been categorized as **Priority 3** sensitive receptors. With **Medium** impact intensity (as detailed earlier in this Section), impact consequence on urban vegetation, scrubland, and exotic-dominated secondary forest was assessed to be **Very Low**. As the potential groundwater level decrease might happen **Occasionally**, the overall impact of groundwater level decrease to beforementioned sensitive receptors has been assessed to be **Minor**.

Mangrove forest, located along both sides of Sungei Pang Sua has been categorized as **Priority 2** sensitive receptor as it is a habitat of high ecological value that is only partly supported by groundwater. As the impact intensity was Medium, impact consequence was assessed to be **Low**. As the likelihood of this impact was assessed to be Possible/ Occasional the overall impact significance was assessed to be **Minor**.

12.7.1.2.2 Assessment of Impacts on Human Receptors

It is understood that currently groundwater in Singapore is not extracted for any beneficial purposes (i.e., drinking and industrial purposes, irrigation). Hence, it is **Unlikely** that the potential groundwater level decrease will have any impact on human receptors and the overall impact significance is assessed to be **Negligible**.

Table 12-15 Summary of Soil, Groundwater and Waste Management Impact Assessment for the Construction Phase of the Project

Impact	Sources of Impact	Environmental Parameter Affected	Sensitive Receptor Affected	Receptor Sensitivity	Impact Intensity	Impact Consequence	Impact Likelihood	Impact Significance
Ecological Receptors								
Disturbances in habitats and/ or reduction in size of species' population	• Heavy rain and stormwater washoff pollutants built up in the new development area and discharge into surrounding soil and groundwater • Leakage of waste leachate into the underlying soil • Discharge and/ or leakage of chemicals/ hazardous waste during maintenance activities, inclusive of maintenance of vehicles, machinery and equipment	• Soil quality • Groundwater quality	Urban vegetation	Priority 3	Low	Very Low	Possible/ Occasional	Minor
			Scrubland	Priority 3	Low	Very Low	Possible/ Occasional	Minor
			Mangrove forest	Priority 2	Low	Very Low	Possible/ Occasional	Minor
			Exotic-dominated secondary forest	Priority 3	Low	Very Low	Possible/ Occasional	Minor
			Pang Sua Canal	Priority 3	Low	Very Low	Possible/ Occasional	Minor
			Sungei Pang Sua	Priority 2	Low	Very Low	Possible/ Occasional	Minor
	• Groundwater extraction/ soil dewatering for the activities that require dry soil conditions • Decreased infiltration into the ground due to increase of impervious surfaces within study area	Groundwater level	• Urban vegetation	Priority 3	Medium	Very Low	Possible/ Occasional	Minor
			• Scrubland	Priority 3	Medium	Very Low	Possible/ Occasional	Minor
			• Mangrove forest	Priority 2	Medium	Low	Possible/ Occasional	Minor
			• Exotic-dominated secondary forest	Priority 3	Medium	Very Low	Possible/ Occasional	Minor
			• Pang Sua Canal	Priority 3	Medium	Very Low	Less Likely/ Rare	Negligible
			• Sungei Pang Sua	Priority 2	Medium	Low	Possible/ Occasional	Minor
Human Receptors								

Impact	Sources of Impact	Environmental Parameter Affected	Sensitive Receptor Affected	Receptor Sensitivity	Impact Intensity	Impact Consequence	Impact Likelihood	Impact Significance
Adverse impact to human health due to exposure to contaminated soil and/ or groundwater	• Seepage of contaminants (if any) from excavated soil, extracted groundwater, exposed soil and waste • Seepage of contaminants from toxic chemical waste and hazardous chemicals	• Soil quality • Groundwater quality	Future on-site construction workers and permanent off-site residents downgradient of the study area	Priority 1	Low	Low	Possible/ Occasional	Minor
			Off-site visitors	Priority 1	Low	Low	Less Likely/ Rare	Minor
Groundwater level decrease	• Groundwater extraction/ soil dewatering • Decreased infiltration into the ground due to increase of impervious surfaces	Groundwater level	• Future on-site construction workers and permanent off-site residents downgradient of the study area • Off-site visitors	Priority 1	/	/	Unlikely	Negligible

12.7.2 Operational Phase

Prior to opening the MRT to the general public, test trains will run and extensive track testing will be carried out to ensure the safety of the system. During the operational phase (i.e., when the MRT line and accompanying infrastructure are opened for public) it is expected that human activity will increase within the study area especially at and in vicinity of the stations. Periodic maintenance works are assumed to occur during the nighttime (around 1am to 4am) and it will be undertaken within the tunnels and for the equipment within station buildings.

Chemicals used during the maintenance and landscaping activities might accidentally leak into the ground, potentially affecting underlying soil's and groundwater's quality. Furthermore, as described in Section 12.3 of this Report, permanent land use change (i.e., increase in impervious surfaces) may cause decreased infiltration of surface water and rainfall into the ground. The operational footprints of proposed above-ground structures (i.e., NSL elevated station, potential future infrastructure, pedestrian linkbridge, vehicle bridge) indicate that they will occupy relatively small area compared to the overall catchment area. The following sub-section provide detailed assessment and evaluation of expected impacts during operational phase of the Project.

12.7.2.1 Impacts due to Soil and Groundwater Contamination

As the area becomes operational, increased human activity (both from users of MRT and passersby) will possibly lead to higher generation of solid and liquid waste (largely general waste). Proposed potential future infrastructure and vehicle bridge may also be potential source of contamination as the surface water runoff (which could contain pollutants from car emissions) is planned to be drained off directly via holes in the structures. It is recommended that these holes should not be directly over the waterbodies to decrease the chances of pollution. Furthermore, the maintenance of green areas surrounding the facilities as well as the facilities may require the usage of certain chemicals (e.g., pesticides, solvents) which may or may not be stored on the site. If not managed properly, leachate from waste generated and collected on the site and accidental leakage of chemicals stored and used on site may infiltrate the ground, potentially affecting soil and groundwater quality. However, it is expected that during operational phase, the study area will have little use of hazardous substances and chemicals. Furthermore, potential small, localized contamination that may happen in certain areas due to accidental spillages and leakages will most likely cause limited impacts and are unlikely to extend beyond the study area. Mandatory worker trainings regarding environmental management and spill management and regular site inspections serve 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 impact intensity was assessed to be **Low**.

12.7.2.1.1 Assessment of Impacts on Ecological Receptors

As detailed in Section 12.7.1.1.1, ecological sensitive receptors have been categorized as **Priority 3** (i.e., urban vegetation, scrubland, exotic-dominated secondary forest and Pang Sua Canal) and **Priority 2** (i.e., mangrove forest and Sungei Pang Sua), based on their ecological significance and dependence of groundwater. As the impact intensity is assessed to be **Low**, the impact consequence will be **Very Low** for Priority 3 and Priority 2 ecological sensitive receptors (based on the Impact Consequence Matrix, as shown in Table 6-7). 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 and chemicals will be in quantity that may adversely impact the environment and will only occur during the operational phase as often as maintenance is scheduled. Therefore, the impact likelihood was assessed to be **Occasional**. Based on the Impact Significance Matrix (as shown in Table 6-9), the overall impact on ecological receptors due to soil and groundwater contamination during operational phase of the Project was assessed to be **Minor** and no further mitigation measures were required.

12.7.2.1.2 Assessment of Impacts on Human Receptors

Human receptors during operational phase will include future maintenance workers and visitors of the area, both categorized as **Priority 1** receptors, due to potential exposure to contaminated soil. As the impact intensity was assessed to be **Low**, impact consequence on identified human receptors was assessed to be **Low** (as per Table 6-7). As accidental spills and leaks are expected to occur rarely, and under the assumption that minimal controls have been successfully implemented, likelihood of exposure of human receptors to potential contamination was assessed to be **Less Likely**. Therefore, the overall impact significance (as per Impact Significance Matrix, as shown in Table 6-9) of potential soil and groundwater contamination on human sensitive receptors is assessed to be **Minor**.

12.7.2.2 Impacts due to Groundwater Level Decrease

Taking into consideration proposed activities during operational phase of the Project, it is anticipated that there will be limited sources of impact on groundwater level during this phase. Permanent land use change and increase of impermeable surfaces may decrease infiltration of surface water into the ground and therefore obstruct replenishment of groundwater. However, operational footprints of proposed aboveground structures (i.e., proposed NSL elevated station, potential future infrastructure, pedestrian linkbridge, vehicle bridge) seem to be relatively small compared to the overall area. This implies that the proposed land use change will have limited, if any, impact on groundwater levels and it is expected that after construction period groundwater will find new equilibrium. Therefore, the impact intensity of groundwater level decrease during operational phase was assessed to be **Low**.

12.7.2.2.1 Assessment of Impacts on Ecological Receptors

As detailed in Section 6.2.2 of this Report, all identified ecological receptors that are not of high ecological value (as per biodiversity assessment detailed in Section 7 of this Report) were categorized as **Priority 3** receptors (i.e., urban vegetation, scrubland, exotic-dominated secondary forest and Pang Sua Canal). Mangrove forest and Sungei Pang Sua have been categorized as **Priority 2** sensitive receptors due to their high ecological value and partial dependance on groundwater resources. Therefore, with impact intensity assessed to be **Low**, it is expected that the consequence of potential groundwater level decrease on identified ecological sensitive receptors will be **Very Low.** It is anticipated that the groundwater decrease during operational phase, if any, will be more prominent during dry weather conditions and hence the likelihood was assessed to be **Occasional**. Based on the anticipated impact consequences and likelihood of impact, the overall impact of groundwater level decrease on ecological receptors during operational phase was assessed to be **Minor**. It should be noted that groundwater level decrease is **Less Likely** to have an impact on Pang Sua Canal (for the same reasons as detailed in Section 12.7.1.2.1). Therefore, the overall consequence to Pang Sua Canal has been assessed as **Negligible**.

12.7.2.2.2 Assessment of Impacts on Human Receptors

It is understood that currently groundwater in Singapore is not extracted for any beneficial purposes (i.e., drinking and industrial purposes, irrigation). Hence, it is **Unlikely** that the potential groundwater level decrease will have any impact on human receptors and the overall impact significance is assessed to be **Negligible**.

Table 12-16 Summary of Soil, Groundwater and Waste Management Impact Assessment for the Operational Phase of the Project

Impact	Sources of Impact	Environmental Parameter Affected	Sensitive Receptor Affected	Receptor Sensitivity	Impact Intensity	Impact Consequence	Impact Likelihood	Impact Significance
Ecological Receptors								
Disturbances in habitats and/ or reduction in size of species' population	• Heavy rain and stormwater wash-off pollutants built up in the new development area and discharge into surrounding soil • Leakage of solid waste leachate into the underlying soil • Discharge or leakage of chemicals into the soil and groundwater	• Soil quality • Groundwater quality	Urban vegetation	Priority 3	Low	Very Low	Possible/ Occasional	Minor
			Scrubland	Priority 3	Low	Very Low	Possible/ Occasional	Minor
			Mangrove forest	Priority 2	Low	Very Low	Possible/ Occasional	Minor
			Exotic-dominated secondary forest	Priority 3	Low	Very Low	Possible/ Occasional	Minor
			Pang Sua Canal	Priority 3	Low	Very Low	Possible/ Occasional	Minor
			Sungei Pang Sua	Priority 2	Low	Very Low	Possible/ Occasional	Minor
	• Decreased infiltration into the ground due to more areas with impervious surfaces within the new development	Groundwater level	• Urban vegetation	Priority 3	Low	Very Low	Possible/ Occasional	Minor
			• Scrubland	Priority 3	Low	Very Low	Possible/ Occasional	Minor
			• Mangrove forest	Priority 2	Low	Very Low	Possible/ Occasional	Minor
			• Exotic-dominated secondary forest	Priority 3	Low	Very Low	Possible/ Occasional	Minor
			• Pang Sua Canal	Priority 3	Low	Very Low	Less Likely/ Rare	Negligible
			• Sungei Pang Sua	Priority 2	Low	Very Low	Possible/ Occasional	Minor
Human Receptors								

Impact	Sources of Impact	Environmental Parameter Affected	Sensitive Receptor Affected	Receptor Sensitivity	Impact Intensity	Impact Consequence	Impact Likelihood	Impact Significance
Adverse impact to human health due to exposure to contaminated soil and/ or groundwater	• Heavy rain and stormwater wash-off pollutants built up in the new development area and discharge into surrounding soil • Leakage of solid waste leachate into the underlying soil • Discharge or leakage of chemicals into the soil and groundwater	• Soil quality • Groundwater quality	• Future maintenance workers • Visitiors of the area	Priority 1	Low	Low	Less Likely/ Rare	Minor
Groundwater level decrease	• Decreased infiltration into the ground due to more areas with impervious surfaces within the new development	Groundwater level	• Future maintenance workers • Visitiors of the area	Priority 1	/	/	Unlikely	Negligible

12.8 Recommended Mitigation Measures

No mitigation measures are proposed to further minimize the adverse impacts on the environment as none of the impacts on the sensitive receptors have been assessed to be Moderate or Major.

12.9 Residual Impacts

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

12.10 Cumulative Impacts with Other Concurrent Projects

This section focuses on assessing the cumulative impacts of the construction and operational activities from identified concurrent developments. It should be noted that the details of the scope of work as well as the timeline of identified concurrent projects is not available at writing this report so only high-level qualitative cumulative impact assessment was carried out based on standard practices utilized in similar projects.

12.10.1 Construction Phase

Construction of CCK N1 HDB will alter the current land use (i.e., more impervious areas) and changes in hydrological cycle are expected. Furthermore, construction activities may lead to accidental spillages and leaks into the surrounding environment which could be transferred downgradient via groundwater. Additional impacts on soil and groundwater may be expected during the timeline overlap period. Appropriate mitigation measures should be proposed to cater for such additional impacts. However, it is expected that these disturbances will only be short-term (i.e., during the construction).

The proposed realignment of Woodlands Road is expected to slightly change the current land use of the surrounding area and with the implementation of minimum control measures it is expected that the impact on soil and groundwater will not be significant.

12.10.2 Operational Phase

Although HDB CCK N1 is expected to alter the hydrological cycle long-term (due to the permanent changes in land use), as mentioned in the previous section, it is expected that some time after construction phase the groundwater levels will find a new equilibrium. The potential contamination from operational activities of these developments is expected to be unlikely, given that the best management practices have been successfully implemented. Therefore, the proposed developments are unlikely to increase the impact on soil and groundwater.

For the proposed realignment of Woodlands Road, its footprint will occupy relatively small area and it is expected that after some time the groundwater levels will find a new equilibrium. Under the assumption that the minimum control measures and best management practices have been implemented, the proposed development is unlikely to increase the impact on soil and groundwater.

12.11 Summary of Key Findings

The main objective of soil, groundwater and waste baseline study as part of the ES was to determine the potential environmental liabilities (i.e., soil and groundwater contamination) arising from past or existing facilities and/ or activities. The baseline study was conducted based on the findings from previously carried out HLUS [R-79].

The HLUS has found that there is a potential for existence of underground buried structures within study area (i.e., demolished buildings along Sungei Kadut Street 2 and remnants of the Singapore-Kranji railway tracks) while the presence of UXO is considered to be unlikely. Based on the non-intrusive investigation (carried out as a part of HLUS), potential sources of contamination within study area include:

- Discharge/ release of chemicals, oil products or other hazardous material due to accidental spills, leaks, and releases in storage, transport, and utility equipment areas;
- Land previously used for storing or handling chemicals, oil products, or other hazardous material;
- Manufacture of furniture and woodworks; and
- Repair of vehicles.

The potential CoC to be found in underlying soil were assessed based on the historical and current land uses and include: aromatic compounds, phenols, PAHs, metals, TPHs, VOCs, SVOCs, dioxins/ furans, chlorinated hydrocarbons, organotin and cyanides. Additional intrusive soil and groundwater investigation has been recommended to be conducted to confirm the findings of the HLUS and assess the severity of the contamination, if any.

Based on the information obtained during the intrusive soil investigation study, the soil profile encountered at the study area generally consisted of clay. Furthermore, layers of clayey sand, sandy clay and silty clay were also encountered within the study area.

Soil samples collected from the study area reported detections of metals (i.e. arsenic, barium, chromium, copper, nickel and zinc) and Total Petroleum Hydrocarbons (TPH). These detections were all below the DIVs.

Based on the groundwater data available at the time of writing this Report, groundwater level ranged from +1.73 mSHD to +9.80 mSHD with average groundwater levels ranging from +2.65 mSHD to +9.28 mSHD. Generally, higher groundwater elevations were observed at the southern portion of the site, slowly decreasing towards the north and generally following the topography of the area. Oscillations of groundwater levels were relatively low, with average difference between highest and lowest observed groundwater levels being 1.38 m.

Groundwater samples collected from the study area reported detections of metals (i.e. arsenic, barium, cadmium, chromium, cobalt, copper, lead, molybdenum and zinc), Polynuclear Aromatic Hydrocarbons (PAHs) and Total Petroleum Hydrocarbons (TPH). All of the detections were below their respective DIVs, and concentrations of these metals were all below their respective DIVs and AUS.

As the HLUS findings indicate possible historical contamination of soil within the study area, identified human sensitive receptors have been categorized as Priority 1 due to possible exposure to such soil. The sensitivity of ecological receptors has been determined based on their ecological significance and their dependency on groundwater. Urban vegetation, scrubland, exotic-dominated secondary forest and Pang Sua Canal have been assessed as Priority 3, while Mangrove forest and Sungei Pang Sua as Priority 2 sensitive receptors.

The potential impacts on soil and groundwater resources associated with the construction phase of the Project include groundwater level decrease due to soil dewatering and decreased infiltration into the ground due to increase in impervious surfaces. Additionally, soil and groundwater quality could be affected due to seepage of contaminants from excavated contaminated soil (if encountered) and extracted groundwater, soil erosion as well as leakage of toxic chemical waste and chemicals used and stored on site.

During the operational phase of the Project, it is anticipated that the impact on soil and groundwater quality will be limited as the use of chemicals and generation of toxic chemical waste is expected to be of limited quantities. Although more impervious surfaces are expected to decrease infiltration into the ground, it is anticipated that the groundwater table in the long-term will equilibrate to its new level.

Based upon implementation of the minimum controls, the prediction and evaluation exercise of soil and groundwater impacts showed that there will be Negligible to Minor impact during both construction and operational phase of the Project. Therefore, no additional mitigation measures have been proposed to further minimize the adverse effect on the environment and receptors.

With regards to cumulative impacts from surrounding concurrent developments during construction phase, construction of HDB CCK N1 may increase impact on soil and groundwater during timeline overlap period and therefore appropriate mitigation measures should be proposed to alleviate any additional impacts. The proposed

realignment of Woodlands Road is unlikely to cause any significant impact on soil and groundwater. During the operational phase, both of the proposed developments are unlikely to increase impact on soil and groundwater.

Table 12-17 Summary of Soil, Groundwater and Waste Impact Assessment

Sensitive Receptors and Phases	Impact Significance with minimum controls	Residual Impact Significance with mitigation measures (if required)
Construction Phase		
Ecologically Sensitive Receptors	Negligible to Minor	**Negligible to Minor**
Human Sensitive Receptors	Negligible to Minor	**Negligible to Minor**
Operational Phase		
Ecologically Sensitive Receptors	Negligible to Minor	**Negligible to Minor**
Human Sensitive Receptors	Negligible to Minor	**Negligible to Minor**

13 Vectors

This section provides an assessment of the potential impacts of vectors' populations arising from the construction and operational activities of the Project within the defined study area for vectors. It also details the baseline vectors' conditions around the study area, identifies potential breeding habitats during the construction and operational phases, evaluates the significance and likelihood of potential impacts from the vectors, as well as outlines control measures to minimise the occurrence of vector-breeding sites within the study area.

13.1 Introduction

Construction and operational activities can generate large amounts of stagnant water and waste, which if not managed properly, can lead to the breeding or infestation of vectors in the study area. Under the Control of Vector and Pesticide Act (CVPA) [R-57], vectors are defined as any insect, including its egg, larva or pupa, and any rodent (e.g., rats), including its young, carrying or causing, or capable of carrying or causing any disease to human beings. According to LTA's Guidebook in Vector Control at LTA Sites [R-73], vectors are organisms that transmit vector-related disease from one host to another but do not cause diseases themselves.

Due to the loss of their original habitats from rapid urbanisation, vectors have quickly adopted alternative breeding grounds in built-up areas [W-37]. As such, they pose a risk to public health and should be controlled and eliminated. The five main vectors in Singapore and their associated diseases are listed in Table 13-1.

Table 13-1 Main Vectors in Singapore and Their Associated Diseases [R-73]

Type of Vector	Vector-borne Diseases
Mosquito	• Dengue and Dengue Haemorrhagic Fever • Zika virus • Chikungunya • Malaria • Japanese Encephalitis • Filariasis
Rat Flea	• Plague
Rat	• Rat Bite Fever • Leptospirosis
Cockroach	• Cholera • Food-borne Diseases
Fly	• Cholera • Typhoid and Para Typhoid • Salmonellosis • Dysentery

Local legislation such as CVPA provides legal forcing for the control of vector-borne diseases by prohibiting vector-breeding activities. This deters the proliferation of vector-breeding grounds. However, the occurrence of vectors infestation can still occur due to favourable conditions created by rain or negligence. In recent years, virulent vectors problems in construction sites and premises (e.g., residential estates, schools) have been mostly attributed to mosquitoes and rats, to the extent that NEA has provided examples of scope of works for mosquito control [W-43] and specifications for rat control [W-42] as part of the vector control effort. Therefore, the study on vectors in this report has been focusing on these two types of vectors which are more common in local context.

Mosquitoes are the most widely-known disease vector, that can transmit the dengue virus, which puts more than 2.5 billion people at risk globally, and Singapore is no exception [W-38]. A mosquito becomes dengue-infected after taking a blood meal from an infected human. After a certain incubation period, the mosquito becomes infective and can spread virulent diseases such as Dengue Fever and Dengue Haemorrhagic Fever by feeding on other humans. According to WHO [W-14], matured female Aedes mosquitoes tends to breed in water-filled containers (stagnant water) but usually remains close to human habitation, with peak biting periods early in the

morning and in the evening before dusk. The common mosquito breeding habitats in a construction site that can accumulate stagnant water include but not limited to the material storage area, site office, empty containers at workers area and water tanks at construction area. Whilst the common mosquito breeding habitats in public areas include but not limited to the covered perimeter drains, discarded receptables, gully traps, plants and covered carpark drains. If left uncontrolled, it may lead to mosquito breeding. Hence, as an effective and targeted approach, it is important to reduce/eliminate conditions that creates these suitable breeding habitats in order to control the mosquito population within the study area.

Rats' infestations are problematic as they can spread diseases through their urine and droppings and chew up wires, pipes and insulation [W-50]. They tend to find new habitats easily and can repopulate quickly at locations with ample food, water and shelter available – which are typically found in hawker centres and vicinity of food waste bins. The removal of potential food sources and areas of harbourages can help prevent the nesting and breeding of rats, and thus prevents rats' infestations [W-42]. At a construction worksite, there may be poorly maintained food-waste bins, poor refuse management and a lack of housekeeping practices onsite. As such, rats may thrive in these environments as food, water and shelter are readily available as well. Hence, if proper housekeeping practices are not strictly enforced, construction worksites can potentially become rat-infested.

13.2 Methodology

This assessment has been undertaken in accordance with the methodology detailed in Section 6. It identifies the study area and sensitive receptors, also describes the method to assess the intensity of impact, likelihood and impact significance of vectors. The following describes a few assumptions made to define the methodology for the vector impact assessment:

13.2.1 Definition of Study Area

As discussed earlier, the study on vectors in this section has been focusing on the two main types of vectors, i.e., mosquitoes and rats. According to Ministry of Health (MOH) Singapore [W-49], a dengue cluster is defined as two or more cases epidemiologically linked by place (within 150 m) and time (within 14 days). According to WHO [W-14], the maximum distance that a matured female Aedes mosquito can fly is 400 m. Based on the research on rodent (mainly rats species) infestations through a city [P-54], it is suggested that 450 feet (approx. 138 m) is a good estimate of rodent's travel distance from its nesting ground, which is shorter if compared to that defined by MOH and WHO for dengue cluster. In other words, the definition of study area shall be based on the largest area defined for dengue mosquitoes as the worse-case scenario for vectors study.

Considering that vectors-borne diseases transmission to humans is prone to epidemiologically-linked locations which situated above-ground, hence the study area for vectors has been defined as 400 m away from the above-ground construction and operational footprint of this Project, as presented in Figure 13-1 or defined in Section 5. Since the operational footprint is indicative at this stage and is deemed to be smaller in area size if compared to the construction footprint, hence the study area for operational footprint is assumed to be the same as the construction phase.

13.2.2 Classification of Sensitive Receptors

The potential sensitive receptors for vector impact would be mainly focusing at epidemiologically-linked locations where human resides within the 400 m study area, especially for those sensitive receptors with long-term and/or frequent uses of natural ventilation which are more prone to be affected by vectors. As defined in Table 6-2, potential human habitats with natural ventilation identified within 50 m, between 50 m and 150 m, between 150 m and 400 m from the construction worksites were categorized as Priority 1, 2 and 3 respectively.

While for buildings enclosed with mechanical ventilation and public open spaces/ parks where human exposure is short-term or less frequent, they will be classified with lesser receptor sensitivity as Priority 2 and 3 respectively for distance from 50 m to 150 m and 150 m to 400 m. Any vector sensitive receptors identified beyond 400 m may not be contributed by this Project, hence were not of an immediate concern and excluded from this vector impact assessment.

13.3 Potential Sources of Impacts

The potential sources of vector impacts from construction and operational activities from the Project are described as follows:

13.3.1 Construction Phase

When carrying out construction activities, it was expected that water would be used, drainage patterns would be altered, and waste would be generated. This may potentially increase the risk of widespread breeding of vectors at the construction site, particularly for those areas in close proximity to existing vector-breeding habitats. Sources of vector-breeding from above-ground construction worksites are listed in Table 13-2.

Table 13-2 Potential Sources of Vectors Impacts from Construction Activities [R-73, W-14]

Potential Vectors Sources During Construction Phase		Associated Vectors Impacts
Areas	**Common Sources/ Activities**	
Site Boundary/ Perimeter Area	• Water accumulation at the openings/ damaged holes on water-filled barricades and concrete barriers. • Water stagnation due to ineffective drainage and poor housekeeping along hoarding/ perimeter noise barrier.	• Mosquito breeding due to water accumulation in the openings, holes, barriers, voids, etc. at site boundary/ perimeter.
Material Storage Area	• Water accumulation at non-sheltered storage/ stockpile areas: – On top of untaut canvas sheets. – Plastic cover for material packaging. – On top of chemical drums. – Exposed bolt socket holes and lifting/ grouting socket holes of tunnel segment rings. – Exposed test cube tanks. • Water stagnation due to improper storage/ handling of construction materials: – Discarded water-bearing receptacles. – Storage of loose items and spare parts (e.g., fittings, joints etc.). • Poor housekeeping at storage area resulting in inadequate access for regular inspection.	• Mosquito breeding due to water accumulation at non-sheltered storage areas.
Construction Area	• Water ponding on uneven surface or ground depressions, as well as at the areas excavated for trial trenches, utility diversions, and other temporary works where water drainage is not possible. • Water stagnation on equipment/ machinery and construction area without shelter or cover, such as: - Gaps/ voids on walers and struts, sheet piles, vertical toe board, scaffold clamp covers, discarded receptacles etc. - Recessed concrete surface. - Opening of standpipe and end of pipes / water hoses. - Openings on hollow blocks. - Uncovered or tilted-up lifting bucket. - Unattended waste bins/ skips. - Rainwater collection tanks - On top of recharge well. - Exposed train tracks.	• Mosquito breeding due to water accumulation at non-sheltered construction areas and excavated areas without site drainage, as well as ineffective site drainage.

Potential Vectors Sources During Construction Phase		Associated Vectors Impacts
Areas	**Common Sources/ Activities**	
	• Ineffective site drainage causing water stagnation due to silt build-up and poor gradient. • Poor housekeeping resulting in water ponding at gaps or grounds.	
Site Office, Canteen, Restaurant/ Eatery and Rest Area	• Water accumulation at/ near site office, such as: - Site container office with missing or poorly maintained pitched roofs. - Random construction materials or discarded items located outdoor without shelter. - Tree/ Plant holes. • Water stagnation on unwanted items and workers' rest areas or canteen, such as: - Unused water dispenser. - Un-capped water dispenser bottles. - Stagnant water in unwanted flower pot and pail. • Uncovered or poorly managed food handling and disposal and/or random littering.	• Mosquito breeding due to water accumulation at exposed surfaces at/ near site office, tree/ plant holes and unwanted items at workers' rest areas and canteen, where improper waste disposal is possible. • Rat or rodent infestation at food handling and waste areas, where not properly capped or managed.

13.3.2 Operational Phase

The operational activities identified for this Project are mainly the operations of MRT stations and other proposed infrastructures at or above ground level (i.e., proposed Pedestrian Linkbridge). The common sources of vectors from these activities or areas and the associated vectors impacts are summarised in Table 13-2.

Table 13-3 Potential Sources of Vectors Impacts from Operational Activities

Potential Vectors Sources During Operational Phase		Associated Vectors Impacts
Areas	**Common Sources**	
Station exits/ entrances and associated amenities at or above ground level (connected from the underground DTL2e Intermediate Station and DTL2e Interchange Station)	• Flower troughs, plant boxes and plant pots • Tree holes and bifurcations between branches, leaf axils of banana trees, Travellers Palms and other palms (if any planted at the station perimeter) • Air-conditioner trays • Rooftop, roof drainage and gutters • Rooftop water tanks (if any) • Roof drainage and gutters • Puddles on the ground or concrete floors • Non-sheltered or unused containers in open areas and under bushes • Open and closed drains • Gully traps • Toilet bowls • Poorly-managed litter bins	• Mosquito breeding due to water accumulation at exposed surfaces, uncovered containers and/or other common non-sheltered areas. • Rat or rodent infestation at poorly-managed or uncovered litter bins.
Open-air boarding/ waiting area of the new NSL Sungei Kadut Elevated Station	• Flower troughs, plant boxes and plant pots • Rooftop, roof drainage and gutters • Puddles on the floor of the boarding/waiting area • Non-sheltered or uncovered containers • Poorly-managed litter bins	
Open-air Pedestrian Linkbridge beside	• Flower troughs and plant boxes alongside the bridge (depends on the bridge design) • Puddles on the floor of the bridge	

Potential Vectors Sources During Operational Phase		Associated Vectors Impacts
Areas	Common Sources	
DTL2e Intermediate Station	• Poorly-managed litter bins	

13.4 Identification of Sensitive Receptors

As described in Section 13.2, vectors-borne diseases are transmitted to humans at above-ground epidemiologically-linked locations within the 400 m study area of the Project, hence the vectors study in this report has been focusing on human sensitive receptors only, in other words, excluding the consideration of ecologically sensitive receptors. Any vector sensitive receptors identified beyond 400 m may not be contributed by this Project, hence are not of an immediate concern and will be excluded from this vector impact assessment.

13.4.1 Construction Phase

Existing vector sensitive receptors within the 400 m study area were identified based on the assessment methodology described in Section 13.2 and defined in Table 6-2. The highest receptor sensitivity identified for sensitive receptors within 50 m from the construction footprint or Project boundary is Priority 1, whereas sensitive receptors identified between 50 m to 150 m is Priority 2, while between 50 m to 400 m is Priority 3. The identified sensitive receptors have been summarised in Table 13-4 and presented in Figure 13-1, where the detailed list is provided in Appendix DD of this report.

Table 13-4 Summary of Identified Sensitive Receptors for Vectors

Distance	Identified Receptors	Key Examples (detailed list in Appendix DD)	Receptor Sensitivity
Within 50 m from the Project boundary	Human Habitats with Natural Ventilation	• Residential (e.g., HDB blocks at Senja Road)	Priority 1
	Buildings with Mechanical Ventilation	• Commercial building (i.e., BHL Factories at Mandai Estate) • Industrial buildings (e.g., factories/ buildings at Sungei Kadut Street) • Civic and community institution (i.e., Sungei Kadut Fire Post)	Priority 2
	Public footpath, playing fields, parks and public areas for utility and transport	• Recreational facility/ space (i.e., the Rail Corridor) • Utility facility (i.e., Gali Batu Train Depot)	Priority 2
Between 50 m to 150 m from the Project boundary	Human Habitats with Natural Ventilation	• Residential (e.g., HDB blocks at Choa Chu Kang Street 64)	Priority 2
	Buildings with Mechanical Ventilation	• Commercial buildings (e.g., Innovation Place and other buildings at Mandai Estate) • Industrial buildings (e.g., factories/ buildings/ shops at Sungei Kadut Street 1 – 4) • Place of worship (i.e., Sri Arasakesari Sivan Temple)	Priority 2
Between 150 m to 400 m from the Project boundary	Human Habitats with Natural Ventilation	• Residential (e.g., HDBs at Senja Road, Recent Grove Condominium)	Priority 3
	Buildings with Mechanical Ventilation	• Commercial buildings (e.g., Hua Kok Industrial Building and others near Mandai Estate) • Industrial buildings (e.g., buildings at Mandai Link and Woodlands Road) • Educational institutions (e.g., Yew Tee Primary School)	Priority 3

Distance	Identified Receptors	Key Examples (detailed list in Appendix DD)	Receptor Sensitivity
		• Place of worship (i.e., Senja Soka Centre) • Civic and community institution (i.e., Westlite Mandai Dormitory)	
	Public footpath, playing fields, parks and public areas for utility and transport	• Recreational facilities/ spaces (e.g., playgrounds at Choa Chu Kang Drive and Senja Grand) • Utility facility (i.e., Shell at 695 Mandai Road) • Public transport facility (i.e., Yew Tee MRT station)	Priority 3

13.4.2 Operational Phase

During operational phase, human activities involving the operation of above-ground rail and/or station facilities of are the potential sources that generate vector-breeding areas, hence human within operational footprint of this Project are not considered as the future sensitive receptors. Potential sources of impact during operational phase is detailed in Section 13.3.2.

The existing sensitive receptors of surrounding human habitats identified in Section 13.4.1 are assumed to be the same during the operational year of this Project, therefore the list of identified sensitive receptors (see Table 13-4 and Appendix DD) for construction phase is applicable for operational phase of this Project.

13.5 Vector Baseline Findings

Baseline study to identify and understand the existing vectors breeding grounds (see Figure 13-1) within the defined study area was undertaken in the form of secondary data collection via desktop research on publicly available online resources. The secondary data collection was considered sufficient to identify existing vectors breeding grounds (i.e., Dengue and Zika clusters, Areas with higher Aedes mosquito population, hawker centres) within the 400 m study area of the Project, hence no field assessment was conducted. Nonetheless, if the existing vector breeding grounds are found outside of the 400 m study area, the nearest site/ground/hotspot/cluster have been briefly discussed for comprehensiveness in this report.

This section presents the baseline findings about vectors for this Project, with focus on mosquitoes and rats as explained in Section 13.2. Note that the identified existing vectors breeding grounds will be updated constantly by NEA from time to time, hence it can only serve as a reference to understand the baseline vectors environment at the time of writing this report, which subject to future changes when the actual construction takes place, therefore would not be taken into consideration as the potential vectors' sources for this Project.

13.5.1 Vector Breeding Grounds - Mosquitoes

Existing hotspots for mosquitoes were identified using resources from NEA's website - the *Areas with Higher Aedes aegypti Mosquito Population* [W-47], *Dengue Cluster* [W-46] and *Zika Cluster* [W-48] as shown in Figure 13-1.

Areas with Higher *Aedes aegypti* Mosquito Population

According to NEA [W-46], the female *Aedes aegypti* mosquito is the primary vector of Dengue and Zika in Singapore. There are numerous habitats in our urban environment which provide the condition for the female *Aedes aegypti* mosquito to lay eggs, and hosts to blood feed upon. These areas with relatively higher *Aedes aegypti* mosquito population are recorded based on the data collected by Gravitraps deployed by NEA.

As of the review of baseline information from NEA's website on 2 June 2022, three (3) Areas with higher *Aedes aegypti* mosquito population were recorded within the vectors' study area as shown in Figure 13-1 and listed below:

- HDB residential blocks at 690 – 692 Choa Chu Kang Crescent
- HDB residential blocks at 657 – 668 Choa Chu Kang Crescent
- HDB residential blocks at 687 – 689 Choa Chu Kang Drive beside Choa Chu Kang Crescent

Dengue Cluster

A dengue cluster is defined by NEA [W-46] as a locality with active transmission where intervention is targeted. It is formed when two or more cases have onset within 14 days and are located within 150 m of each other (based on residential and workplace addresses). This information will be updated by NEA based on reported active dengue cases from time to time.

As of the baseline review conducted on 2 June 2022 based on NEA's latest update dated 1 June 2022, five (5) dengue clusters were recorded within the vectors' study area as shown in Figure 13-1 and listed below:

- Mandai Estate
- HDB residential Block 662 and Block 692A at Choa Chu Kang Crescent
- The Quintet condominium at Choa Chu Kang Street 64
- Regent Grove condominium at Choa Chu Kang North 7
- HDB residential Block 627, Block 630 and Block 636A at Senja Road

Zika Cluster

The spread of Zika virus is mainly through the bite of the infective female Aedes mosquito. As of the baseline review conducted on 2 June 2022 based on NEA's latest update dated 2 June 2022, there was no record of active zika cluster.

Conclusion

Overall, the identified mosquitoes' hotspots below are mainly residential buildings or estates where appropriate vector control measures should have been undertaken by their own local community/ council/ facility management, which does not fall under this Project's authority, hence it was presumed that minimum control measures for vectors are being practiced as that advised by NEA through the *Scope of Work for Mosquito Control in Condominium Estates/ Schools/ Town Councils* [W-43] and under *Control of Vector and Pesticide Act (CVPA)* [R-57].

13.5.2 Vector Breeding Grounds - Rats

Hawker centres are known as vector-prone areas with potential infestation of rats/rodents and cockroaches, or even mosquitoes. Based on the review of NEA's hawker centre list [W-51] on 21 March 2022, there were no hawker centres observed within the defined study area for vectors (i.e., 400 m from the above ground construction worksites and the future operational stations), therefore hawker centres are not of an immediate concern in this Project.

Whereas outside of the study area, there will be a new hawker centre to be opened in the 3rd quarter of 2022 [W-52], i.e., Senja Hawker Centre, which is located approximately 450 m from the proposed docking shaft worksite.

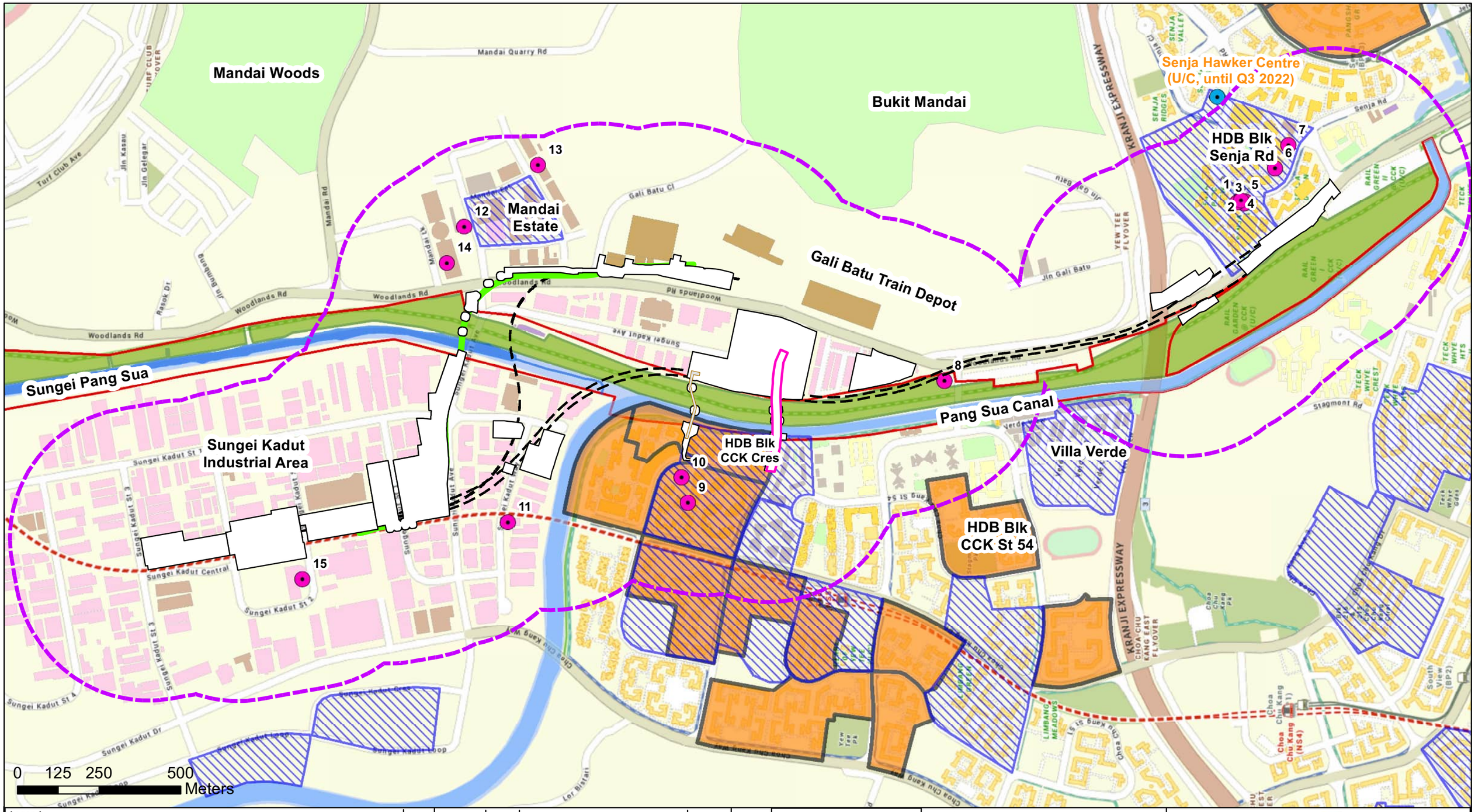
There are a few restaurants/ eateries found within the Study Area during desktop research. The list of the restaurants/ eateries is presented below in

Table 13-5 and the location are presented in Figure 13-1.

Table 13-5 Summary of Identified Sensitive Receptors for Vectors

No.	Name	Address
1	My Thai Pot	635C Senja Road
2	Tian Jia Fu (Zhi Char)	635C Senja Road
3	Xing Xing Mian Jia Senja	635C Senja Road
4	Al-madina Famous Prata Corner	635C Senja Road
5	90's Chef	635C Senja Road
6	Winifred Kriste Cake	627 Senja Road
7	Kopitiam	628 Senja Road, #01-07 Senja Grand
8	Club July	5 Stagmont Ring
9	Broadway Coffeeshop	668a Choa Chu Kang Crescent
10	NonyaBong the Peranakan	663 Choa Chu Kang Crescent
11	Hawkerway Pte Ltd	16A Sungei Kadut Way
12	566 Seafood Restaurant at Mandai Estate	566 Woodlands Road
13	Lion City Food Court Pte Ltd	Innovation Place #07-08, 27 Mandai Estate
14	One Ocean Seafood	7 Mandai Link, #01-06 Mandai Connection
15	Stickies Bar @ Sungei Kadut	18 Sungei Kadut Street 2

Nonetheless, the hawker centres governed under their own local community/ council does not fall under this Project's authority, hence it is presumed that the Rat Control [W-42] measures (applicable for food establishments/ supermarkets/ shopping malls/ construction sites) are being practiced as that advised by NEA.



Legend

- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- 400m Study Area
- Proposed Worksite Areas
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Potential Vector Breeding Ground

- Restaurants/ Eateries
- Hawker Centres
- Dengue Clusters 2022
- Areas with Higher Aedes Population

Sensitive Receptors

- Educational Institution
- Bus Depot/ Interchange/ Terminal
- Industrial/ Business Building
- Commercial/ Recreational Building
- Public Housing
- Park/ Playground
- Place of Worship
- Utility
- Unclassified Building (incl. Private Residentials)

Note: Sourced from NEA Website as of 2nd June 2022. The restaurants/ eateries are listed out in Table 13-2.

N

Rev.	Date	By	Description	Chk'd	App'd
D	AUG 2024	MNS	Final Report	RAK	JAG
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
-	AUG 2022	TTR	Draft Final Report	HHL	JAG

Qualified Person Endorsement :
N/A

LTA Endorsement :
N/A

Consultant : AECOM

Land Transport Authority
We Keep Your World Moving

Project Title :
CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Designed	Checked	Approved
TTR	RAK	JAG
	Drawn: TTR	Date: MAY 2023

Figure Title :
BASELINE VECTORS BREEDING GROUNDS AND SENSITIVE RECEPTORS WITHIN STUDY AREA

Figure No. :	Rev.	Sheet
13-1	D	1 of 1

CAD File Name :N/A | A3

Note: Source of basemap - OneMap

13.6 Minimum Control Measures

This section proposes minimum controls or standard practices commonly implemented in Singapore for similar construction activities and human habitats. These minimum controls focus on reducing sources of stagnant water and the implementation of control for mosquito larvae and pupae as well as rats. It has been assumed that these practices will be implemented and thus, any impacts identified are post-implementation of these standard measures. Generally, the minimum control has also considered design optimization detailed in Section 3.2.1.

13.6.1 Construction Phase

Under Section 15 of CVPA, the Act states that "*No person shall create or cause or permit to be created any condition favourable to the propagation or harbouring of vectors.*" The maximum fine for vector breeding detected will be up to $50,000 or imprisonment for up to 6 months or both. NEA may also issue Stop Work Order (SWO) to errant contractors with poorly maintained sites. Therefore, vector control is mandatory for all construction worksites and minimum control measures on site are required as stated in LTA's *SHE Specifications* [R-19] and NEA's guidelines for mosquito and rat control [W-43, W-42], which generally include but not limited to the following:

- Prepare and implement an effective Vector Control Plan as required under LTA's *SHE Specifications* and the NEA's *Code of Practice for Environmental Control Officers (ECO)* [W-91], focusing on the source reduction of stagnant water.
- Conduct vector control and surveillance on site at least once a week (especially after every rainfall) by a NEA-licensed Vector Control Operator (VCO) and/or the competent vector control personnel (i.e., NEA-licensed Vector Control Technicial (VCT) and Vector Control Worker (VCW) the *Code of Practice for Vector Control Operator, Technician and Worker* [W-93, W-92]. An in-house vector control team led by the licensed VCO/VCT/VCW can be formed as suggested in *LTA's Guidebook in Vector Control at LTA Sites* [R-73] to closely monitor the implementation of vector control measures (e.g., manage Gravitraps, detect rodent and cockroaches droppings, etc.);
- Application of physical control measures for mosquito larvae/ pupae at areas with stagnant water that cannot be permanently removed, inaccessible areas or when typical minimum control measures (see examples in Table 13-6) are ineffective:

    - Anti-Mosquito (AM) Oil is recognised by LTA as one of the most commonly used control measures on site, typically spraying into tanks with stagnant water to block the oxygen supply for the mosquito larvae/ pupae. According to both LTA and NEA guidelines, it can be applied at least once a week and/or after heavy rain which would have washed away the oil.
    -
    - Mono-Molecular Film (MMF) follows a similar mechanism as AM oil that blocks oxygen supply for mosquito larvae/ pupae, as well as reducing water surface tension so that female mosquitoes could not stay on the water surface.
    -
    - Larvicides including chemical larvicides (e.g., Temephos sand granule/ Abate, Relief T, etc.) and biological larvicides (e.g., *Bacillus Thuringiensis Israelensis* (Bti)) which are submerged into the stagnant water to prevent mosquito breeding. As stipulated under CVPA, if any pesticide/ repellent products (including larvicides) which should be registered under NEA falls under the category of "For Restricted Use" (*Guidebook to the Registration of Public Health Pesticides and Repellents Against Vectors*) [W-39], it shall only be handled and applied by NEA-licensed Vector Control Technicians (VCTs) or NEA-certified Vector Control Workers (VCWs) because of their high toxicity.

- Application of adult mosquito control measures can only be conducted by NEA-licensed VCTs or NEA-certified VCWs, as follows:
    - Thermal Fogging shall only be carried out when there is a Dengue outbreak or when high mosquito population is detected at construction worksite. Regular fogging is not encouraged as it may build up the mosquitoes' resistance over time [R-73, W-43].

- Misting and/or Residual Spray is similar to thermal fogging which kills adult mosquitoes through spraying a mixed solution with prescribed ratio for both outdoor and indoor applications.

- Mosquito Traps are commercially available to lure and trap adult mosquitoes either through ultraviolet light or emitting carbon dioxide with mild heat and then eliminated due to dehydration. It is suitable to be placed at workers' resting areas, canteens or near forested boundaries where there are more mosquito breeding habitats.

- Introduction of personal protection on site, such as wearing repellent-treated safety vests, long sleeves clothing, etc. shall also be considered to prevent site workers from being bitten by adult mosquitoes.

The following table describes the common practices as minimum control measures for the identified potential sources of vector impacts at construction worksites, which mainly focusing on reduction of vectors at source.

Table 13-6 Minimum Control Measures During Construction Phase

Potential Sources of Vectors Impacts During Construction Phase		Minimum Controls
Areas	**Common Sources/ Activities**	
Site Boundary/ Perimeter Area	• Water accumulation at the openings/ damaged holes on water-filled barricades and concrete barriers. • Water stagnation due to ineffective drainage and poor housekeeping along hoarding/ perimeter noise barrier.	• Ensure openings of barricades and concrete barriers are capped or covered. • Implement consistent housekeeping along hoarding/ site perimeter. • Ensure gaps on ground are sealed and ground depression is filled up to prevent water ponding.
Material Storage Area	• Water accumulation at non-sheltered storage/ stockpile areas: – On top of untaut canvas sheets. – Plastic cover for material packaging. – On top of chemical drums. – Exposed bolt socket holes and lifting/ grouting socket holes of tunnel segment rings. – Exposed test cube tanks. • Water stagnation due to improper storage/ handling of construction materials: – Discarded water-bearing receptacles. – Storage of loose items and spare parts (e.g., fittings, joints etc.). • Poor housekeeping at storage area resulting in inadequate access for regular inspection.	• At non-sheltered storage / stockpile areas: – Canvas sheets shall be pulled taut and the bottom is cult/ folded in to avoid water collection. – Remove unwanted plastic covers or store the materials under shelter. – Openings of tunnel segment rings can be temporarily covered by sponge plugs and/or tape. • Ensure proper storage of loose items, spare parts and receptacles at a sheltered area and do not collect water. • Implement consistent housekeeping schedule to ensure adequate access to storage area for regular inspection.
Construction Area	• Water ponding on uneven surface or ground depressions, as well as at the areas excavated for trial trenches, utility diversions, and other temporary works where water drainage is not possible. • Water stagnation on equipment/ machinery and construction area without shelter or cover, such as: – Gaps/ voids on walers and struts, sheet piles, vertical toe board, scaffold clamp covers, discarded receptacles etc.	• Site entrance shall be paved to avoid ground depression. • Milled waste can be used to level the ground before laying steel plates. • Provide movable roof over shaft to prevent rainwater ingress. • Pump shall be deployed to clear water at areas where drainage is not possible, as well as for larger recessed surfaces. • For other non-sheltered area/equipment: – Drill holes in walers or scaffold clamp covers to drain water.

Potential Sources of Vectors Impacts During Construction Phase		Minimum Controls
Areas	**Common Sources/ Activities**	
	– Recessed concrete surface. – Opening of standpipe and end of pipes / water hoses. – Openings on hollow blocks. – Uncovered or tilted-up lifting bucket. – Unattended waste bins/ skips. – Rainwater collection tanks – On top of recharge well. – Exposed train tracks. • Ineffective site drainage causing water stagnation due to silt build-up and poor gradient. • Poor housekeeping resulting in water ponding at gaps or grounds.	– Filled up empty gap/ void, small recessed surfaces with sand or lean concrete, where applicable. – Cover opening on standpipe, water hoses, etc. with tape if not in use. – Patch up opening of hollow blocks. – Turn lifting bucket upside down when not in use. – Provide platform at waste skip to allow easy checking of stagnant water. – Cover rainwater tanks with anti-mosquito nets. – Install pitched roof for recharge well. • Implement housekeeping schedule for regular maintenance of water drains to be free from silt and/or litter obstructions, as well as to clean other potential water ponding areas on site.
Site Office, Canteen and Rest Area	• Water accumulation at/ near site office, such as: – Site container office with missing or poorly maintained pitched roofs. – Random construction materials or discarded items located outdoor without shelter. – Tree/ Plant holes. • Water stagnation on unwanted items and workers' rest areas or canteen, such as: – Unused water dispenser. – Un-capped water dispenser bottles. – Stagnant water in unwanted flower pot and pail.	• Install pitched roof on top and/or seal up bottom of site container office. • Include in regular site inspection checklist to ensure clearing of stagnant water at least once a week. • After trees clearance, top of tree stumps have to be either remove thoroughly or patched up. • Pipette can be used for larvae-checking at the hard-to-reach parts of a tree. • Conduct daily housekeeping and regular carpet combing at canteen and workers' rest areas. • Removed and properly disposed unwanted items or cover it properly.
General and Others	• Poor housekeeping and improper littering on site. • Improper handling, transfer and storage of water/ wastes, such as waste bins with overflowing food waste and washing area with spilled food waste.	• Conduct regular inspection to detect infestation of other vectors and remove or sealed up where applicable: – Rodent infestation can be identified by visible rodent droppings, burrows/ runways, smear marks and gnawing marks, etc. – Cockroach infestation can be indicated by cockroach droppings, cockroach egg cases, odour, live cockroaches. – Flies breeding is typically indicated by the presence of adult flies and maggots at potential areas with food waste like canteen and workers' resting areas. • Store food in rodent proof storage containers/cabinets with at least 60 cm clearance above ground level.

Potential Sources of Vectors Impacts During Construction Phase		Minimum Controls
Areas	**Common Sources/ Activities**	
		• Fly trap stickers or electrical fly traps can be installed. • Ensure proper waste/food waste disposal with the provision of food waste bins which are tightly covered and are regularly cleaned. • Conduct daily housekeeping to ensure discarded items are cleared.

13.6.2 Operational Phase

Governing under the same act (i.e., CVPA), the following table describes some best and/or common practices as minimum control measures for the identified potential sources of vector impacts from the operational areas of the Project, which mainly focusing on reduction of vectors at source. References were made to the NEA's guidelines of the *Scope of Work for Mosquito Control in Condominium Estates/ Schools/ Town Councils* [W-43] and the Rat Control [W-42] measures suggested by NEA.

Table 13-7 Minimum Control Measures During Operational Phase [W-41,W-94,W-95]

Potential Vectors Sources During Operational Phase		Minimum Controls
Areas	**Common Sources**	
Station exits/ entrances and associated amenities at or above ground level (connected from the underground DTL2e Intermediate Station and DTL2e Interchange Station)	• Flower troughs, plant boxes and plant pots • Tree holes and bifurcations between branches, leaf axils of banana trees, Travellers Palms and other palms (if any planted at the station perimeter) • Air-conditioner trays • Rooftop, roof drainage and gutters • Rooftop water tanks (if any) • Roof drainage and gutters • Puddles on the ground or concrete floors • Non-sheltered or unused containers in open areas and under bushes • Open and closed drains • Gully traps • Toilet bowls • Poorly-managed litter bins	• Rail operator to conduct periodic checks on the potential vector-breeding areas: – Ensure water tanks are properly covered – Ensure all drainage outlets are properly sealed – Clear fallen leaves and tree branches from drains, and seal up tree holes if any at the perimeter of the station/ bridge – Cover rarely-used gully traps and install anti-mosquito valves – Cover all containers storing water – Removed unused containers or unwanted receptables so they do not store water – Avoid using canvas or plastic sheets as they may trap water – Place sand granular insecticide in areas where stagnant water cannot be easily removed – Ensure all refuse bins are covered, recycling bins are not overflowing, and all damaged bulk bins are replaced. – Ensure all bins have working stoppers to prevent leakage of sullage water, and entry point for rats. – Remove food or refuse spillage • Engage and/or assign licensed personnel to: – Carry out fogging (only when there is a mosquito nuisance problem or disease outbreak) – Destroy vector breeding habitats (e.g., mosquito breeding grounds, rat/rodent burrows) if found, and perform treatment where necessary – Undertake vector control measures and vector surveillance regularly at the station and its perimeter. • Practice the 5-steps (B-L-O-C-K) of Mozzie Wipeout at least once a week for the station and around its perimeter, where applicable:
Open-air boarding/ waiting area of the new NSL Sungei Kadut Elevated Station	• Flower troughs, plant boxes and plant pots • Rooftop, roof drainage and gutters • Puddles on the floor of the boarding/waiting area • Non-sheltered or uncovered containers • Poorly-managed litter bins	

Potential Vectors Sources During Operational Phase		Minimum Controls
Areas	**Common Sources**	
		– **B**reak up or loosen hardened soil of flower pots or plant boxes (if any) on alternate days – **L**ift and empty flowerpot plates (if any) where possible – **O**verturn pails and wipe their rims, so as to keep water storage containers or pails dry when not in use. – **C**hange water in vases – **K**eep roof gutters clear and place Bti insecticide once a month • Conduct daily housekeeping, cleaning and/or maintenance routine to ensure proper hygiene of the concerned public areas and litter/refuse bins.
Open-air Pedestrian Linkbridge beside DTL2e Intermediate Station	• Flower troughs and plant boxes alongside the bridge (depends on the bridge design) • Puddles on the floor of the bridge • Poorly-managed litter bins	Periodic cleaning of public areas such as overhead bridges will be governed by the NEA's Division of Public Cleanliness separately, hence the minimum controls for this specific potential source are not discussed in this report. [W-96]

13.7 Prediction and Evaluation of Vectors Impacts

13.7.1 Construction Phase

There are common vector-breeding areas in construction sites (see Table 13-2), such as site boundary, material storage area, canteen etc., which may create vectors impacts to the human sensitive receptors nearby the Project, especially to human habitats with natural ventilation where human resides and are more prone to long-term exposure to vectors like mosquitoes and rats. The potential sources or activities of vectors impacts are mainly from the accumulation of stagnant water, poor housekeeping and improper handling during transfer and storage of waste.

Within the 400 m study area for vectors, where the highest receptor sensitivity identified for sensitive receptors within 50 m from the construction footprint or Project boundary is Priority 1, whereas sensitive receptors identified between 50 m to 150 m is Priority 2, while between 50 m to 400 m is Priority 3. The list of identified sensitive receptors has been summarised in Table 13-4 and detailed in Appendix DD.

With the implementation of minimum controls outlined in Section 13.6.1, the accumulation of stagnant water, poor housekeeping and improper handling during transfer and storage of waste are expected to be greatly reduced. Hence, the impact intensity of vector-breeding associated with the construction activities was deemed to be **Low**. For sensitive receptors with Priority 1 sensitivity and Low impact intensity, the impact consequence was expected to be **Low**. For sensitive receptors with Priority 2 & 3 sensitivity and Low impact intensity, the impact consequence was expected to be **Very Low**.

In addition, given that vector control measures and/or plans such as the application of AM oil or larvicide, proper and regular food/waste disposal, daily housekeeping etc., will be routinely implemented at the construction worksites, the likelihood of vector-breeding originated from the construction phase of this Project was expected to be **Less Likely**.

The impact significance level with Low impact consequence and Less Likely to occur were assessed to be **Minor**, whilst the impact significance level with Very Low impact consequence and Less Likely to occur were assessed to be **Negligible**.

Therefore, no further mitigation measures were required beyond the minimum controls outlined in Section 0. Nonetheless, environmental monitoring and management measures for vector impacts were discussed for comprehensiveness in the Section 14.12.

The prediction and evaluation of vector impacts above are summarised in the Table 13-8.

13.7.2 Operational Phase

There are common vector-breeding areas at the above-ground station buildings and around their perimeters (see Table 13-7), such as flower pots, planter boxes, air-conditioned trays, refuse bins, unused containers etc., which may cause mosquito nuisances or rat infestation hence impacting the human sensitive receptors (e.g., residential, school, etc.) nearby the operational footprint of this Project. The potential sources or activities of vectors impacts are mainly from the accumulation of stagnant water, poor housekeeping and improper management of station facilities and/or waste disposal containers such as refuse bins.

As mentioned in Section 13.4.2, the existing sensitive receptors of surrounding human habitats identified for construction phase are assumed to be the same for operational phase of this Project. In overall, the highest receptor sensitivity, i.e., Priority 1 receptor, was identified as a cluster of residential blocks situated within 50 m from the operational footprint of the Project, while Priority 2 and 3 receptors were also identified at other areas within the 400 m study area as detailed in Table 13-4 or Appendix DD.

With consideration of the station operational hours from 6 am to 11 pm daily, it is expected to have increase in human activities within the operational footprint, which may generate a relatively moderate amount of waste or other vector-prone areas that may attract rats and/or mosquitoes. Therefore, the impact intensity for operational phase is considered to be **Medium**. For sensitive receptors with Priority 1 sensitivity and Medium impact intensity, the impact consequence was expected to be **Medium**. For sensitive receptors with Priority 2 sensitivity and Medium impact intensity, the impact consequence was expected to be **Low**. For sensitive receptors with Priority 3 sensitivity and Medium impact intensity, the impact consequence was expected to be **Very Low**.

With the implementation of minimum controls outlined in Section 13.6.2, the accumulation of stagnant water, poor housekeeping and improper management of station facilities and/or waste disposal containers can be reduced and well-managed during the operational phase of the Project, hence the likelihood of vector-breeding from operational activites was expected to be **Less Likely**.

The impact significance level with Medium & Low impact consequence and Less Likely to occur were assessed to be **Minor**, whilst the impact significance level with Very Low impact consequence and Less Likely to occur were assessed to be **Negligible**.

Therefore, no further mitigation measures were required beyond the minimum controls outlined in Section 0. Nonetheless, environmental monitoring and management measures for vector impacts were discussed for comprehensiveness in the Section 14.12.

The prediction and evaluation of vector impacts above are summarised in the Table 13-9.

Table 13-8 Evaluation of Vector Impacts for Construction Phase

Potential Sources of Impacts	Distance from Project boundary	Identified Receptors	Receptor Sensitivity	Impact Intensity	Impact Consequence	Likelihood	Impact Significance (with minimum controls)
• Accumulation of stagnant water • Poor housekeeping • Improper handling, transfer and storage of water/ wastes	**Within 50 m**	Human Habitats with Natural Ventilation	Priority 1	Low	Low	Less Likely	Minor
		Buildings with Mechanical Ventilation	Priority 2	Low	Very Low	Less Likely	Negligible
		Public footpath, playing fields, parks and other public areas	Priority 2	Low	Very Low	Less Likely	Negligible
	Between 50 m to 150 m	Human Habitats with Natural Ventilation	Priority 2	Low	Very Low	Less Likely	Negligible
		Buildings with Mechanical Ventilation	Priority 2	Low	Very Low	Less Likely	Negligible
	Between 150 m to 400 m	Human Habitats with Natural Ventilation	Priority 3	Low	Very Low	Less Likely	Negligible
		Buildings with Mechanical Ventilation	Priority 3	Low	Very Low	Less Likely	Negligible
		Public footpath, playing fields, parks and other public areas	Priority 3	Low	Very Low	Less Likely	Negligible

Table 13-9 Evaluation of Vector Impacts for Operational Phase

Potential Sources of Impacts	Distance from Project boundary	Identified Receptors	Receptor Sensitivity	Impact Intensity	Impact Consequence	Likelihood	Impact Significance (with minimum controls)
• Accumulation of stagnant water • Poor housekeeping • Improper management of station facilities and/or waste disposal containers	**Within 50 m**	Human Habitats with Natural Ventilation	Priority 1	Medium	Medium	Less Likely	Minor
		Buildings with Mechanical Ventilation	Priority 2	Medium	Low	Less Likely	Minor
		Public footpath, playing fields, parks and other public areas	Priority 2	Medium	Low	Less Likely	Minor
	Between 50 m to 150 m	Human Habitats with Natural Ventilation	Priority 2	Medium	Low	Less Likely	Minor
		Buildings with Mechanical Ventilation	Priority 2	Medium	Low	Less Likely	Minor
	Between 150 m to 400 m	Human Habitats with Natural Ventilation	Priority 3	Medium	Very Low	Less Likely	Negligible
		Buildings with Mechanical Ventilation	Priority 3	Medium	Very Low	Less Likely	Negligible
		Public footpath, playing fields, parks and other public areas	Priority 3	Medium	Very Low	Less Likely	Negligible

13.8 Recommended Mitigation Measures

13.8.1 Construction Phase

Given the implementation of minimum control measures on site, the impact significance of vector was expected to be Negligible to Minor, thus no mitigation measures are required. Nonetheless, environmental monitoring and management measures for vector impacts during construction phase were discussed for comprehensiveness in Section 14.12.1.

13.8.2 Operational Phase

Given the implementation of minimum control measures on site, the impact significance of vector was expected to be Negligible to Minor, thus no mitigation measures are required. Nonetheless, environmental monitoring and management measures for vector impacts during operational phase were discussed for comprehensiveness in Section 14.12.2.

13.9 Residual Impacts

13.9.1 Construction Phase

No residual impact assessment has been undertaken as there is no Moderate or Major impact significance for the sensitive receptors identified. Nonetheless, all the suggested minimum control measures and EMMP measures shall be applicable for any other construction works (e.g., temporary or permanent utilities diversion) associated with this Project that may occur outside of the current worksites in this report.

13.9.2 Operational Phase

No residual impact assessment has been undertaken as there is no Moderate or Major impact significance for the sensitive receptors identified. General minimum control measures and best operational practices are applicable.

13.10 Cumulative Impacts with Other Concurrent Projects

The potential major concurrent development and other ongoing construction projects have been discussed in Section 3.5, and presented in Figure 3-31 and Figure 3-32 of this report, comprising:

- JTC Woodlands Road realignment
- HDB CCK N1 construction

These construction activities are expected to have potential overlapping period with the construction phase of this Project.

13.10.1 Construction Phase

During the overlapping construction period, the concurrent and/or ongoing construction works nearby this Project will become the potential sources of vector breeding grounds which may cause vector impact towards the similar group of vector sensitive receptors identified in this report and the cumulative impact could become significant when put together.

Since these areas are not governed under the same party/authority of this Project, it was presumed that minimum vector control measures will be implemented by the Project proponent on the concurrent and ongoing projects' worksites. Nonetheless, LTA shall establish effective communication with the relevant Project proponent to ensure that vector control measures and other best practices advised by NEA (Refer to Section 13.6) as well as similar EMMP measures (Refer to Section 14.12) will be implemented so that cumulative impacts could be controlled and brought down to insignificant levels.

13.10.2 Operational Phase

There are no sufficient information (e.g., schedule) about the major concurrent development and other nearby ongoing projects for the evaluation of cumulative vectors impacts. Nonetheless, general vectors control measures as highlighted as minimum control measures in Section 13.6 or suggested as EMMP measures in Section 14.12 may be applicable in case there are future overlapping works in the vicinity of the operational footprint of this Project.

13.11 Summary of Key Findings

Potential vectors sources identified during construction and operational phases are mainly vector-prone areas due to water accumulation and poor housekeeping on site and at station buildings, as well as improper management of construction site storage, waste areas and operational station facilities. Priority 1, 2, 3 sensitive receptors within the 400 m study area have been identified and listed in Table 13-4 or Appendix DD, which are assumed to exist during both construction and operational phases of the Project. Any vector sensitive receptors identified beyond 400 m may not be contributed by this Project, hence are not of an immediate concern and will be excluded from this vector impact assessment.

A baseline study for vectors was conducted via desktop assessment on 2 June 2022. The vector breeding grounds within the study area (i.e., 400 m from the above ground construction worksites and the future operational footprint) were identified at the time of writing this report, as listed below:

- 3 areas with higher *Aedes aegypti* mosquito population at residential blocks near Choa Chu Kang Crescent
- 5 dengue clusters near Choa Chu Kang Crescent, Mandai Estate and Senja Road
- No active zika cluster (i.e., a potential mosquito hotspot).
- No hawker centres (i.e., mainly prone to rat infestation) were identified within the 400 m study area. The nearest future hawker centre will be the Senja Hawker Centre located approximately 450 m from the proposed docking shaft worksite.
- 15 restaurants/ eateries were identified within the 400 m study area.

Note that the above real-time baseline information will be constantly updating by NEA from time to time, hence subject to future changes when the actual construction takes place, therefore would not be taken into consideration as potential vector sources for this Project.

Being governed under the *Control of Vector and Pesticide Act (CVPA)* [R-51], minimum control measures and common best practices shall be implemented at construction worksites according to *LTA's SHE Specifications* [R-19], NEA's guidelines for mosquito and rodent control, as well as the NEA's *Code of Practice for Environmental Control Officers (ECO)* [W-91] and the NEA's *Code of Practice for Vector Control Operator, Technician and Worker* [W-93].

With consideration of the minimum control measures or best practices (see Section 13.6), the likelihood of vector-breeding within the construction and operational footprints was assessed to be Less Likely, resulting in **Minor to Negligible** impact significance levels for both construction and operational phases as detailed in Section 13.7.1 and Section 13.7.2 respectively.

As such, no further mitigation measures were required hence no residual impact assessments were undertaken. Nonetheless, vector control measures as part of the EMMP measures (see Section 14.12) for the implementation at construction worksites and operational station buildings or other associated facilities of this Project, shall be undertaken based on the relevant LTA and NEA guidelines governed under *Control of Vector and Pesticide Act (CVPA)* [R-57]

There are a few major concurrent development and other ongoing construction projects discussed in Section 3.5, and presented in Figure 3-31 and Figure 3-32 of this report, which were expected to have overlapping construction period with the construction phase of this Project. Since these areas are not governed under the same party/authority of this Project, it was presumed that minimum vector control measures will be implemented by the Project proponent on the concurrent and ongoing projects' worksites. Nonetheless, LTA shall establish effective communication with the relevant Project proponent to ensure that vector control measures and other best practices advised by NEA (Refer to Section 13.6) as well as similar EMMP measures (Refer to Section 14.12) will be implemented so that cumulative impacts could be controlled and brought down to insignificant levels.

Table 13-10 Summary of Vectors Impact Assessment

Sensitive Receptors and Phases	Impact Significance with minimum controls	Residual Impact Significance with mitigation measures (if required)
Construction Phase		
Ecologically Sensitive Receptors	Not applicable for vectors as justified in Section 13.4.	
Human Sensitive Receptors	Negligible to Minor	**Negligible to Minor [1]**
Operational Phase		
Ecologically Sensitive Receptors	Not applicable for vectors as justified in Section 13.4.	
Human Sensitive Receptors	Negligible to Minor	**Negligible to Minor [1]**

Note:

[1] No additional mitigation measures are required for vectors impact, as there are no Moderate or Major impact significance levels identified. With consideration of minimum controls, the potential vectors impacts which range from Negligible to Minor can be managed during both construction and operational phases of the Project.

14 Environmental Monitoring and Management Plan

The proposed EMMP is prepared for environmental impacts of the construction, commissioning and operational phases associated with the Project in overall for comprehensiveness of the study as well as to provide an overall picture of the potential roles and responsibilities required during each phase of the Project. The coverage of the proposed EMMP involves the environmental parameters that were assessed in this ES, namely biodiversity, hydrology and surface water quality, air quality, airborne noise, ground-borne vibration, soil and groundwater, waste management and vector control. The EMMP details how the key mitigation measures recommended from the impact assessment/study are to be implemented and specifies environmental monitoring measures to assess the effectiveness of the proposed mitigation measures. These EMMP measures were also summarised and documented in the EIR (See Appendix A).

- During construction phase, this document is intended to provide a broad framework for various players in the construction phase to develop a more contract-specific EMMP, as per their responsibilities in Section 14.4 in order to comply with LTA's SHE specifications and any contract-specific requirements.
- During the operational phase, this document is intended to provide a brief understanding of the responsibilities of Rail Operator (see Section 14.5) and other relevant personnel who perform or ensure the implementation of minimum control measures as per the relevant legislations and the proposed mitigation measures based on the impact assessment/study findings.

This section outlines the objectives of the EMMP, the Project organisation, describes the roles and responsibilities relevant to implementation of the EMMP, and summarises the EMMP requirements for each discipline. A summary of the proposed EMMP of different phases, incorporated with the relevant minimum controls and key mitigation measures, is provided in Section 14.13.

14.1 EMMP Objectives

The EMMP details the implementation and deliverables of the key mitigation measures recommended from the impact assessment for each technical discipline. The EMMP progressively scrutinises construction and operational activities as they ensue and applies flexible monitoring and management procedures to protect the Project's environmental values throughout the Project period. The objective of the EMMP is twofold:

- Environmental monitoring focuses on overseeing those impacts to the Project's environmental values from construction phase are within the anticipated level and tackle unforeseen impacts that may arise; and
- It also tracks the effectiveness of the recommended mitigation measures to allow amendment or review of the mitigation measures to better address any issues faced during construction and operational phases of the Project.

Environmental management employs a more active approach to ensure those impacts on human and ecological receptors are directly avoided through documentation, auditing and enforcement.

14.2 Project Organisation during Construction Phase

The proposed Project organization and lines of communication with respect to environmental protection works for construction and commissioning phases of this Project are presented in Figure 14-1. The roles and responsibilities of the various parties responsible for implementing the EMMP during the construction and commissioning phases are outlined in Section 14.4.

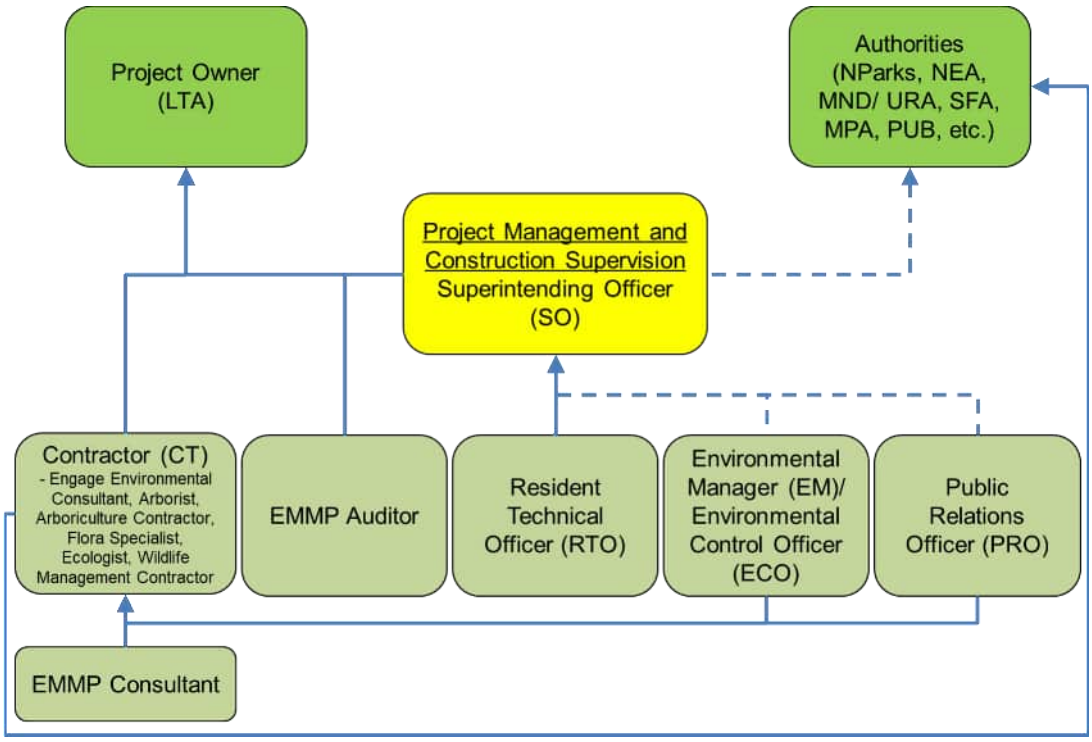


Figure 14-1 Project Organization and Lines of Communication during the Projects' Construction and Commissioning Phase

14.3 Project Organisation during Operational Phase

The proposed Project organization and lines of communication with respect to the general management and implementation of the recommended minimum control measures as well as key mitigation measures during operational phase of this Project are presented in Figure 14-2, forming a typical Environmental Management Committee or as part of the Environmental, Health and Safety (EHS) Committee for a particular organization/operation. The roles and responsibilities of the various parties involved in the operational phase are outlined in Section 14.5.

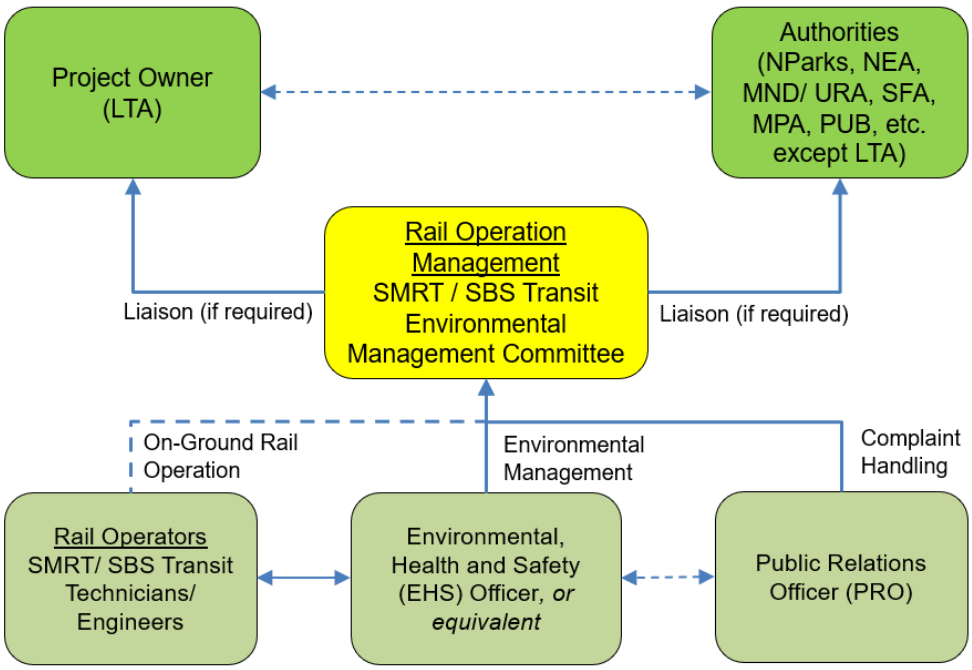


Figure 14-2 Project Organization and Lines of Communication during the Projects' Operational Phase

14.4 Roles and Responsibilities of the EMMP for Construction Phase

This section describes the roles and responsibilities of the EMMP members presented on the organisational chart for construction and commissioning phases in Section 14.2.

14.4.1 Technical Agencies

Technical agencies constitute but are not limited to NParks, PUB, NEA, and URA. These agencies shall assess and/or approve the detailed EMMP for the construction and commissioning phases prior to commencement of works and where required during the course of the relevant Project phases.

14.4.2 Project Owner (LTA) and Resident Technical Officer (RTO)

LTA, being the Project owner, oversees the construction and commissioning phases of the Project in accordance with the design. LTA, in conjunction with the Resident Technical Officer (RTO) (Contractor), are required to:

- Ensure resources are available to achieve the requirements of the EMMP;
- Provide leadership in the development and implementation of the EMMP;
- Ensure all environmental incidents and near misses are promptly investigated and reported;
- Resolve any non-compliance issues;
- Record, respond to, and action on any complaints from members of the public, if any, with inputs from the Technical agencies, if required; and
- Reporting to the Technical Agencies regarding implementation of the EMMP.

14.4.3 Superintending Officer (SO)

The Superintending Officer is responsible for overseeing the construction works undertaken by various staff, Contractors and sub-contractors. The SO should ensure that the construction works are performed by the Contractors and personnel in accordance with the specification, contractual requirements, and EMMP. The SO should also:

- Communicate the requirements of this plan to all staffs, Contractors and sub-contractors
- Monitor all staffs, Contractor's and sub-contractor's compliance with contract specifications and regulatory requirements, including the implementation of the environmental mitigation and monitoring measures and ensure their effectiveness, and other aspects of the environmental audit program;
- Coordinate with the Project's EM/ECO to monitor and participate in the implementation of the environmental audit program, and ensure that the requirements in the environmental audit program are correctly followed;
- Implement measures to reduce impacts where emission/discharge levels are exceeded;
- Coordinate with the Project Owner and RTO for submission of environmental audit reports;
- Carry out any complaint investigations with PRO (see Section 14.4.12);
- Resolve any non-compliance issues; and
- Promote environmental awareness and responsibility and lead by example.

14.4.4 Contractor (CT)

The term "Contractor" refers to all construction Contractors and sub-contractors working onsite at any time, which also the "Occupier of Construction Site" as defined by NEA. In addition to reporting to the SO, the Contractor should:

- Work under the relevant contract scope, specifications, and other tender conditions;

- Ensure that the roles of Environmental Manager (EM), Environmental Control Officer (ECO), Certified Arborist, Arboriculture Contractor, Flora Specialist, Ecologist, Wildlife Management Contractor(s) are adequately resourced;
- Notify the Director-General of Public Health on the employment of ECO (also applicable for EM who shall also be an registered ECO in the context of this Project) by submitting the Notification on Employment of Environmental Control Officer (as per the format *in the NEA's Code of Practice of Environmental Control Officers*), as well as to notify in writing to the Director-General of Public Health and to employ another registered ECO/EM within 14 days of the termination of the employment of the originally appointed ECO/EM;
- Employ a temporary ECO or engage a registered Workplace Safety and Health Officer (WSHO) with valid ECO certificate obtained under NEA if both EM and ECO working on the construction site are on leave or absent for more than 5 days, and neither of them can take on the work responsibility of an ECO during the absence period;
- Endorse and submit the Site Environmental Control Programme prepared by the ECO/EM to the Director-General of Public Health at least two weeks before work commences on the construction site;
- Discuss about the Site Environmental Control Report with the EM/ECO within one week on receipt of the report, then countersign and stamp after finalization and implement the recommendations made by the ECO;
- Keep the Site Environmental Control Report available for inspection by the Director-General of Public Health or Public Health Officers when required, as well as to submit when required to so by the Director-General of Public Health;
- Participate in the required environmental site audits (via the SO) undertaken by a registered EM/ECO and undertake any corrective actions;
- Provide up-to-date information and advice to the RTO, SO, EM, ECO, Certified Arborist, Arboriculture Contractor, Flora Specialist, Ecologist, Wildlife Management Contractor(s) regarding any work activities which may contribute or continuously create adverse environmental conditions, or any changes to the work plan;
- Implement measures to reduce impacts where emission/discharge levels are exceeded;
- Prepare a detailed contract-specific EMMP, incorporating the relevant mitigation measures and monitoring works recommended in this study and seek technical agencies' approval prior to the commencement of any works for the construction and commissioning phases of the Project. This detailed EMMP shall include, as a minimum, a Standard Operating Procedure (SOP) detailing:
    - Trees to be felled or retained shall be determined by the Arborist.
    - Handling and storage of hazardous chemicals;
    - Biodiversity management plan;
    - Individual environmental management plans as detailed in the LTA's SHE Specifications (air, vector, waste, noise, water pollution management plans);
    - Monitoring plans (including but not limited to noise, air, waste, ecology and water pollution);
    - Environmental Impact Register;
    - Existing legislation and environmental best practices to be implemented; and
    - Contingency planning during emergency situations.

14.4.5 Environmental Personnel

According to LTA's SHE Specifications, the Contractor shall comply with all legislative safety, health and environmental (SHE) requirements as stipulated. SHE personnel refer to Workplace Safety and Health Officer (WSHO) registered with the Ministry of Manpower (MOM) and ECO registered with the NEA. After consultation with LTA, the Contractor shall engage the following environmental personnel during the construction and commissioning phases of this Project:

- Environmental Consultant, with strong and relevant experiences in developing and implementing EMMP for similar or larger construction Projects;
- Environmental Manager (EM), who is a NEA-registered ECO with strong and relevant experiences, to oversee/ lead/ guide environmental monitoring and auditing works on the construction site; and

- Environmental Control Officer (ECO), who shall assist the EM and is also registered with NEA, to perform and/or ensure implementation of EMMP, mitigation measures and minimum control measures on site.

14.4.5.1 Environmental Consultant

An environmental consultant shall be engaged by the Contractor to develop a contract-specific EMMP for implementation by all parties, including EM/ECO and relevant workers on site. The appointed environmental consultant may be required to re-establish baseline environmental conditions and perform the recommended environmental monitoring works throughout the construction and commissioning phases, as well as to provide environmental advisory services for the Contractor and to liaise with the authorities and stakeholders, when necessary.

14.4.5.2 Environmental Manager (EM)/ Environmental Control Officer (ECO)

General Introduction

The Environmental Control Officer (ECO) Scheme was launched by NEA on 1 April 2000 to advocate good environmental practices within construction sites. Under the Environmental Public Health Act (EPHA), a part-time ECO working at least 15hr/week is required for construction sites with contract sum of between $10 million and $50 million, whereas a full-time ECO working at least 40hr/week must be engaged by construction sites with contract sum exceeding $50 million.

The main role of a registered ECO is to advise the Occupier of the construction site on what needs to be done, which include advising construction site's Contractors on environmental remediation measures, facilitating compliance with the environmental laws, carrying out site inspections and engagement of stakeholders for environmental lapses, as well as educating workers on maintaining good environmental health standards. NEA has also specified that the role of ECO(s) in general would comprise the following aspects:

- Disease-bearing insects and rodents;
- Proper disposal of construction waste/ marine clay;
- Noise, air and water pollution;
- Earth littering;
- Siltation of drains;
- Food hygiene in on-site canteens (if any);
- Proper maintenance of septic tank(s)/ holding tank(s), chemical/ portable toilet(s) and other sanitary facilities; and
- Any other environmental health matters.

The registered ECO(s) shall be employed by the Occupier of the construction site (the Contractor) but may not be in any way as an associated body of the Contractor, the SO, or the Project's SHE team.

For this Project

As mentioned, both EM and ECO are environmental control officers registered under NEA. In view of the scale and nature of this Project, during construction and commissioning phases, EM shall be the leading role and is expected to have prior experience in EMMP for Projects with biodiversity sensitivity to manage and oversee the overall EMMP implementation and act as the key liaison with agencies and stakeholders on environmental-related matters when necessary; while the ECO can be the same person if possible, else a supporting role officer who is responsible for most of the implementation of EMMP and relevant environmental measures on ground.

Generally, a NEA-registered ECO (applicable for EM and/or ECO of this Project) shall comply with the latest NEA's *Code of Practice for Environmental Control Officers*, where the duties include but not limited to:

- Prepare and submit a Site Environmental Control Programme based on the latest required format in Appendix 2 of the above-mentioned code of practice, within one month after the

commencement of works on the construction site to NEA (after reviewed by the Project Owner LTA) via Form SG;

- Prepare and submit the Site Environmental Control Report(s) based on the latest required format in Appendix 3 of the above-mentioned code of practice, after the commencement of construction works, and at least once a month or any other frequency required by NEA and/or LTA throughout the construction and commissioning phases;
- Identify and attend to all environmental issues, inform the Occupier of the construction site accordingly, and recommend measures to rectify the irregularities;
- Assist the authorities to investigate environmental issues and outbreaks of infectious, vector-borne or food-borne diseases on the construction site; and
- Organise campaigns, training, toolbox briefings and other relevant courses to develop the capability of all relevant workers in implementing EMMP, as well as to raise their environmental and biodiversity awareness in maintaining good environmental performance on site.
- Resources to implement the environmental monitoring program should be allocated time to fulfil the environmental audit/ inspection requirements during construction works. The EM/ECO shall work closely with other EMMP members to ensure environmental compliance of the construction sites, as well as to ensure proper and safe working condition of relevant construction facilities and equipment:
- Oversee and manage the implementation of minimum control measures, mitigation measures and EMMP on site;
- Coordinate with various parties with respective to EMMP, which include:
    - Liaise with the SO and/or WSHO regarding equipment, locations, and schedule of monitoring and auditing works; and
    - Coordinate among the Client, Contractor, and other personnel within the Biodiversity Team for the implementation of the EMMP measures for biodiversity.
- Formulate and implement the environmental monitoring and audit program as required in this document;
- Monitor compliance with conditions in the EMMP, relevant environmental protection, pollution prevention and control regulations and contract specifications;
- Analyse environmental monitoring data and audit findings, review the adequacy of implementation of mitigation measures, identify adverse environmental impacts, and liaise with the SO;
- Carry out weekly site audits/ inspections against the Contractor's site practices, equipment and work methodologies with respect to pollution control and environmental mitigation, and effect proactive actions to pre-empt problems in coordination with the SO;
- Report the results of the environmental monitoring works and audit program, and any required changes to meet the requirements of the EMMP and legal obligations to the SO in a timely manner; and
- Coordinate the investigation of biodiversity-related incidents;
- Provide solutions and address complaints related to environmental incompliances or related incidents, with cooperation from SO and/or WSHO; and
- Compile and submit the updated findings, along with completed remedial actions supported by photographs to LTA fortnightly in the form of an Environmental Performance Report (also known as Environmental Inspection Report).

14.4.6 Arborist

An Arborist certified by the International Society of Arboriculture (ISA) plays an important role as part of the biodiversity monitoring programme during both construction and commissioning phases of this Project. He/She shall possess previous work experience in developments of similar size or complexity who is able to demonstrate capability in monitoring and managing all matters related to the adequate and successful conservation of trees and flora within and adjacent to the contract boundary. A detailed description of biodiversity monitoring programme is provided in Section 14.6, where the key responsibilities of the Arborist are listed as follows:

Construction Phase
The key responsibilities of an ISA-certified Arborist during construction phase include but not limited to:

- Carry out tree mapping and assessment;

- Implement tree protection plans;
- Provide advice on tree transplanting;
- Review Contractor's method statements for site clearance, tree felling and setting up of tree protection zones (TPZ);
- Assess forest edge effects and its associated changes;
- Implement tree maintenance and care; and
- Carry out monthly tree inspection and reporting.

14.4.7 Arboriculture Contractor

The Arboriculture Contractor should meet NParks' safety requirements for work at height and LTA's requirements for temporary works along roadsides. All arboriculture workers engaged by the Arboriculture Contractor to perform tree climbing and chainsaw work shall possess a valid basic tree climbing certification based upon demonstrated competence in the Workforce Skills Qualifications (WSQ) module conducted by Centre for Urban Greenery and Ecology (CUGE) or an equivalent WSQ-approved training organisation. The arboriculture crew deployed by the Arboriculture Contractor for the Contract shall possess the following valid competences:

- Operation of chainsaw for ground work (LS-MT-103E-1);
- Chainsaw safety and maintenance (LS-MT-102E-1);
- Perform formative pruning of young trees (LS-MT-114E-1);
- Provide Arboriculture support on site (LS-MT-116E-1);
- Workplace safety and health – operators (ES-WSH-101G-1);
- Respond to Emergency (LS-HM-208E-1);
- Perform advance rigging and climbing techniques (LS-HM-308S-1);
- Perform aerial tree access and aerial rescue skills (LS-HM-204S-1);
- Implement and apply appropriate risk and safety management to sector practices (LS- BP-301S-1);
- Prepare risk assessment report (LS-HM-406S-1); and
- Operate and work from an elevated work platform (CUGE-ARB-3501).

Construction Phase
The certified Arboriculture Contractor shall be responsible for pruning and maintenance of retained trees, as well as felling of trees during the construction phase of this Project.

14.4.8 Flora Specialist

For this Project, a Flora Specialist plays an important role in the implementation of flora-related EMMP measures (e.g., Flora Management Plans) as part of the biodiversity monitoring program during both construction and commissioning phases of this Project. He/She shall possess previous work experience in developments of similar size or complexity who is able to demonstrate capability in implementing flora management plans. A detailed description of biodiversity monitoring programme is provided in Section 14.6, where the key responsibilities of the Flora Specialist are listed as follows:

Construction Phase
The key responsibilities of a qualified Flora Specialist during construction phase include but not limited to:

- Review soil investigation locations and proposed site access to minimise excessive vegetation removal;
- Identify plant species (e.g., climbers, shrubs, epiphytes, ferns) of value that can be extracted for propagation and harvesting;
- Recommend weed and invasive species management if necessary;
- Review planting palette of reforestation works and ensure that the specifications for planting are met; and
- Carry out monthly flora inspection and reporting.

14.4.9 Ecologist

For this Project, an Ecologist plays an important role in the implementation of fauna-related EMMP measures as part of the biodiversity monitoring program during both construction and commissioning phases of this Project, who can also be known as a Fauna Specialist. He/She shall possess a degree (or equivalent) in ecology-related fields with experience in implementing fauna management plans. In addition, valid certifications of Animal Management Professional Certification Programme (PCP) – Basic Module (CUGE-PCP-7006A)

A detailed description of biodiversity monitoring programme is provided in Section 14.6, where the key responsibilities of the Ecologist are listed as follows:

Construction Phase
The key responsibilities of a qualified Ecologist during construction phase include but not limited to:

- Carry out fauna monitoring surveys including terrestrial transect surveys, aquatic sampling and camera trapping;
- Implement fauna management during site clearance;
- Carry out pre-felling fauna inspections;
- Carry out monthly fauna inspection and reporting;
- Facilitate the implementation of the fauna response plan; and
- Review and ensure impact's magnitude and duration of impact on structural integrity of mud lobster mounds as detailed in Section 11.8.1.1.1.

14.4.10 Wildlife Management Contractor

For this Project, the Wildlife Management Contractor (with at least one veterinary professional with experience within the team) would be responsible in carrying out animal rescue, trapping and transport of large fauna if any human-wildlife conflicts are encountered during construction and commissioning phases on site. The Wildlife Management Contractor shall be listed under NParks' public register of certified Wildlife Management Contractor and have experience carrying out animals rescue, trapping and transport of large fauna.

A detailed description of biodiversity monitoring programme is provided in Section 14.6, where the key responsibilities of the Wildlife Management Contractor are listed as follows:

Construction Phase
The key responsibilities of a qualified Wildlife Management Contractor during construction phase include but not limited to:

- Carry out fauna rescue and translocation in consultation with attending Ecologist and NParks; and
- Propose trapping of fauna in consultation with attending Ecologist and NParks to satisfy Section 10 of the Wildlife Act.

14.4.11 EMMP Auditor

EMMP Auditor will be engaged by LTA independently to conduct regular audit and inspection with regards to implementation of mitigation measures conducted by the Contractor and produce audit/inspection report to LTA.

14.4.12 Public Relation Officer (PRO) for Complaint Handling

The Public Relation Officer (PRO) is responsible for handling complaints and managing feedback and investigative work. The PRO shall be supported by the Project Owner, RTO, SO, EM/ECO, Contractor representatives, and any other relevant parties.

During the construction and commissioning phases, upon receipt of complaints, the PRO should undertake the following procedures:

- Log the complaint and record the date when the complaint is received onto the complaint database and inform the Project Owner, SO, EM/ECO immediately;
- Investigate the complaint with the EM/ECO to determine its validity and assess whether the source of the problem is due to construction works;
- If a complaint is valid and due to construction works, liaise with the EM/ECO on the mitigation measures and seek agreement from SO;
- Review the current situation and the EM/ECO's and SO's implementation of the mitigation measures;
- Engage the EM/ECO to undertake additional monitoring and auditing to verify the complaint if necessary. Ensure that any valid reasons for complaints do not re-occur by revising the work methods, procedures, machines and/or equipment, etc.;
- Submit a complaint report (as well as the implementation of mitigation measures and the effectiveness of the mitigation measures as advised by the EM/ECO) to the Project Owner, RTO and the SO; and
- Log a record of the complaint, investigation, follow-up actions and the results in the environmental audit reports.

The EM/ECO and SO should provide all the necessary information and assistance to the PRO in order to complete the complaint investigation. Following the investigation, the Contractor should promptly undertake the mitigation measures. The PRO and SO should ensure that the measures have been appropriately implemented. The Contractor, RTO, and SO should also be responsible for the reporting of complaint investigation results and followed up actions to the Project Owner. The complaint investigation report and corrective action plan should be prepared and approved by LTA and/or other relevant Authorities within 24 hr upon receipt of complaints.

14.5 Roles and Responsibilities of the EMMP for Operational Phase

This section describes the roles and responsibilities of the EMMP members presented on the organisational chart for operational phase in Section 14.3.

14.5.1 Technical Agencies

Consultation and engagement with the technical agencies (e.g., NParks, PUB, NEA, etc) may be required if there are any major environmental concerns affecting their property, land boundary and/or related to the respective scope of responsibilities, or when inputs from technical agencies are necessary in addressing any major public complaints due to environmental incidents arising from the rail operation (if any) of this Project.

14.5.2 Project Owner (LTA)

The Land Transport Authority (LTA) is a statutory board in Singapore under the Ministry of Transport responsible for public transport in Singapore, which is also the Project owner for this Project.

During the operational phase, under LTA's New Rail Financing Framework (NRFF), LTA owns the rail operating assets (e.g., trains, signalling system) and other associated infrastructure (e.g., viaducts, tunnels, tracks). The role of LTA as the owner involves making decisions on building-up, replacement and upgrading of the rail operating assets and infrastructure, while the licensed rail operator (e.g., SMRT Trains, SBS Transit) is responsible for the operation and maintenance of those assets and infrastructure.

LTA oversees the rail operations and management of the rail operator during the operational phase. In terms of environmental management, the responsibility of LTA includes:

- Regulate the rail operation and maintenance through the stipulated Operating Performance Standard (OPS), Maintenance Performance Standards and ISO14001 Environmental Management System;
- Ensure resources and appropriate personnel are available to achieve the environmental requirements;
- Provide leadership in maintaining overall environmental performance;

- Ensure all environmental incidents and near misses are promptly investigated and reported by the rail operator;
- Resolve any environmental non-compliance issues with the assistance from the rail operator; and
- Record, respond to, and action any complaints from members of the public, if any, with inputs from the Technical agencies, if required, and
- Liaise with the Technical Agencies regarding any relevant issues arising from the environmental incidents, or environmental reporting and submission (if any) by the rail operator.

14.5.3 Rail Operator

As mentioned in Section 14.5.2, the role of rail operator (e.g., SMRT Trains, SBS Transit) is to operate and maintain the rail operating assets and infrastructure of the owner (LTA) which is governed under the NREF regulatory framework.

The responsibilities of rail operator shall include:

- Operate and conduct maintenance by complying with LTA's Operating Performance Standard (OPS), Maintenance Performance Standards and ISO14001 Environmental Management System;
- Allocate sufficient resources and appropriate personnel in maintaining environmental, health and safety of the rail operation;
- Appoint and work with EHS officer or equivalent to ensure environmental, health and safety of rail operations;
- Form an Environmental Management Committee who manage the overall environmental performance and for the decision-making in resolving any environmental-related issues reported by the on-ground rail operators and/or the EHS Officer, which include:
    - Investigate any environmental incidents or near misses identified by the EHS Officer and the on-ground rail operators, and report promptly to LTA;
    - Record, respond to, and take action on any complaints from members of the public, if any, with inputs from the Technical agencies, if required, and
    - Reporting to LTA and relevant Technical Agencies regarding environmental-related issues.

14.5.4 EHS Officer (or Equivalent)

In general, EHS Officer appointed by the rail operator is responsible for the overall environmental, health and safety during the operational phase of the Project. In terms of environmental management, the EHS Officer is required to:

- Conduct regular site inspections to ensure proper housekeeping as well as implementation of the minimum control measures and the proposed mitigation measures for operational phase in this report;
- Identify, record and report promptly any environmental non-compliance issues, incidents and near misses to the Environmental Management Committee; and
- Report the results of the environmental monitoring program, and any required changes, to meet the requirements of the EMMP to the rail operator and/or LTA in a timely manner.

14.5.5 Public Relation Officer (PRO) for Complaint Handling

The Public Relation Officer (PRO) is responsible for handling complaints and managing feedback and investigative work. The PRO shall be supported by the Project Owner, rail operator, EHS Officer and any other relevant parties.

- During the operational phase, upon receipt of complaints, the PRO should undertake the following procedures:
- Log the complaint and record the date when the complaint is received onto the complaint database and inform the rail operator and EHS Officer immediately;

- Investigate the complaint with the rail operator's Environmental Management Committee and EHS Officer to determine its validity and assess whether the source of the problem is due to construction works;
- If a complaint is valid and due to operational works, liaise with the EHS Officer on the mitigation measures and seek agreement from the rail operator's Environmental Management Committee;
    - Review the current situation and the EHS Officer's implementation of the mitigation measures;
    - Engage the EHS Officer to undertake monitoring works for inspection purpose as well as to verify the complaint if necessary. Ensure that any valid reasons for complaints do not re-occur by revising the work methods, procedures, machines and/or equipment, etc.;
    - Submit a complaint report (as well as the implementation of mitigation measures and the effectiveness of the mitigation measures as advised by the EHS Officer) to the rail operator and/or LTA; and
    - Log a record of the complaint, investigation, follow-up actions and the results in the environmental inspection report.

The PRO should work with the rail operator's Environmental Management Committee and EHS Officer to gather all the necessary information and resources necessary to complete a complaint investigation. Following the investigation, the Project/ Operation Manager (who leads the Environmental Management Committee) and EHS Officer shall undertake appropriate mitigation measures. Follow-up is required by the PRO to ensure that the mitigation measures have been appropriately implemented. The complaint investigation report and corrective action plan should be prepared and approved by LTA and/or other relevant Authorities within 24 hr upon receipt of complaints.

14.6 Biodiversity Monitoring Programme Requirement

14.6.1 Construction Phase

At the construction phase, EMMP for both flora and fauna are essential in minimising and managing construction impacts.

14.6.1.1 Flora and Arboriculture Monitoring Programme

The flora and arboriculture monitoring aims to identify impacts arising from the construction to vegetation and habitats, such as tree health, unauthorised and/or excessive vegetation removal, edge effects, habitat degradation from soil erosion, and rubbish dumping. Mitigation measures to address these impacts should be provided where necessary.

Arboriculture and Flora Monitoring Programme should include the following:

- Monitoring of the condition of trees at and around the new development, especially at the potential future infrastructure, to determine the physiological health and structural stability of trees as edge effects can lead to die back of canopies, and branch and structural failures.
- Review of method statements of construction works in proximity to retained trees, if any, to determine if additional tree removal is required post-site clearance.
- Recommendation of solutions such as design changes, reduction of working space, reduction of TPZ area and reassessment of trees in cases of conflict with proposed works.
- Assessment of physiological health, vigour and structural stability of retained trees. Recommend additional mitigating measures if necessary.
- Assessment of the condition of retained trees, if any, to ensure that there has been no deterioration or mechanical damage and to determine if additional tree removal is required.
- Where a tree exhibits signs of stress, the Arborist should inspect the tree and advise on strategies to reduce further impacts and rehabilitation measures. Where monitoring indicates that drying out or edge impacts are occurring, remediation measures shall be undertaken. These measures may be temporary (such as carrying out watering when there is seven continuous days without rainfall). Long-term solutions shall be investigated and implemented.
- Inspection of the integrity of TPZs.
- Identification of excessive or unauthorised tree removal.

Flora Monitoring Programme should include the following works:

- Monthly flora inspections shall be conducted in areas adjacent to the worksite up to 15 m from the hoarding.
- Identification of any unauthorized removal of flora beyond the demarcated development worksite (Figure 14-3).
- Identification of direct/indirect impacts to sensitive vegetation and habitats. Such impacts include soil erosion and degradation that have resulted from construction activities, and unauthorized dumping of waste material, construction debris or oil/chemical leakage.
- Assessment of the status of invasive flora species and weeds and recommendation to remove them where necessary.
- Monitoring of the health of all retained and planted flora, including identification of diseases and recommendations for treatment.

Figure 14-3 Monitoring of vegetation and trees along the hoarding line for unauthorised vegetation clearance and forest edge effects

14.6.1.2 Flora and Arboriculture Management Programme

The flora and arboriculture management programme aims to manage all matters related to the adequate and successful conservation of trees and vegetation within and adjacent to the contract boundary (up to 15-m from the contract boundary).

Arboriculture Management Programme should include the following works:

- Tree Mapping and Assessment
  - Trees to be felled or retained shall be determined by the Arborist.
  - A photographic report shall be provided for the trees affected by the proposed works.
  - No trees shall be felled without prior approval from NParks.
- Tree Protection
  - Where there are trees to be retained within the worksite, specifications shall be formulated by the Arborist for the setting up of tree protection zones (TPZ) to meet NParks requirements (Appendix M).

Sapling Harvesting

- Viable saplings and conservation significant trees that are suitable for harvesting shall be identified by the Arborist. Saplings or trees suitable for transplanting should:
    - Exhibit good physiological health and vigour
    - Have no structural defects
    - Have good branch form
- The root ball size to be extracted shall be based on the girth of the saplings or trees to be harvested as specified in Table 14-1.
- Prior to transplanting, dead branches and climbers shall be cleared from the plant and canopy load and spread will be reduced where necessary, in consultation with the Arborist.
- Manual trenching shall be carried out to determine the shape and size of root ball to be extracted. Where possible, feeder roots shall be retained without cutting.
- The root ball shall be burlapped with cellophane sheet to reduce desiccation effects. When directed by the Flora specialist or Arborist, leaves of the canopy may also need to be enclosed and covered by cellophane or clear plastic bags.
- The root ball shall be secured to the trunk to reduce risk of root ball disintegrating.
- When handling/carrying the plant, care shall be taken not to damage any vegetative parts.

- Tree Transplanting
    - Where trees and vegetation are moved or translocated within the Project area, the Arborist shall review the method statement proposed by the tree transplanting contractor and advise on additional recommendations necessary to ensure the tree's health during transplanting. The transplanting contract shall ensure in their best effort, intact and secured root balls at the point of extraction, during the lifting processes and during the installation at the receiving site. The transplant effort shall be documented for each individual tree to show intact root balls at all the stages mentioned. Transplanted trees shall be managed through adequate watering and monitoring of their health to ensure their long-term survival. Advice shall be sought from the Arborist if the tree exhibit signs of stress, e.g., peeling bark, withered leaves.
- Site Clearance and Tree Felling
    - The Contractor's method statements for site clearance, tree felling and setting up of TPZ shall be reviewed by the Arborist to ensure compliance to the specifications. The site clearance and tree removal method statements shall consider directional felling methods with a hinge and back cut. Trees shall not be removed by pushing with an excavator or other heavy machinery. Cranes shall be deployed to offset the tension of trunks in the direction of the drop. Interlocking canopy branches shall be pruned prior to tree felling.
    - In cases where design changes may affect additional trees or the retained trees, the Arborist shall work with the structural engineers and recommend solutions that will meet NParks guidelines.
    - Whenever reasonable and practicable, cleared vegetation at sloped areas shall be covered with mulch or with 100% biodegradable fauna-friendly ECBs to control erosion of exposed soil. Closed turfing to the exposed areas where possible and maintain proper storage of soil stockpiles to stabilise surfaces and minimise re-entrainment of dust and potential for erosion of waste spoil to watercourses.
    - Clearance activities on-site shall not occur during rainfall or when storm events are forecast to occur within the vicinity to protect forest edge from wind throw. Where forest edges are exposed to wind, temporary measures (e.g., additional hoarding) shall be discussed with the Arborist, and put in place to protect the forest edge during storm events.
    - During site clearance, care will be taken when removing trees in riparian zones to reduce impacts to the bed and banks of waterways.

- Where practicable, saplings, seeds and seed banks will be retained within the soil profiles for use in forest restoration.
- Horticultural waste shall be removed on the same day. This is essential to reduce risk of fauna taking refuge within the cleared waste if left overnight.

- Tree Maintenance and Care
  - Where disease outbreaks are identified, the Arborist and/or Flora Specialist shall advise measures to manage them. Measures can include using selected insecticides/fungicides to control outbreaks; reduction of stressors (dust, water, etc.). The plant may be removed or quarantined if it poses a threat to surrounding individuals.
  - Where forest edges are exposed following site clearance and where impacts to vegetation are evident (e.g., vegetation shows signs of drying out), additional watering shall be carried out to improve moisture differentials around forest edges.
  - The use of herbicides, pesticide shall be minimised. If herbicides or pesticides are used within the Project area, techniques that limit spray or non-target spray drift shall be used. These techniques include but are not limited to cut and paint techniques and drilling injection. All use of herbicides and pesticides shall be conducted in accordance with the relevant Material Safety Data Sheet (MSDS). Any incidents of off label use, spillage or damage to non-target species shall be reported and investigated.
  - When the site experiences seven continuous days without rainfall, the Contractor shall carry out additional watering of conserved trees within the TPZs and at the forest edge (up to 10 m) around the development boundary.
  - Post heavy rainfall, any snapped hanging branches that pose imminent hazards to workers within the site should be removed immediately

Table 14-1 Minimum root ball diameter to girth requirements

Girth (m)	Minimum root ball diameter to extract (m)
<0.1	0.4
0.1–0.2	0.6
0.2–0.3	0.8
0.3–0.4	1.2
0.4–0.5	1.5
>0.5	To be determined by Arborist

Flora Management Programme should include the following works:

- Verification and Review of Footprints for Hoarding, Access Roads and Soil Investigation Works
  - After the worksite hoarding has been installed, the Flora Specialist shall conduct and inspection to verify that the footprint is as proposed, and that no excessive vegetation and tree removal has occurred because of deviations in the hoarding alignment.
  - The Flora Specialist shall review the proposed locations for the soil investigation works and the alignment of the construction access roads with the Client/Contractor. Feasible alternatives, if possible, shall be proposed to minimise vegetation and tree clearance.

- Weed and Invasive Species Management
  - Weeds and invasive species shall be cleared from the Project Site progressively and shall be separated and transported to an appropriate disposal location. Transport shall occur within a covered vehicle to ensure seed/vegetative matter does not dislodge. All vegetative matter and seeds will be rendered inert at the disposal location through incineration at a licensed waste disposal facility. The Project Site shall be carefully cleared of all remaining vegetative matter from the weeds/invasive species. Herbicides may be used to render any stumps/root systems inert. The cleared area shall be inspected monthly to detect any seedlings of invasive species. These seedlings shall be killed using approved herbicides or removed by hand weeding. Any

seedlings or vegetative matter that may sprout will be disposed of at a licensed waste management facility.

- Specific measures shall be undertaken to control and manage flora species within the Project area that have been identified to be invasive (i.e., *Spathodea campanulata, Cecropia pachystachya, Falcataria moluccana*). The Ecologist shall be consulted when managing *Falcataria moluccana* groves as tall trees may serve as nesting sites for birds of prey. The Ecologist shall also be consulted for other weed and invasive species that may also provide important foraging resources. Material imported into the Project area shall be checked for contamination from weeds/invasive species seeds/vegetative matter at source. This is particularly important for imported building materials, such as clay and soil. Source site shall be inspected to determine presence of weeds/invasive species. Where weeds or invasive species are identified, alternative supply sources or decontamination shall occur before the material is transported to site.

- Infill Planting Palette and Plant Salvaging for Reforestation and Landscaping
  - The planting palette including all flora and grasses used for reforestation and other landscape planting shall be from native indigenous stock or non-native species that are not listed as weeds or invasive species or have a low seeding rate.
  - All trees transplanted into the Project area shall have local provenance or will be from within the Johor region for all SRDB and IUCN listed species. Other species shall be obtained within the larger Sunda region. Due diligence shall be conducted on suppliers to ensure that the trees are obtained by legal means and are able to be exported/imported to Singapore. All imported trees shall be inspected and/or undergo quarantine if required to reduce the chance of transmission of weeds and soil pathogens.
  - The success of planting within landscape features shall be monitored. Where a planting strategy is not working, an alternative planting strategy shall be developed suitable for the location. Temporary measures shall be employed to reduce stress on planted individuals. The removal of sources of stress (such as dust) may also be required. If disease outbreaks are present, methods shall be used to control the outbreak or remove the diseased individual.
  - The flora specialist shall also identify other plant material, including ferns, epiphytes, orchids, shrubs, grasses, etc. that are of conservation value and work with NParks for the extraction of these plants by NParks to other sites.
  - The flora specialist shall formulate a salvaging protocol in consultation with NParks if salvaging of plant material is being carried out on site.

The flora specialists, arborists and the arboriculture contractor engaged should meet the expected qualifications as described in Section 14.4. Additionally, the Contractor should fulfil the following:

- The Contractor and the attending arborist shall complete the 'Verification of Tree Protection Checklist' prior to the start of site clearance (refer to Appendix M); and
- The Contractor shall instil discipline and raise awareness amongst all personnel on measures and mitigations to prevent damage to retained and protected trees throughout construction by including reminders on tree conservation guidelines within their daily toolbox briefings to workers and crane/excavator operators.

14.6.1.3 Fauna Management Programme

Fauna management will consist of managing fauna within and around all designated work areas. It consists of (1) monthly site inspections, (2) pre-site clearance inspections, (3) biodiversity awareness training, and (4) fauna response plan in event of animal encounters. The objectives of fauna management are to (1) minimise negative impacts to fauna, particularly to species of conservation significance and (2) prevent human wildlife conflicts.

The following should be inspected for during monthly fauna site inspections (Figure 14-4):

- Visual inspection of sensitive habitats in the vicinity (e.g., Sungei Pang Sua and mangrove) to determine if the construction has damaged or affected them
- Presence of trapped/injured/dead fauna
- Potential fauna entrapments (e.g., ECBs, TPZs, pits, drains, ponds, trenches, tanks)
- Gaps in hoarding that may allow entry of ground-dwelling fauna
- Improperly disposed/stored food and food packaging
- Degradation of adjacent sensitive habitats (e.g., streams, forest)
- Reporting and documentation of all findings and recommendations (Appendix N)

Figure 14-4 Photographs showing monthly fauna monitoring and inspection on-site

Pre-site Clearance Fauna Inspection

Pre-site clearance involves pre-felling inspections. This is to minimize fauna injury and mortality during tree felling and vegetation clearance. Site clearance should be executed outside of the key bird breeding season (March to July) where possible. Refer to Figure 14-5 for pre-felling inspection protocol, and Appendix O for Pre-felling Inspection Form.

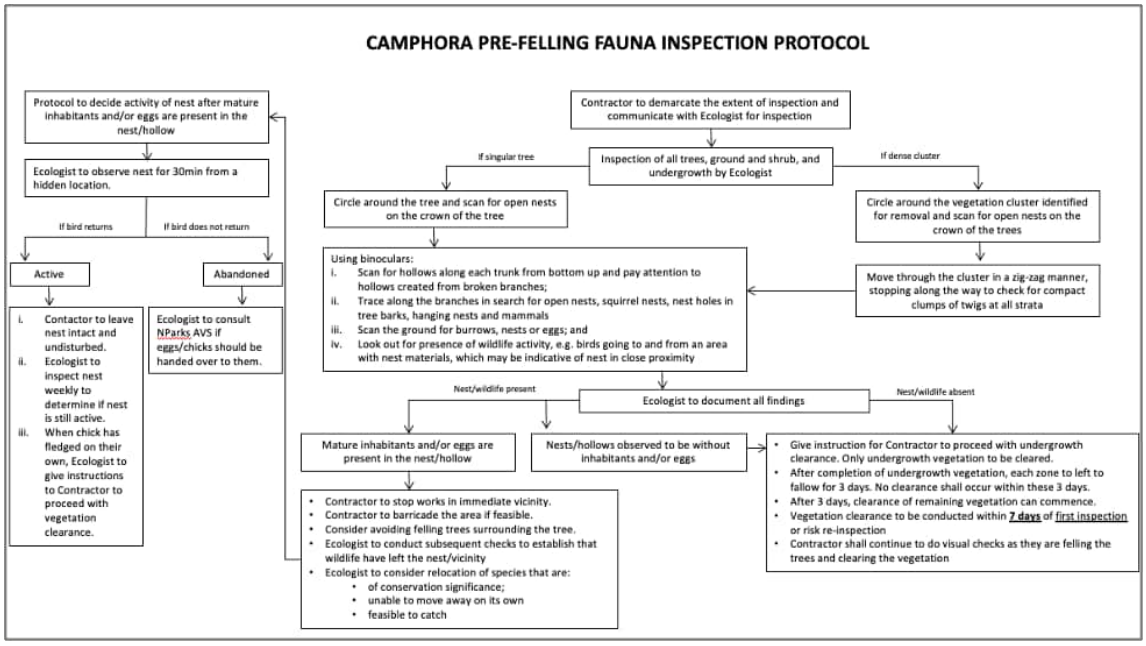


Figure 14-5 Example of pre-felling inspection protocol

Biodiversity Awareness Training

The Ecologist shall conduct toolbox briefings on biodiversity awareness to inform site personnel of but not limited to the following:

- Ecological value of the site and its surrounding habitats
- Types of fauna present
- Biodiversity protection strategies
- Site personnel's responsibilities towards biodiversity
- How to respond to fauna encounters
- No feeding of wildlife
- Prevention of roadkills
- Inspection of trees before felling
- All site personnel shall undergo biodiversity awareness training prior to commencing work at on-site, and regularly (every six months) throughout the duration of the construction. Documentation of such trainings and briefings shall be maintained.

Wildlife Response Plan

The Wildlife Response Plan should be formulated by an Ecologist and enacted when a trapped/injured/dead/dangerous animal is encountered around or within the worksite. The objective of the wildlife response plan is to minimise animal injury and mortality by responding appropriately to the different scenarios in Figure 14-7. The plan should also detail the chain of command, personnel involved, and the roles of the various stakeholders. This should be emphasized during the toolbox briefings. All wildlife encounters are to be documented within 24 h using the Wildlife Incident Form (Appendix P).

Where fauna is trapped on-site, options should be explored to remove them from site (e.g., partitioning worksite, use of one-way exit door) (Figure 14-6).

In scenarios where certain animal groups are encountered around or within the worksite, external specialists may be contacted to handle the animal. These scenarios are shown below:

- For encounters with snakes that require relocation/handling, a snake specialist should be contacted.
- For animal carcasses that require disposal, an animal carcass disposal service should be contacted.

- For injured animals that require medical attention, a veterinarian should be contacted.

Figure 14-6 Example of one-way flap door to allow fauna to exit independently

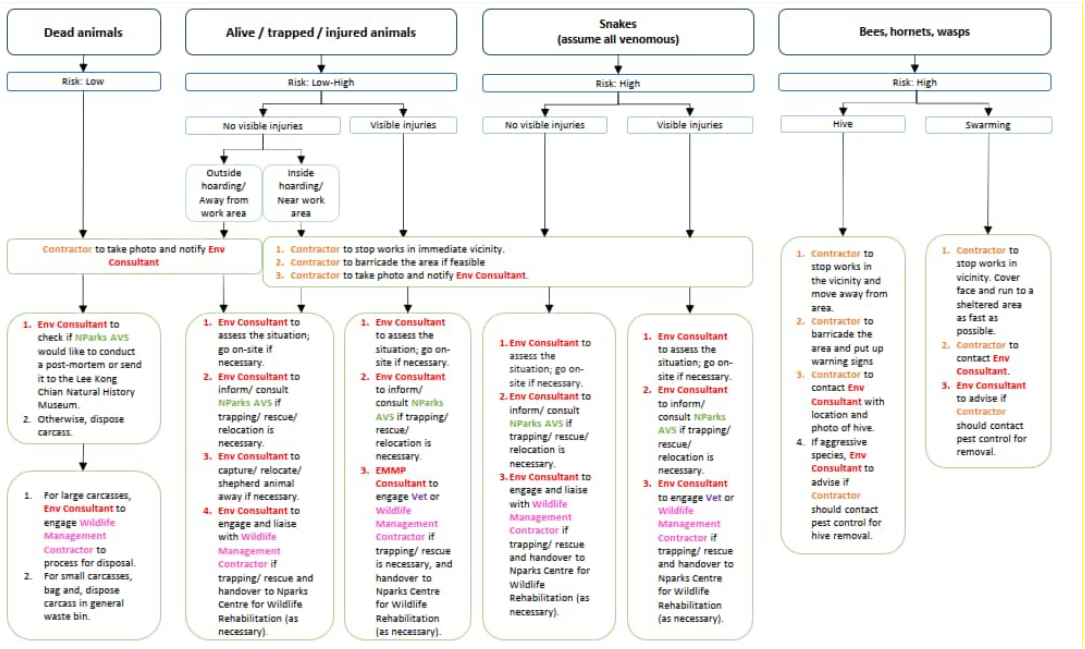


Figure 14-7 A flow chart of wildlife response plan

14.6.2 Commissioning Phase

During the commission phase, habitat and tree monitoring is recommended in the first three months to observe possible impacts of the potential future infrastructure at Sungei Pang Sua mangrove, especially for the *Sonneratia caseolaris* cluster.

14.7 Hydrology and Surface Water Monitoring Programme Requirement

14.7.1 Construction Phase

14.7.1.1 Monitoring Before Commencement of Site Clearance

One (1) time monitoring for hydrology and surface water quality should be conducted before the construction commencement as a baseline reference for the EMMP.

Prior construction, the hydrological conditions of drainage system within construction worksite and at immediate vicinity should be monitored and inspected especially during heavy storm event to ensure no flooding. For surface water quality, the baseline monitoring parameters should follow Table 14-3. All the discharge points from construction worksites should follow NEA's Allowable Limits for Trade Effluent Discharge to Watercourse/Controlled Watercourse and should not contain Total Suspended Solids (TSS) in concentrations greater than the prescribed limits under Regulation 4(1) of the Sewerage and Drainage (Surface Water Drainage) Regulations [R-5]. Meanwhile, the water quality of sensitive watercourses (i.e., Sungei Pang Sua and Pang Sua Canal), should also be recorded and compared with the water quality criteria for aquatic life as listed in Table 14-2 to make sure the aquatic condition will not be impacted by the construction activities.

Table 14-2 Water Quality Guidelines and Criteria

Parameter	NEA Trade Effluent Discharge Limits[1]		International Aquatic Life Criteria[2]
	W	CW	
pH	6 - 9		6 – 9*
Temperature (°C)	≤ 45		< 2°C above the maximum ambient temperature
Dissolved Oxygen, DO (mg/L)	-		≥ 4 ≥ 5 (freshwater)*
Turbidity (NTU)	-		≤ 50
Salinity (psu)	-		-
Conductivity (µS/cm)	-		-
Total Dissolved Solids, TDS (mg/L)	-	≤ 1,000	≤ 1,000
Biochemical Oxygen Demand, BOD_5 (mg/L)	≤ 50	≤ 20	≤ 3 ≤ 5 (freshwater)*
Chemical Oxygen Demand, COD (mg/L)	≤ 100	≤ 60	≤ 25 ≤ 30 (freshwater)*
Total Organic Carbon, TOC (mg/L)	-		-
Total Suspended Solids, TSS (mg/L)	≤ 50	≤ 30	≤ 10 % increase over seasonal average ≤ 50 (freshwater)*
Oil & Grease (Total) (mg/L)	≤ 10	≤ 1	≤ 0.14
Total Phosphorous, TP (mg/L)	-		Eutrophic limit: 0.075 mg/L
Orthophosphate, PO_4-P (mg/L)	≤ 1.63 (equivalent to 5 as PO_4)	≤ 0.65 (equivalent to 2 as PO_4)	≤ 0.015
Total Nitrogen, TN (mg/L)	-		Eutrophic Limit: 1.5 mg/L
Ammoniacal Nitrogen, NH_4-N (mg/L)	-		≤ 0.07 ≤ 0.3 (freshwater)*
Nitrate, NO_3-N (mg/L)	-	≤ 4.52 (equivalent to 20 as NO3)	≤ 0.06
Enterococcus[3] (CFU/100 mL)	-		≤ 35
Chloride, Cl (mg/L)	-	≤ 250	-
Cyanide, CN (mg/L)	≤ 0.1		≤ 0.007
Calcium, Ca (mg/L)	-	≤ 150	-
Chlorophyll-a (µg/L)	-		-
Arsenic (µg/L)	≤ 100	≤ 10	-
Barium (µg/L)	≤ 2,000	≤ 1,000	-
Cadmium, Cd (µg/L)	≤ 100	≤ 3	≤ 10
Chromium, Cr (µg/L)	≤ 1,000	≤ 50	-
Lead, Pb (µg/L)	≤ 100		Acute LOEL[4]: 82 Chronic LOEL[4]: 3.2
Iron, Fe (µg/L)	≤ 10,000	≤ 1,000	-

Parameter	NEA Trade Effluent Discharge Limits[1]		International Aquatic Life Criteria[2]
	W	CW	
Zinc, Zn (µg/L)	≤ 1,000	≤ 500	-
Nickel, Ni (µg/L)	≤ 1,000	≤ 100	-
Copper, Cu (µg/L)	≤ 100		≤ 8.0
Mercury, Hg (µg/L)	≤ 50	≤ 1	≤ 0.16
Phenol (mg/L)	≤ 0.2	-	≤ 0.12

Notes:

- **NEA Trade Effluent Discharge Limits are for watercourse (W) and controlled watercourse (CW)**
- **The sources of water quality criteria for aquatic life include ASEAN Guidelines [R-17 & R-72], United Nations Economic Commission for Europe [R-9], World Health Organization [R-10], United States Environmental Protection Agency [R-11], Australian & New Zealand [R-12], Canada [R-13], Philippines [R-14], and Malaysia [R-16]**
- **Singapore's Water Quality Guidelines for Recreational Beaches and Fresh Water Bodies requires that the *Enterococcus* count should be less than or equal to 200 counts per 100 millilitres of water at 95% of the time**
- **LOEL – Lowest Observed Effect Level**

***Referenced from limits under Class I: Potable Water of ASEAN Strategic Plan of Action on Water Resources Management [R-72].**

14.7.1.2 Monitoring Throughout Construction Period

In order to ensure that procedures are followed appropriately, the construction phase of the Project should be accompanied by an EMMP.

Water quality monitoring is essential as discharge of excess contaminants, especially pH, nutrients and heavy metals, may lead to severe consequences (e.g., algae blooms). Discharges from the construction worksites to nearby watercourses will take place, therefore discharge monitoring on the ponds and tanks within the worksites was recommended to be undertaken to complement surface water quality to assure compliance with the relevant standards. In addition, due to the sensitive watercourses such as Sungei Pang Sua and Pang Sua Canal, it was also recommended to monitor the water quality throughout the construction period to ensure minor construction impacts on the water quality. For all discharge points from construction worksites, it is recommended to monitor water quality following Singapore NEA's Allowable Limits for Trade Effluent Discharge to Watercourse/Controlled Watercourse. Meanwhile, the water quality of sensitive natural streams should also be recorded and compared with the water quality criteria for aquatic life as listed in Table 14-3 to make sure the aquatic condition will not be impacted by the construction activities.

Table 14-3 Recommended Monitoring Program during Construction Phase (Surface Water Quality)

Test	Parameters	Monitoring Recommendation and Frequency
In-situ	Temperature pH Conductivity Total Dissolved Solids (TDS) Turbidity and Total Suspended Solids (TSS) Dissolved Oxygen (DO)	• Online real-time monitoring for Turbidity and TSS at the discharge point location at all the construction sites throughout the construction period • Monthly one-time monitoring for temperature, pH, conductivity, TDS and DO at all the discharge point locations at the construction sites throughout out the construction period • Monthly one-time monitoring for all the in-situ parameters at Sungei Pang Sua and Pang Sua Canal throughout the construction period
Ex-situ	Biochemical Oxygen Demand (BOD_5)	• Monthly one-time monitoring for all the ex-situ parameters at the discharge point

Test	Parameters	Monitoring Recommendation and Frequency
	Chemical Oxygen Demand (COD)	if discharging into public drains during the construction period • Monthly one-time monitoring for all the ex-situ parameters at Sungei Pang Sua and Pang Sua Canal throughout the construction period
	Total Nitrogen (TN)	
	Nitrate (NO_3-N)	
	Ammoniacal Nitrogen (NH_4-N)	
	Total Alkalinity	
	Total Organic Carbon (TOC)	
	Total Phosphorus (TP)	
	Orthophosphate (PO_4-P)	
	Oil & Grease (Total)	
	Oil & Grease (Hydrocarbon)	
	Lead (Pb)	
	Zinc (Zn)	
	Mercury (Hg)	
	Detergents	
	Enterococcus	
Note: In addition to the above monitoring list, Contractor is to ensure that the discharge also complies to NEA's allowable limit for trade effluent discharge - in particular the limits for heavy metals (e.g., through monthly testing)		

Beside the water quality monitoring, hydrological conditions of drainage system within construction site and at immediate vicinity should also be closely monitored during construction phase. Before draining to public drains or watercourses, surface runoff from the construction site should be drained to the treatment system to be filtered and to reduce peak runoff based on ECM Guidebook. The hoarding and perimeter drains of construction site should be inspected daily to ensure no surface runoff flowing out from the site untreated and no clogging which would affect the flow capacity of the drains/streams. During heavy storm event, site inspection should be carried out to ensure no flooding. Monthly audit on the site should also be carried out by EMMP consultant.

14.7.2 Operational Phase

The operational phase of the Project should be accompanied by an EMMP to ensure the proposed development will have minor impact on the surrounding watercourses. Water quality monitoring is essential as discharge of excess contaminants, especially pH and suspended solids may lead to severe consequences (e.g., water with less clearance) due to the operational activities. Hence, due to the sensitive watercourses of Sungei Pang Sua and Pang Sua Canal, it was recommended to monitor the water quality during the first three (3) months of operational phase to ensure minor impacts on their water quality. For main outlets/drains (if any) of the Project site, it is recommended to monitor water quality following Singapore NEA's Allowable Limits for Trade Effluent Discharge to Watercourse/Controlled Watercourse. Meanwhile, the water quality of Sungei Pang Sua should also be recorded and compared with the water quality criteria for aquatic life as listed in Table 14-4 to make sure the aquatic condition will not be impact by the operational activities.

Table 14-4 Recommended Monitoring Program during Operational Phase (Surface Water Quality)

Test	Parameters	Monitoring Recommendation and Frequency
In-situ	Temperature	Monthly one-time monitoring for all the in-situ parameters at the main outlets/drains (if any) of the Project site, as well as sensitive watercourses (i.e., Sungei Pang Sua and Pang Sua Canal) during the first three (3) months of operational phase.
	pH	
	Conductivity	
	Total Dissolved Solids (TDS)	
	Turbidity and Total Suspended Solids (TSS)	
	Dissolved Oxygen (DO)	
Ex-situ	Biochemical Oxygen Demand (BOD_5)	Monthly one-time monitoring for all the ex-situ parameters at the main outlets/drains (if any) of the Project site,
	Chemical Oxygen Demand (COD)	
	Total Nitrogen (TN)	

Test	Parameters	Monitoring Recommendation and Frequency
	Nitrate (NO_3-N)	as well as sensitive watercourses (i.e., Sungei Pang Sua and Pang Sua Canal) during the first three (3) months of operational phase.
	Ammoniacal Nitrogen (NH_4-N)	
	Total Alkalinity	
	Total Organic Carbon (TOC)	
	Total Phosphorus (TP)	
	Orthophosphate (PO_4-P)	
	Enterococcus	

For the hydrology monitoring during operational phase, drainage system within the site and at immediate vicinity should be inspected especially during heavy storm event to ensure no flooding. Monthly audit on the site should be carried out by an EMMP consultant during the first three (3) months of operational phase.

14.8 Air Quality Monitoring Programme Requirement

14.8.1 Construction Phase

As noted in the mitigation measures (Section 9.8.1), dust monitoring will be undertaken during the construction phase. Dust deposition monitoring is recommended due to the potential of High consequence dust impact conducted within the ecological sensitive receptors and also a few human receptors during construction phase. Based on a review of sensitive receptors around the construction worksite areas, a continuous monitoring program as per Table 14-5 is proposed to be conducted during project construction. The Contractor is also 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 around the Project area.

Table 14-5 Recommended Monitoring Program during Construction Phase (Air Quality)

Location	Parameters	Frequency and Duration	Triggers
• **Rail corridor near Intermediate Station worksite** • **Sungei Pang Sua near worksite for potential future infrastructure** • **HDB Blk Senja Road near Docking Shaft worksite**	PM_{10} and $PM_{2.5}$	Continuous monitoring of PM_{10} and $PM_{2.5}$ for 1 week prior to site clearance averaged over 1-day period	-
• **Rail corridor near Intermediate Station worksite** • **Sungei Pang Sua near worksite for potential future infrastructure**	Dust Deposition in $mg/m^2/day$	Continuous monitoring of dust deposition during construction phase averaged over 4-week period	Investigation and corrective actions to be taken, when • Any of the following documentation are found inadequate / missing: Air Pollution Control Plan; Compliance certificate of an Off-Road Diesel engine; or Monitoring Log. • If the monitored PM_{10} and $PM_{2.5}$ exceed Singapore long term air quality targets. • If the dust deposition monitored exceeds 200
• **HDB Blk Senja Road near Docking Shaft worksite**	PM_{10} and $PM_{2.5}$	Continuous monitoring during site clearance and earthworks phase	

Location	Parameters	Frequency and Duration	Triggers
			mg/m^2/day averaged over 4-week • If complaints are received due to project activities. • If visual non-compliance to any of the minimum control or mitigation measures are observed on-site.

Legend

- EMMP Air Monitoring Locations
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Proposed Worksite Areas
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicle Bridge
- Proposed DTL2e Stations (Underground)
- Proposed NSL Elevated Station
- Biodiversity Study Area
- Existing Vegetated Area
- Pang Sua Canal
- Sungei Pang Sua

Rev.	Date	By	Description	Chk'd	App'd
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
-	AUG 2022	TTR	Draft Final Report	HHL	JAG

Qualified Person Endorsement : N/A

LTA Endorsement : N/A

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
CONTRACT 9175 ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
PROPOSED EMMP AIR MONITORING LOCATIONS

Designed	Checked	Approved
TTR	HHL	JAG
	Drawn TTR	Date MAY 2023

Figure No. : 14-8 | Rev. : A | Sheet : 1 of 1

CAD File Name :N/A | A3

Note: Source of basemap - OneMap

14.8.2 Operational Phase

During operational phase, ambient air quality monitoring may not be required. General housekeeping and environmental management measures will be applied.

14.9 Airborne Noise Monitoring Programme Requirement

14.9.1 Construction Phase

Based on a review of the noise sensitive receptors around the Project site, a continuous monitoring programme as per Table 14-6 is proposed to be conducted during the construction phase.

Table 14-6 Recommended airborne noise monitoring programme during construction phase

No.	Location	Parameters	Frequency and Duration
1	Vicinity of Nexxis Asia Pte. Ltd., Sungei Kadut Street 3	$L_{Aeq(12\ hours)}$, $L_{Aeq(1\ hour)}$, $L_{Aeq(5\ mins)}$	Pre-construction baseline and continuous monitoring for the entire duration of the construction phase of the aforementioned parameters at all locations.
2	JTC Lot No. MK11-00541K near The Stone Gallery by Hafary, Sungei Kadut Central		
3	Vicinity of JSM Construction Group Pte Ltd facing Woodlands Road		
4	Vicinity of HDB Block 691B facing Pang Sua Canal		
5	Vicinity of commercial buildings such as Chong Timber Pte Ltd, along Rail Corridor		
6	Along Rail Corridor on side opposite and facing Windermere Residences		
7	HDB Block 632A Senja Road		
8	Near Teck Whye Secondary School, facing the Pang Sua Canal		
9	Along Rail Corridor near Sungei Kadut Avenue		

14.9.2 Operational Phase

During operational phase, airborne noise monitoring and audit is not required. General housekeeping and environmental management measures shall be applied.

In general, the Rail Operator shall ensure the implementation of minimum control measures according to the relevant legislations (i.e., the NEA ACMV Guideline, 2018 [R-26], and TNIA Guideline, 2016 [R-25]), as well as the proposed mitigation measures where the key ones are summarised in Section 10.8.2.

If there are any noise monitoring works to be carried out during operational phase in future, the same no worse-off than baseline noise criteria (see Section 10.5.3.2) shall be complied.

14.10 Ground-borne Vibration Programme Requirement

A summary of the recommended EMMP requirements for ground-borne vibration during the construction, commissioning and operational phase for the construction phase is provided in the table below.

14.10.1 Construction Phase

14.10.1.1 EMMP for Structural Integrity of Burrows and Mud Lobster Mounds

The Contractor shall control construction vibration levels using the best available techniques (BAT). The construction activities include rock breaking and excavation, and tunnel boring. The Contractor shall ensure that the vibration levels for any construction activities along the Rail Corridor (excluding the worksite area) do not exceed PPV 8.0 mm/s. Barriers using GI pipes and canvas sheets shall be set up to prevent road kills.

Additionally, an Ecologist and Environmental Officer shall be present to survey burrows and mud lobster mounds before any construction activities. Camera traps should be deployed to assess any fauna activity if they are detected within the Biodiversity Study Areas. Construction works are allowed to be continued if no burrows, mud lobster mounds, or fauna activity is detected.

The adaptive monitoring programme is proposed for tunnel boring. A qualified Ecologist shall observe the reaction and suggest ways to further mitigate on-site based on observations causing the impact. The inspection shall be carried out on site once (1) every fourteen (14) days.

Table 14-7 Recommended Monitoring Program during Construction Phase (Ground-borne Vibration for Structural Integrity of Burrows and Mud Lobster Mounds)

Construction Worksite and Activities	Recommended Monitoring Program
Rock Breaking and Excavation	• Contractor shall ensure that the vibration levels for any construction activities along the Rail Corridor (excluding the worksite area) do not exceed PPV 8.0 mm/s. • Set up barriers using GI pipes and canvas sheets to prevent road kills • The Ecologist shall be present to survey burrows and mud lobster mounds before any construction activities. Camera traps may be deployed if required to confirm fauna activity in the event they are detected within the Biodiversity Study Area. Construction works are allowed to be continued if no burrows, mud lobster mounds, or fauna activity is detected.
Rotary Bore Piling	• Contractor shall ensure that the vibration levels for any construction activities along the Rail Corridor (excluding the worksite area) do not exceed PPV 8.0 mm/s. • Set up barriers using GI pipes and canvas sheets to prevent road kills • The Ecologist shall be present to survey burrows and mud lobster mounds before any construction activities. Camera traps may be deployed if required to confirm fauna activity in the event they are detected within the Biodiversity Study Area. Construction works are allowed to be continued if no burrows, mud lobster mounds, or fauna activity is detected.
Tunnel Boring Machine	• Contractor shall ensure that the vibration levels for any construction activities along the Rail Corridor (excluding the worksite area) do not exceed PPV 8.0 mm/s. • The Ecologist shall be present to survey burrows and mud lobster mounds before any construction activities. Camera traps may be deployed if required to confirm fauna activity in the event they are detected within the Biodiversity Study Area. Construction works are allowed to be continued if no burrows, mud lobster mounds, or fauna activity is detected. • During Tunnel Boring, the Ecologist and ECO shall monitor for the collapse of specific burrow/mound that is confirmed to be used by a fauna and suggest ways to further mitigate on-site based on observations causing the impact. This is to be included in the daily checks by the ECO and monthly inspection by the Ecologist.

14.10.1.2 EMMP for Behavioural Impacts of Ecologically Sensitive Species

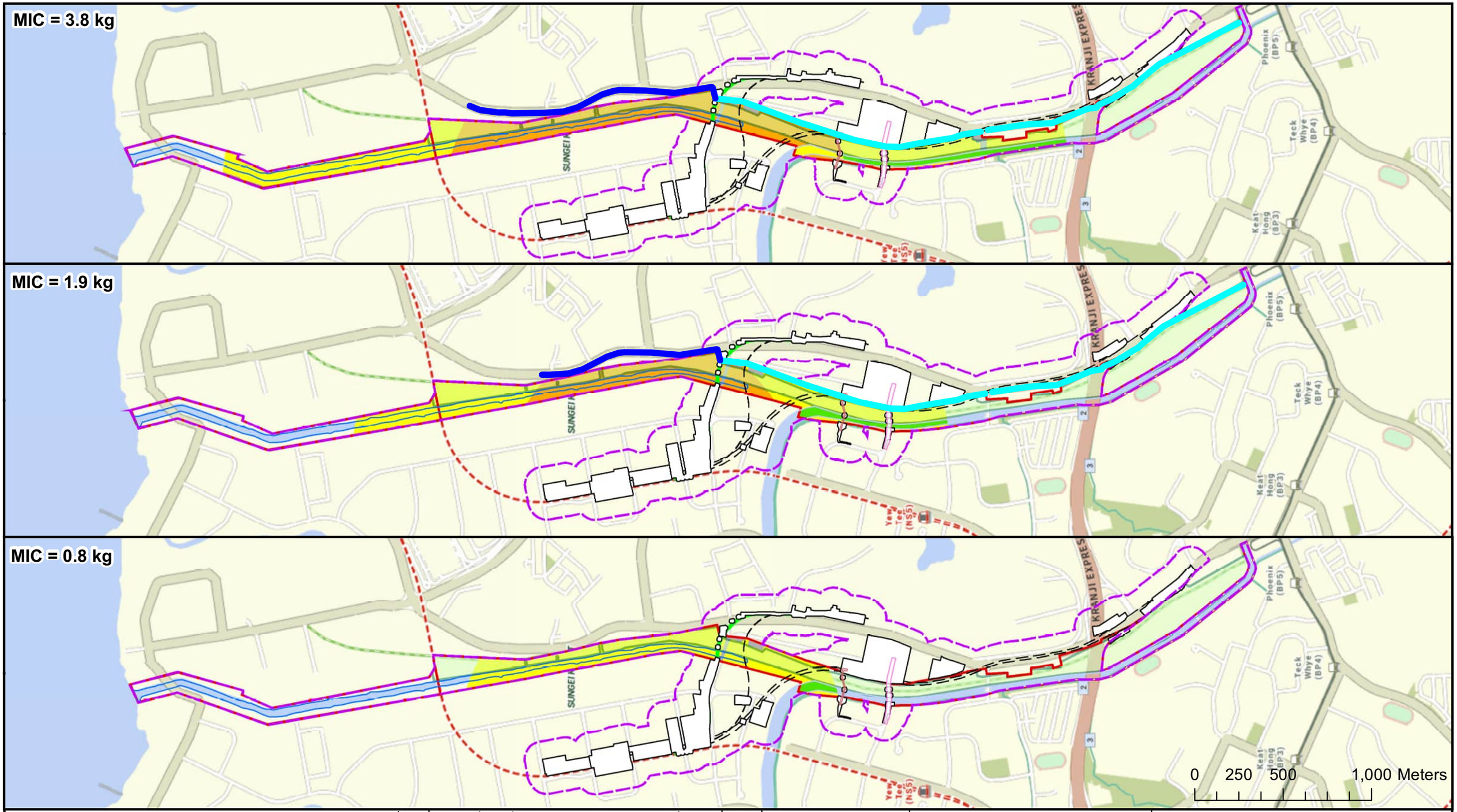
During rock breaking and excavation for the docking shaft and Sungei Kadut Station, Ecologist shall monitor for any fauna behaviour for at least thirty (30) minutes after the event. In addition, during these construction activities, Ecologists will be present to observe fauna movements. Suppose fauna is seen trying to dash onto the road. In that case, construction activities will be immediately suspended, and mitigation measures (e.g., setting up barriers using GI pipes and canvas sheets) should be applied to prevent such events from happening in the future. If there are industrial estates and/or E63 drain abutting the Rail Corridor, there is no need for barriers along the road's external perimeter, as roadkill risks are low. Canvas sheets must be used to cover existing fences to prevent fauna from passing through. Along the road at Sungei Kadut Avenue, no barriers are required to maintain connectivity for fauna. However, to address the concerns about roadkill along this road, speed bumps can be considered to minimize the chances of roadkill. The extent of existing and proposed barriers based on different scenarios (i.e., MIC 3.8 kg, 1.9 kg and 0.8 kg) of rock breaking and excavation at Sungei Kadut Station are shown in Figure 14-9.

The adaptive monitoring programme is proposed for tunnel boring. A qualified Ecologist shall observe the reaction and suggest ways to further mitigate on site based on observations causing the impact. The inspection shall be carried out on site once (1) every fourteen (14) days.

Lastly, no night work should be conducted after 7 pm for all non-safety critical activities since the site is next to the sensitive receptors.

Table 14-8 Recommended Monitoring Program during Construction Phase (Ground-borne Vibration for Ecologically Sensitive Species)

Construction Worksite and Activities	Recommended Monitoring Program
Rock Breaking and Excavation	• Set up barriers using GI pipes and canvas sheets to prevent road kills. • EM/ECO shall monitor for any fauna behaviour at the GI pipes and canvas sheets barrier for at least thirty (30) minutes after the event. If any animal found dashing into the barriers, Wildlife Response Plan will be activated.
Rotary Bore Piling	• Set up barriers using GI pipes and canvas sheets to prevent road kills. • EM/ECO shall monitor for any fauna behaviour at the GI pipes and canvas sheets barrier for at least thirty (30) minutes after the event. If any animal found dashing into the barriers, Wildlife Response Plan will be activated.
Tunnel Boring Machine	• The Ecologist shall be present to survey burrows and mud lobster mounds before any construction activities. Camera traps may be deployed if required to confirm fauna activity in the event they are detected within the Biodiversity Study Area. Construction works are allowed to be continued if noS burrows, mud lobster mounds, or fauna activity is detected. • EM/ECO shall monitor for any fauna behaviour at the GI pipes and canvas sheets barrier for at least thirty (30) minutes after the event. If any animal found dashing into the barriers, Wildlife Response Plan will be activated. • During Tunnel Boring, the Ecologist and ECO shall monitor for the collapse of specific burrow/mound that is confirmed to be used by a fauna and suggest ways to further mitigate on-site based on observations causing the impact. This is to be included in the daily checks by the ECO and monthly inspection by the Ecologist.



Legend

- Vibration Study Area
- Proposed Pedestrian Overhead Bridge
- Proposed Vehicular Bridge
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Impact Significance

- Negligible
- Minor
- Moderate
- Major
- Not Assessible

Barriers

- Existing Barriers
- Proposed New Barriers

N

Rev.	Date	By	Description	Chk'd	App'd
A	MAY 2023	TTR	Draft Final Report	HHL	JAG

Qualified Person Endorsement :
N/A

LTA Endorsement :
N/A

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :
CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
PROPOSED BARRIERS FOR ECOLOGICAL RECEPTORS

Designed	Checked	Approved
TTR	HHL	JAG
	Drawn TTR	Date MAY 2023

Figure No. : 14 - 9 | Rev. : A | Sheet : 1 of 1

CAD File Name :N/A | A3

Note: Source of basemap - OneMap

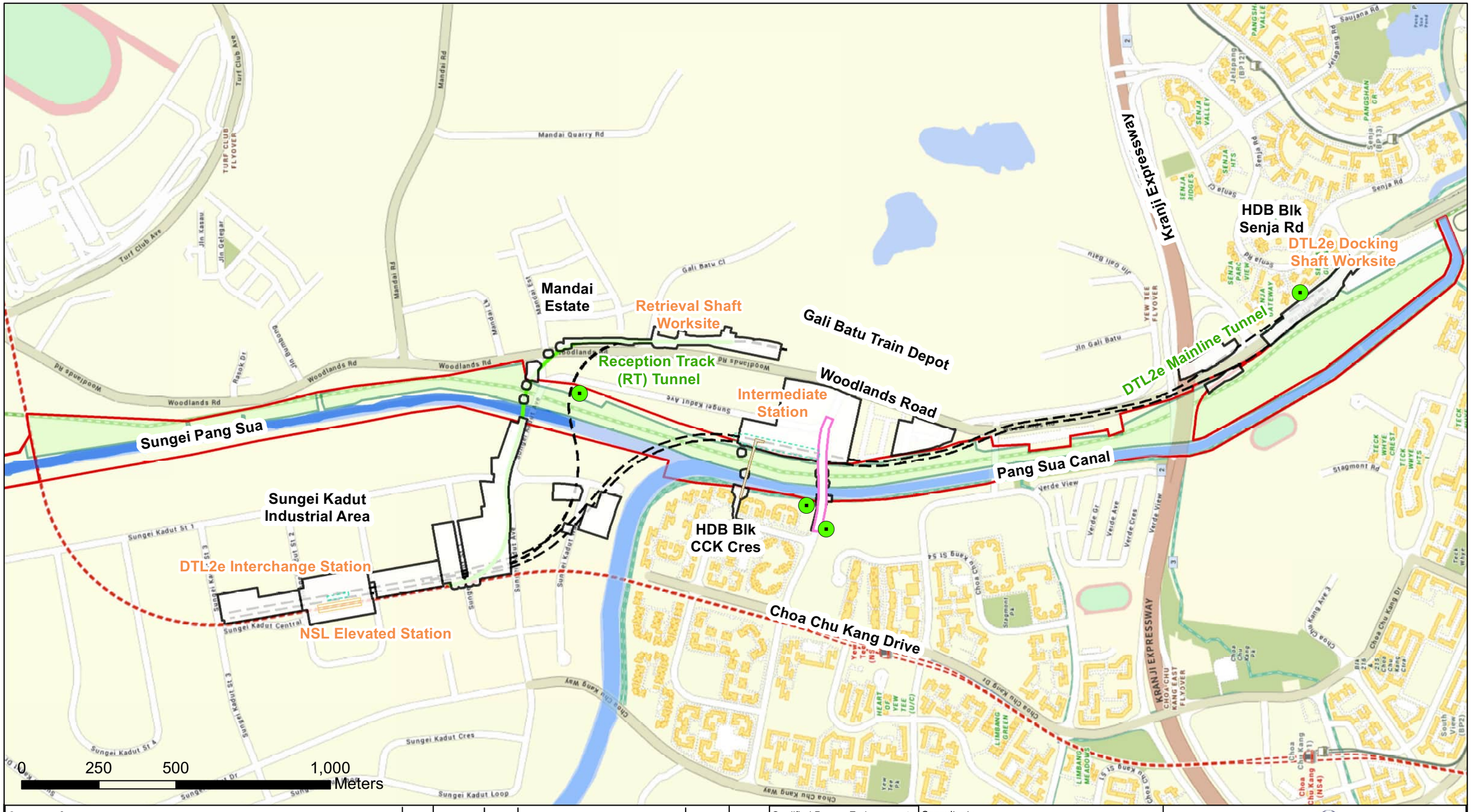
14.10.1.3 EMMP for Ground-borne Vibration on Human Receptors

This section presents the minimal proposed locations for the recommended monitoring program by selecting the sensitive receptors nearest to the construction activities, such as rotary bore piling, vibratory piling and tunnel boring.

Table 14-9 lists the recommended monitoring program for all worksites during construction phase. The recommended monitoring locations are shown in Table 14-10.

Table 14-9 Recommended Monitoring Program during Construction Phase (Ground-borne Vibration on Human Receptors)

Construction Worksite and Activities	Address	Building Use	Parameter	Frequency and Duration
Rotary Bore Piling	• 691B Choa Chu Kang Crescent	Residential	Peak Particle Velocity PPV, mm/s	**Before Construction Phase:** 1 week monitoring prior to site clearance. **During Construction Phase:** Continuous monitoring for 24 hours during the start of rotary bore piling
Vibratory Piling	• 632A Senja Road • 691B Choa Chu Kang Crescent	Residential	Peak Particle Velocity PPV, mm/s	**Before Construction Phase:** 1 week monitoring prior to site clearance. **During Construction Phase:** Continuous monitoring for 24 hours during the start of vibratory piling
Tunnel Boring Machine	• 25 Sungei Kadut Avenue	Sri Arasakesari Sivan Temple – Place of Worship	Peak Particle Velocity PPV, mm/s	**Before Construction Phase:** 1 week monitoring prior to site clearance. **During Construction Phase:** Continuous monitoring for 24 hours when the TBM approaches the receptor



Legend

- EMMP Vibration Monitoring Points
- Proposed Worksite Areas
- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Proposed Vehicle Bridge
- Proposed Pedestrian Overhead Bridge
- Proposed DTL2e Stations (Underground)
- Proposed NSL Elevated Station
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Rev.	Date	By	Description	Chk'd	App'd
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
-	AUG 2022	TTR	Draft Final Report	HHL	JAG

Qualified Person Endorsement : N/A

LTA Endorsement : N/A

Consultant : AECOM

Land Transport Authority — We Keep Your World Moving

Project Title :

CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :

RECOMMENDED GROUND-BORNE VIBRATION MONITORING LOCATIONS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	14-10	A	1 of 1
	Drawn TTR	Date MAY 2023	CAD File Name :N/A		A3

Note: Source of basemap - OneMap

14.10.2 Operational Phase

Validation of the vibration track attenuation will be carried out post-construction, thus, vibration monitoring is not required during operational phase. General housekeeping and maintenance shall be applied to the trackform.

Generally, the Rail Operator shall ensure the implementation of minimum control measures and recommended mitigation measures, summarising the key measures in Section 14.13.2 of this document.

14.11 Soil and Groundwater and Waste Monitoring Programme Requirement

14.11.1 Construction Phase

A summary of the recommended monitoring for soil and groundwater during the construction phase is provided in the table below.

Table 14-10 Recommended Monitoring Program during Construction Phase (Soil and Groundwater)

Location	Parameters	Frequency and Duration
Within the development boundary	Groundwater level	Continuous monitoring of groundwater level throughout the lifetime of the construction phase as per the instrumentation and monitoring plan developed by the Qualified Professional (QP).
At locations within the study area where excavated soil and extracted groundwater are generated and stored	Improper management of excavated soil and extracted groundwater	• Visual monitoring of spoil generated by the TBM to be conducted daily. Refer Figure 12-8 and Figure 12-9 for procedures for screening and handling of suspected contaminated soils and groundwaters. • Records on chemical waste from the waste generator should be properly kept and records produced when requested. • Inspection of hazardous chemical/substances storage condition weekly during construction phase. • Environmental audit monthly during construction phase.
At locations within the study area where toxic chemical waste is generated/ stored	Toxic chemical waste generation and management	
At locations within the study area where hazardous chemicals/ substances are used/ stored	Improper handling of hazardous chemicals/ substances	

14.11.2 Operational Phase

A summary of the recommended monitoring during the operational phase is provided in the table below

Table 14-11 Recommended Monitoring Program during Operational Phase (Soil and Groundwater)

Location	Parameters	Frequency and Duration
At locations within the study area where waste (e.g., liquid, solid) is generated or stored	Solid and liquid waste generation	• Monthly monitoring records of the amount and type of toxic chemical waste generated during the first three (3) months of commissioning phase. • Monthly inspection of hazardous chemical/ substances storage conditions during the first three (3) months of operational phase.
At locations within the study area where chemicals and hazardous substances are used or stored	Improper handling of hazardous chemicals/ substances	

14.12 Vectors Monitoring Programme Requirement

14.12.1 Construction Phase

In order to ensure that procedures are closely followed, the construction phase of Projects should be accompanied by a vector monitoring program. This vector monitoring program is dedicated for the construction worksites of this Project only. Areas outside of the Project boundary is not within the Project's authority and minimum control measures shall be carried out by each household or its housing/ school/ building/ public committee and other relevant party according to the stipulated legislations and guidelines.
All construction worksites were identified to be the potential sources of vector impact due to accumulation of stagnant water, poor housekeeping and improper waste handing, transfer and storage of waste onsite. Vector-breeding may lead to severe consequences such as the spread of virulent diseases (e.g., dengue fever) both to the workers onsite and to other people near the worksite.

14.12.1.1 Submission of Vector Control Plan

Aligning with LTA's Guidebook in Vector Control at LTA Sites [R-73] and LTA's SHE Specifications [R-19], the Contractor shall submit a site-specific Vector Control Plan upon contract award, which encompassing the following elements:

- **Pre-existing Conditions:** To conduct a pre-construction survey and establish vector baseline based on the *LTA's Procedure for Pre-Construction Vector Baseline Survey*, which purpose is to identify high-risk areas for vectors-breeding and eliminate pre-existing vector issues before starting work.
- **Zoning Method (see example in Figure 14-11):** To divide the construction site into a maximum of three (3) zones for vector control and surveillance activities which to be conducted at least one (1) zone per day, where each zone will be combed at least twice a week.
- **Dengue Contingency Plan:** To develop response plan based on "*LTA Dengue Contingency Plan*" in case that any person found on site is discovered to be a carrier of vector-borne disease, and when outbreak of dengue or mosquito breeding ground is detected on site.

14.12.1.2 Submission of Vector Baseline Report

As per NEA's sample contract specifications for mosquito and rodent control [W-92], the Contractor shall submit a full Vector Baseline Report with photographs (where applicable) to the S.O. by the second week after the commencement of the contract or at the beginning of each construction stage. The Vector Baseline Report shall be able to:

- Identify all potential mosquito breeding habitats and/or other relevant environmental irregularities (e.g., stagnant water, public litters at bus stop near worksite) in the required format as shown in the Annex C1 of the NEA's sample contract specifications.
- Identify all rat/rodent burrows, activity and/or other relevant environmental irregularities (e.g., signs of rub marks, live rodents) in the required format as shown in the Annex C2 of the NEA's sample contract specifications.

14.12.1.3 Submission of Vector Service Report(s)

As per NEA's sample contract specifications for mosquito and rodent control [W-92], the Contractor shall submit a Vector Service Report to the S.O. at the end of each mosquito and rodent/rat control services. The Vector Baseline Report shall:

- Report the performance of all mosquito control services conducted in the format as shown in Annex D1 of the NEA's sample contract specifications.

- Report the performance of all rodent/rat control services conducted in the format as shown in Annex D2-1 of the NEA's sample contract specifications.
- Recommend specific solutions to prevent mosquito breeding and rat/rodent infestation (e.g., building design details, repairs, housekeeping programmes, user habits) and any other factors that have direct bearing on mosquito breeding and rat/rodent infestation. Photos of each vector-breeding location (e.g., mosquito-breeding area, rodent burrow) or structural defect and the respective treatment shall be taken from different perspectives/angles and included in the report.

In specific for rat/ rodent control, a Monthly Service Report shall be submitted to the S.O. at the end of each month, with consolidated findings and the outcomes of relevant actions undertaken for the month.

14.12.1.4 Implementation of Vector Control Plan and Vector Monitoring Programme On Site

For the implementation of Vector Control Plan, the Contractor shall provide licensed personnel on site as follows:

- **A NEA-licensed ECO** shall be appointed by the Contractor to draw up and implement an effective vector control programme, which outlines vector surveillance and control measures to eliminate, reduce and/or manage vector risks as stated in NEA's *Code of Practice for Environmental Control Officers (ECO)* [W-91]. The ECO shall assist the Contractor in engaging external NEA-licensed VCO to undertake vector control measures on site.
- **A NEA-registered VCO (Vector Control Operator),** which is a registered company formed by a team of NEA-licensed Vector Control Technicians (VCTs) and NEA-certified Vector Control Workers (VCWs), shall be engaged by the Contractor and/or the ECO to undertake vector control measures as per the *Code of Practice for Vector Control Operator, Technician and Worker* [W-93], as well as to carry out vector control and surveillance at least once a week on site based on the requirement in LTA's *Guidebook in Vector Control at LTA Sites* [R-73]. The VCO shall lead and/or provide guidance for in-house vector control programme, if required to be formed by the Contractor, LTA and/or relevant authorities. The registered VCO, licensed VCT and/or certified VCW shall be able to identify potential vector-breeding grounds and propose measures to prevent propagation of vectors on site.
- **An in-house vector control team** is suggested to be formed as referred to the LTA's *Guidebook in Vector Control at LTA Sites* [R-73]. This in-house team should be led by an NEA-licensed VCT, joined by NEA-certified VCWs and/or a supporting group of individuals who have undergone vector control trainings provided by the NEA-registered VCO, NEA-licensed VCT and/or have passed other equivalent trainings (e.g., *Joint ITE-NEA Certificate in Pest Management*).
- **Note:** Under the *Control of Vector and Pesticide Act (CVPA)* [R-56], only registered VCO, licensed VCT or certified VCW under NEA can be engaged to carry out vector control works on site. The employment of any unlicensed/ uncertified vector control technicians/workers may be a potential breach of the CVPA Chapter 59 [W-92].

Noted as one of the minimum control measures on site, Gravitraps will normally be employed to prevent mosquito breeding. The vector control team shall develop a vector control program (see example in Figure 14-11) to conduct a daily routine of "Search and Destroy [15]" activities at each zone, as well as to monitor and maintain Gravitraps using the Zoning Method.

The recommended monitoring program for vectors is summarised in Table 14-12 below.

Table 14-12 Recommended Monitoring Programme during Construction Phase (Vector Control)

Location	Parameters	Frequency and Duration
Contractor to define vector zones (see example in Figure 14-11) as per LTA's	• Inspection of potential mosquito breeding grounds	• Daily inspection across different zones (see example

[15] According to *LTA's Guidebook in Vector Control at LTA Sites*, "Search and Destroy" refers to the search for and destruction of potential mosquito breeding grounds. This includes clearing of stagnant water, removal of unwanted water-bearing receptacles and eliminating conditions that are prone to water stagnation.

Location	Parameters	Frequency and Duration
SHE specifications [R-19], for each individual construction worksite (including storage and resting areas) under this Project, as listed below: • Worksite for DTL2e underground Intermediate Station; • Worksite for DTL2e underground Interchange Station and the new NSL Sungei Kadut Elevated Station; • Temporary Docking Shaft Worksite near HDB blocks at Senja Road; • Worksite for Retrieval Shaft • Worksite for potential future infrastructure; and • Any other individual worksites set up for other supporting works (e.g., underpinning works).	(stagnant water), rat/ rodent burrows and droppings of other vectors (e.g., cockroaches, flies)	in Figure 14-11) and their respective Gravitraps, with each zone inspected at least twice a week; • Weekly vector control and surveillance by the NEA-registered VCO, NEA-licensed VCT and/or NEA-certified VCWs.

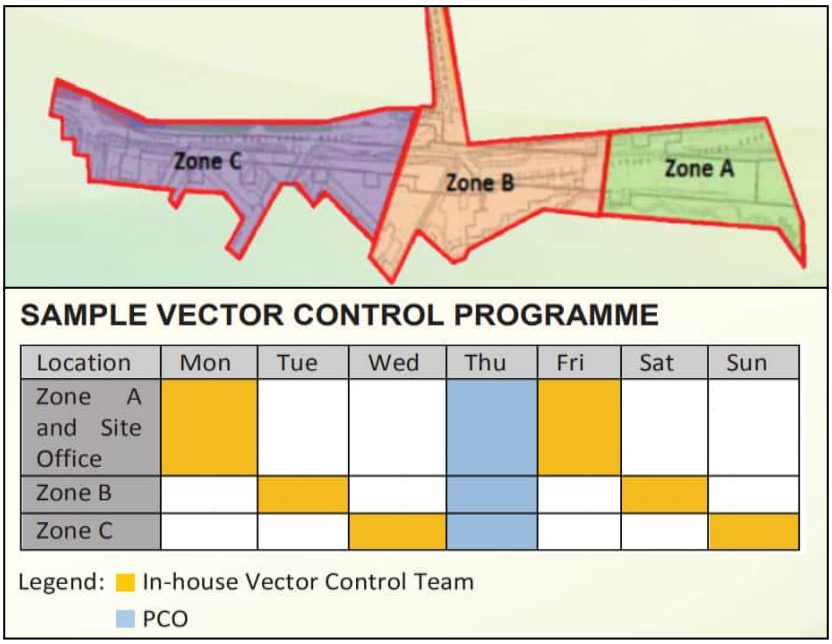


Figure 14-11 Example of Zoning Method and Vector Control Programme [R-73]

14.12.2 Operational Phase

A summary of the recommended monitoring for vector control during the operational phase is provided in the table below.

Table 14-13 Recommended Monitoring Program during Operational Phase (Vector Control)

Location	Parameters	Frequency and Duration
At above-ground station buildings and the perimeters	• Inspection of potential mosquitoes breeding grounds (water ponding) • Inspection of rat/rodent burrows • Inspection of cockroaches and flies' droppings	• Daily housekeeping and cleaning • Clear roof gutters and place Bti insecticide once a month • Periodic checks on potential vector-breeding areas (frequency not specified)

14.13 Summary of Proposed EMMP

The framework for the proposed EMMP is detailed below; however, it is important to note that this is not an exhaustive list of potential impacts, monitoring requirements and triggers. This EMMP is intended to be a living document and should be reviewed thoroughly by the Client/ Project Owner and the Contractor (CT) prior to implementation. Development of the following inputs, that have not been addressed in this report, by the CT are also required, including but not limited to:

- Stakeholder Communications Plan;
- Air Pollution Control Plan;
- Site log for all monitoring activities and complaints;
- Construction Logistics Plan;
- Standard Operating Procedures;
- Emergency Response Plan;
- Inventory of wastewater streams;
- Training protocols for staff, where appropriate; and
- Maintenance and Audit Schedules.

14.13.1 Construction Phase

The EMMP for construction phase of the project is described in table below.

Table 14-14 Proposed EMMP for Construction Phase

Environmental Parameters	Environmental Issues	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[16,17]
Biodiversity	Minimisation of construction impacts to flora/vegetation	• Mark out site boundary where works will be conducted; • Set up Tree Protection Zones (TPZs) around trees or other plant specimens to be retained within the worksites; and • Tag trees (with or without TPZs) meant to be protected or transplanted to avoid accidental removal.	• The boundary of the construction site should be clearly demarcated; • Ensure working space to be at least 5m away from the banks of Sungei Pang Sua to maintain slope integrity	Flora and Arboriculture	Within development boundary	Prior to site clearance	CT, ECO, Flora Specialist	N.A.
		• Establishment of TPZs; • Inspect the integrity of the TPZ hoarding; • Assess tree physiological health and vigour; • Check for mechanical damage on trees that may impair stability; • Review method statements of construction works in proximity to retained trees; and • Implement soil erosion control measures as soon as vegetation has been removed and soil is exposed.	• Identify excessive or unauthorized tree removal, especially at Sungei Pang Sua mangrove • Identify trees that require management and maintenance such as tree care and pruning; • Check on the health and condition of the TPZs within the construction site as well as the cluster of *Sonneratia caseolaris* at Sungei Pang Sua in proximity of working space; • Determine if there are any unauthorized removal of flora within RAC (if any) or beyond the demarcated worksite; • Identify areas with soil erosion and degradation that have resulted from construction activities; • Determine if there are unauthorized dumping of waste material, construction debris or oil/chemical leakage that may contaminate the soil and waterbodies, and/or be detrimental to the vegetation; and • Identify areas that are responding poorly due to the development impacts.		Within development boundary and 15 m beyond hoarding line	Monthly for duration of construction	CT, ECO, Flora Specialist, Arborist	
	Minimisation of construction impacts to fauna	• Ensure proper storage of machineries likely to leech harmful chemicals and fuel-powered equipment; • Store the aforementioned equipment away from waterbodies and/or sensitive habitats; and • Ensure noise levels are kept within the approved limits.	• Establish a wildlife response plan in consultation with NParks Animal Management Centre for encounters with trapped, injured or dead wildlife, as well as incidents of human-wildlife conflict; Implement wildlife shepherding via directional clearing; and • Conduct pre-felling fauna inspection before executing directional clearance. • Monitor for degradation or siltation within Sungei Pang Sua	Fauna	Within development boundary	Prior to site clearance	CT, ECO, Fauna specialist/ Ecologist	
		• Ensure proper storage of machineries likely to leech harmful chemicals and fuel-powered equipment; • Store the aforementioned equipment away from waterbodies and/or sensitive habitats; and	Check if hoardings are properly installed with no gaps; and check on erosion control blankets (ECB) to check on possible entrapment of fauna		Within development boundary	Monthly for duration of construction	CT, ECO, Fauna specialist/ Ecologist	

[16] Resident Technical Officer (RTO) and Site Officers (SO, WSHO and ECO) check the Study Area for construction progress and implementation of environmental mitigation measures.
[17] If there is trigger then all the mitigation and management measures should be audited in detail for compliance and corrective action must be taken in liaison with the Project Owner.

Environmental Parameters	Environmental Issues	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[16,17]
		• Ensure hoardings has been properly erected.						
		Ensure that noise mitigation measures (as detailed in the Airborne Noise EMMP section below) are adhered to.	Conduct biodiversity survey to monitor construction impacts on fauna activity and presence.		Adjacent to development boundary	Monthly for duration of construction	CT, ECO, Fauna specialist/ Ecologist	When fauna is encountered within development boundary
Hydrology and Surface Water Quality	• Temporary Land Use Change • Liquid Effluent and Stormwater Runoff Generation • Solid & Toxic Waste Generation • Improper Management of Chemical Substances	<u>Key Minimum Control Measures:</u> *a. Temporary Land Use Change* • Geotechnical aspect of site's slope stability (such as Earth Retaining and Stabilising structures (ERSS) to be included in detailed design engineering for the construction stage. • The design engineers for detailed design may need to ensure that Earth Retaining Stabilisation structures (ERSS) are proposed when the site is cleared and excavated. Concurrently the ECO must ensure that these measures are implemented in the construction phase, as cutting of slopes may result in slope instability. *b. Liquid Effluent Generation and Stormwater Runoff* • A full inventory of all anticipated wastewater streams and volumes should be finalised before the onset of the construction works. • No unmanaged discharge of wastewater stream permitted. • Effective ECM and monitoring implemented as required in the Code of Practice on Surface Water Drainage to ensure that discharge into the stormwater drainage system does not contain TSS in concentrations greater than the prescribed limits under the Sewerage and Drainage (Surface Water Drainage) Regulations. • Reduce, reuse, and recycle hierarchy principle to be applied to wastewater on-site. • Hazardous wastewater, such as oily water, thinners, solvents, or paints, should be stored on hard stand, under shelter with a kerb around the storage area. The wastewater should be removed for treatment and disposal off-site by an approved Waste Management Contractor. Hazardous liquids to be handled as Hazardous Waste. • Adequate drainage, cut-off drains, sump pit, road kerb, piping and toe wall will be designed for channelling of construction process wastewater streams (e.g., concrete batching, wash water, etc.) and stormwater runoff separately through detailed design for capture and treatment in the containment pond/kerbs. Where applicable (e.g., in the vicinity of liquid storage or refuelling areas), this infrastructure	• Discharge from worksite should not contain Total Suspended Solids (TSS) in concentrations greater than the prescribed limits under Regulation 4(1) of the Sewerage and Drainage (Surface Water Drainage) Regulations.	All water quality parameters identified in Table 14-3. And any flooding issues should be recorded and inspected.	Before every discharge outlet and at the sensitive watercourses (i.e.Sungei Pang Sua and Pang Sua Canal).	One-time monitoring prior to site clearance.	CT, EM/ECO	Investigation and corrective actions to be taken there is a significant drawdown of groundwater level.
				All water quality parameters identified in Table 14-3. And any flooding issues should be recorded and inspected.	Before every discharge outlet and at the sensitive watercourses (i.e., Sungei Pang Sua and Pang Sua Canal).	• Permanent Turbidity and TSS monitor installed at every discharge outlet; • Implementation of CCTV including a SIDS at every discharge outlet to monitor the surface runoff discharges from the sites; • Monthly one-time water quality monitoring for all discharge locations and Sungei Pang Sua and Pang Sua Canal during construction phase; • Intensity of the laboratory analysis will be increased (e.g., fortnightly, weekly) if in-situ measurements and/or monthly laboratory results indicate deterioration in the water quality. Intensified monitoring will be carried out until in-situ measurements and/or laboratory results indicate 'normality'/consistency with earlier monitored conditions; and • Daily inspection on perimeter drains to ensure no surface runoff flowing out from the site untreated done by the site officer with monthly audit.	CT, EM/ECO	Investigation and corrective actions to be taken, when: • The following documentation are found inadequate/missing: - ECM Plan; - Monitoring Log; - Training Log; - Audit Reports; • If the monitored parameters exceed applicable values of NEA Trade Effluent Discharge Limits/ Water Quality Criteria for Aquatic Life at discharge point and Sungei Pang Sua and Pang Sua Canal (refer to Table 14-2); • If any flooding or clogging issues observed; • If complaints are received due to project activities; and • If visual non-compliance to any of the minimum control or mitigation measures are observed on-site.

Environmental Parameters	Environmental Issues	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[16,17]
		will include oil-water separators to capture inadvertent spills or leaked oils or greases. • 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. • Contractor will seek for comment and approval from relevant authorities (e.g., SCDF and NEA) on the treated wastewater to be used for firefighting purpose. • Tunnel washing effluent should be discharged to containment pond/kerbs that manually collected by operator assigned private wastewater collector to be transferred to wastewater treatment plant. • Appropriate disposal of any waste listed in the Environmental Public Health (General Waste Collection) Regulations by licensed waste operator/collector. • Runoff within, upstream of, and adjacent to the worksite will be effectively drained away without causing flooding in the vicinity; • Appropriate permits for discharge to be obtained from relevant authority prior to discharge. No trade effluent other than that of a nature or type approved by NEA Director-General will be discharged into any watercourse or land. • Regular and dedicated procedures for the management of stormwater collection, settling, testing and eventual discharge of 'clean' water to watercourses. • Sizing of sediment/detention pond and its associate structures will strictly comply with the criteria required in ECM, i.e., design to cater for at least 5-year return period storm event. • *c. Solid & Toxic Waste Generation* • Hazardous substances and toxic wastes should be stored on hard stand, under shelter with a kerb around the storage area. • Implementation of CCTV including SIDS at the public drain to monitor the surface runoff discharges from the sites as per the Public Utilities Board of Singapore's (PUB) circular on Preventing Muddy Waters from the Construction Sites (October 2015).					

Environmental Parameters	Environmental Issues	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[16,17]
		• Protection of stockpiles with erosion blanket coverage and proper scheduling of the demolition and earthworks to reduce the quantity of stockpiles to be stored onsite. • All wastes will be disposed only in the designated waste disposal facilities and appropriately separated, i.e., by trained workers to properly sort and label the different types of waste (reusable and recyclable waste, toxic and non-toxic waste, etc.) If there is any earth filling work at worksite, the good earth that free of any debris or construction waste materials should be used. If sand is used for backfilling work, marine sand is prohibited and only washed sand with chloride content not exceeding 0.01% (by weight) should be allowed. *d. Improper Management of Chemical Substances* • Development of SOP for safe handling, transfer and storage of toxic waste; housekeeping checks once a day to ensure all toxic waste is cleared from site. • Appropriate tests to ascertain the presence/absence of contamination of the excavated earth and sand. • Appropriate fully sheltered storage area with storage volume to be 110% of the largest volume of chemical substances to be stored (kerb up and enclosed on at least 3 sides, covered and with adequate ventilation) for hazardous substances. • Appropriate construction material for toxic waste storage containers with leak detection tests conducted periodically. • Provision of secondary containment for all toxic waste stored in bulk as per the requirements in the COPPC/SS593. • Preparation of an emergency response plan, training of the emergency response team (ERT) to be competent in the response mechanism and provision of response kits for any spillages. • Consignment notification/tracking system and transport emergency response plan for transport of toxic waste.					
Air Quality	Air quality impact from dust nuisance from the demolition, earthworks, construction activities and gaseous emissions from the construction equipment and vehicles	• The construction footprint will be hoarded on all sides; • Road construction or expansion will be completed first and paved where possible before the construction of other development commences.	General mitigation measures to be implemented throughout construction period. Communications: • Develop and implement a stakeholder communications plan that includes community engagement before work commences on site. • Display the name and contact details of person(s) accountable for air quality and dust issues on the site boundary. This may be the	$PM_{2.5}$ and PM_{10} Dust deposition in $mg/m^2/day$	• Rail corridor near Intermediate Station worksite • Sungei Pang Sua near worksite for potential future infrastructure	• Prior to site clearance: Conduct one-time air quality monitoring of PM_{10} and $PM_{2.5}$ for 1 week for the establishment of baseline • Throughout construction period: Continuous dust	CT, EM/ECO	Investigation and corrective actions to be taken, when • Any of the following documentation are found inadequate / missing: Air Pollution Control Plan;

Environmental Parameters	Environmental Issues	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[16,17]
			environment manager/engineer or the site manager. • Develop and implement an Air Pollution Control Plan (APCP) 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. • Make the complaints log available to the local authority when asked. • 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. • 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. 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. • Carry out regular site inspections to monitor and record compliance with the Air Pollution Control Plan. • Increase the frequency of site inspections during prolonged dry or windy conditions. • Conduct monitoring for dust deposition at suitable locations (refer to Section 10 for details) Preparing and maintaining the site: • Plan site layout so that machinery and dust causing activities are located away from receptors, where possible. • 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. • 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. • Keep site fencing, barriers, and scaffolding clean by cleaning regularly using wet methods (dry methods may give rise to fugitive dust). • 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. Operating vehicle/machinery and sustainable travel: • 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.		• HDB Blk Senja Road near Docking Shaft worksite	deposition monitoring, averaged over 4-week period at Rail Corridor near Intermediate Station worksite and Sungei Pang Sua near worksite for potential future infrastructure • During site clearance and earthworks phases: Continuous monitoring of PM_{10} and $PM_{2.5}$ at HDB Blk Senja Road near Docking Shaft worksite • Environmental audit by independent EMMP Consultant, monthly during construction phase.		Compliance certificate of an Off-Road Diesel engine; or Monitoring Log. • If the monitored PM10 and PM2.5 exceed Singapore long term air quality targets. • If the dust deposition monitored exceeds 200 mg/m2/day averaged over 4-week • If complaints are received due to Project activities. • If visual non-compliance to any of the minimum control or mitigation measures are observed on-site.

Environmental Parameters	Environmental Issues	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[16,17]
			• Produce a Construction Logistics Plan to manage the sustainable delivery of goods and materials. • Ensure all vehicles and engine powered equipment comply with the legislative requirements of Singapore • Ensure all vehicles and equipment switch off their engines when stationary – i.e., no idling vehicles or engines. Clear signs will be erected at site entrance to inform all visitors. • Where practicable, avoid the use of diesel- or petrol-powered generators and use mains electricity or battery powered equipment Construction: • 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. • Ensure an adequate water supply on the site for effective dust/particulate matter suppression/mitigation, using non-potable water where possible and appropriate. • Use enclosed chutes and conveyors and covered skips wherever possible. • Minimise drop heights from conveyors, loading shovels, hoppers and other loading or handling equipment and use fine water sprays on such equipment wherever appropriate. • 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 and dry spillages, and cleaning should be conducted as soon as reasonably practicable after the event using wet cleaning methods. Waste Management: • Avoid burning of waste or other materials MITIGATION MEASURES FOR DEMOLITION • Soft strip inside buildings before demolition (retaining walls and windows in the rest of the building where possible, to provide a screen against dust). • Ensure effective water suppression is used during demolition operations. Hand held sprays are more effective than hoses attached to equipment as the water can be directed to where it is needed. In addition high volume water suppression systems, manually controlled, can produce fine water droplets that effectively bring the dust particles to the ground. • Avoid explosive blasting, using appropriate manual or mechanical alternatives. • Bag and remove any biological debris or damp down such material before demolition. MITIGATION MEASURES FOR EARTHWORKS • Re-vegetate earthworks and exposed areas/soil stockpiles to stabilise surfaces as soon as practicable. • Use Hessian, mulches or soil tackifiers where it is not possible to re-vegetate or cover with topsoil, as soon as practicable. • Only remove the cover in small areas during work and not all at once.					

Environmental Parameters	Environmental Issues	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[16,17]
			MITIGATION MEASURES FOR CONSTRUCTION • Avoid scabbling (roughening of concrete surfaces) if possible. • Sand and aggregates will be delivered in a dampened stage and will be re-wetted before being dumped into storage bunker. • Drop heights at transfer points will be minimised to lessen dust generation • Special covered area will be provided for loading and unloading process • Water sprays or sprinklers will be employed at conveyor transfer points • 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. • 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. • For smaller supplies of fine power materials ensure bags are sealed after use and stored appropriately to prevent dust. • Vent will be provided with efficient fixed filter bags to comply with the dust emissions criteria. • Silos will not be filled up with cement more than 90% of its loading capacity, to avoid overfilling, • Silos will 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. 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. • Avoid dry sweeping of large areas. • Ensure vehicles entering and leaving sites are covered to prevent escape of materials during transport. • Inspect on-site haul routes for integrity and instigate necessary repairs to the surface as soon as reasonably practicable. • Record all inspections of haul routes and any subsequent action in a site log book. • Install hard surfaced haul routes, which are regularly damped down with fixed or mobile sprinkler systems, or mobile water bowsers and regularly cleaned. • Implement a wheel washing system (with rumble grids to dislodge accumulated dust and mud prior to leaving the site where reasonably practicable). • 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. • Site access gates to be located at least 10 m from receptors where possible					
Airborne Noise	Noise from construction machines and equipment, especially rotational and vibratory equipment (e.g.,	• All machinery and equipment used shall be labelled with a weather-proof sticker clearly indicating its noise emission level (at source) under normal operating conditions;	MITIGATION MEASURES FOR GENERAL CONSTRUCTION NOISE CONTROL:	$L_{Aeq(12\ hours)}$, $L_{Aeq(1\ hour)}$, $L_{Aeq(5\ mins)}$	• JTC Lot No. MK11-00541K near The Stone Gallery by	Pre-construction baseline and continuous monitoring for the entire duration of the construction phase of the	CT, ECO	Investigation and corrective actions to be taken, when any of the following documentation

Environmental Parameters	Environmental Issues	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[16,17]
	dozers, cranes, excavators, trailers, generators, etc.)	• All machinery and equipment used on site should be sound reduced, as far as is practicable; • Stationary noisy equipment should be housed in enclosures on site where necessary; • Machine operators and workers must be trained and briefed on quieter work techniques; • Ad-hoc noise monitoring must be carried out when work progresses during noisy operations; • Additional noise measures should be implemented when noise monitoring indicates the noise levels are approaching or exceeding permissible noise levels; • Avoid shouting, whistling, sirens, or similar loud intermittent noises especially near ecologically sensitive receptors which can be impacted by them; • Minimize noise disturbances by restricting construction activities that are not safety critical to 8am – 6pm; • Concrete walls along boundary of premises selected for building demolition (if any) shall not be removed until demolition is complete; and • Apply noise reduction netting of a rating of STC18 or higher on all façades of buildings selected for demolition	• Control of noise sources at the source from construction site. Analyse construction inventory list and check equipment causing high noise levels. The equipment with lower noise level shall be prioritized; and • Where controlling noise sources at the source is not feasible, acoustic enclosures or sheds are to be introduced to mitigate noise at the source. Typical acoustic enclosures covers the machine as fully as possible (with or without ventilation where applicable) to provide sound insulation. MITIGATION MEASURES FOR CONSTRUCTION NOISE: • Proposed noise reduction netting of at least STC18 on all façade of building selected for demolition. • Proposed 3m, and 12m vertical noise barrier of at least STC20 along worksites nearest to ecological and human NSRs predicted to experience noise exceedances; • Proposed 15m noise enclosure of at least STC20 for docking shaft construction area.		Hafary, Sungei Kadut Central • Vicinity of JSM Construction Group Pte Ltd facing Woodlands Road • Vicinity of HDB Block 691B facing Pang Sua Canal • Vicinity of commercial buildings such as Chong Timber Pte Ltd, along Rail Corridor • Along Rail Corridor on side opposite and facing Windermere Residences • HDB Block 632A Senja Road • Near Teck Whye Secondary School, facing the Pang Sua Canal • Along Rail Corridor near Sungei Kadut Avenue	aforementioned parameters at all locations.		are found inadequate / missing: • Construction Noise Management Plan; • Monitoring Log. 1. If the monitored parameters exceed applicable values of EPM regulations. 2. If complaints are received due to project activities. 3. If visual non-compliance to any of the minimum control or mitigation measures are observed on-site. 4. If there are any cracks / leaks present on the noise barrier erected.
Ground-borne Noise and Vibration	Ground-borne vibration from rock breaking and excavation and tunnel boring machine.	• Equipment Selection and Maintenance. Associated with the piling during the construction of the potential future infrastructure, vehicular bridge and Pedestrian Linkbridge, cut and cover tunnel, plus the operation of the TBM. • Works Scheduling and Respite Periods. • Community Consultation. It is recommended that the surrounding community be notified before commencing any piling and TBM related works, as a matter of good community relations. • Use low vibration equipment and construction techniques; and • Use micro piling techniques for the foundations of the potential future infrastructure, vehicular bridge and pedestrian linkbridge. • Liaison with the occupants of the receptors is the best method of mitigating the temporary impacts from the tunnel boring activity by providing prior warning and details on the likely duration of the impact (whilst the tunnel boring machine passes).	• Schedule rock breaking and excavation activities during day time. • Avoid rotary bore piling, rock breaking and excavation, and tunnel boring near Rail Corridor during peak bird breeding season from March to July. • Reduce the maximum instantaneous charge (MIC) at Sungei Kadut Station. • The Contractor will ensure that the vibration levels for any construction activities at Rail Corridor (excluding the worksite area) do not exceed PPV, 8 mm/s, especially for rock breaking and tunnel boring. • No night works should be conducted after 7pm for all non-safety critical activities. • The Ecologist shall be present to survey burrows and mud lobster mounds before any construction activities. Camera traps may be deployed if required to confirm fauna activity in the event they are detected within the Biodiversity Study Area. Construction works are allowed to be continued if no burrows, mud lobster mounds, or fauna activity is detected; • During, rock breaking and excavation, rotary bore piling and tunnel boring construction activities, EM/ECO shall monitor for any fauna behaviour at the GI pipes and canvas sheets barrier for at least thirty (30) minutes after the event. If any animal found dashing into the barriers, Wildlife Response Plan will be activated. • If there are justified complaints from the operations, particularly from the tunnel boring machine, then the operation may need to consider the use of reduced thrust force or rotational speed. • Set up barriers using GI pipes and canvas sheet to prevent road kills. • If there are industrial estates and/or E63 drain abutting the Rail Corridor, there is no need for barriers along the external perimeter along the road as risks of roadkill are low. Canvas sheets must be used to cover existing fences to	Peak Particle Velocity, PPV mm/s	Ecological Receptors: N.A. Human Receptors: • 632A Senja Road • 44 Choa Chu Kang Street 64 • 692 Choa Chu Kang Cres • 25 Sungei Kadut Avenue	• In the event of a valid complaint, until the complaint has been resolved. • Environmental audit monthly during construction phase. • Continuous monitoring for 24 hours during the start of rotary bore piling/ vibratory piling/ when the TBM approaches the receptor.	CT, EM/ECO	Investigation and corrective actions to be taken, when: 1. If the monitored parameters exceed applicable limits. 2. If complaints are received due to project activities. 3. If visual non-compliance to any of the minimum control or mitigation measures are observed on-site.

Environmental Parameters	Environmental Issues	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[16,17]
			prevent fauna from passing through. Along the road at Sungei Kadut Avenue, no barriers are required to maintain connectivity for fauna. However, to address the concerns on roadkills along this road, speed bumps can be considered to minimize chances of roadkill. • During Tunnel Boring, the Ecologist and ECO shall monitor for the collapse of specific burrow/mound that is confirmed to be used by a fauna and suggest ways to further mitigate on-site based on observations causing the impact. This is to be included in the daily checks by the ECO and monthly inspection by the Ecologist.					
Soil, Groundwater and Waste Management	• Decreased infiltration into the ground due to increase in impervious surfaces • Groundwater extraction/ soil dewatering for the activities that require dry soil conditions	• Install piezometers to monitor the changes in groundwater level in compliance with Building Control Regulations 2003 as part of its 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. • Plan soil dewatering in phases to avoid as much as practicably possible groundwater drawdown	No additional mitigation measures are required.	Groundwater level	Actual monitoring location to be decided by QP.	To continuously monitor the groundwater level throughout the lifetime of the construction phase.	CT, ECO	Investigation and corrective actions to be taken there is a significant drawdown of groundwater level.
	• Seepage of contaminants (if any) from excavated soil into the underlying soil and groundwater • Soil erosion of exposed soil from excavations and stockpiles • Leakage of contaminants (if any) from extracted groundwater into the underlying soil and groundwater • Improper management of wastewater generated from tunnelling activities • Uncontrolled discharge and leakage of waste and chemicals due to improper management • Inappropriate or inadequate design parameters for storage containers • Discharge or leakage of chemicals used for refuelling and maintenance of vehicles, machinery and equipment	• Identify all types of solid 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 will be free of debris, and of good material soil. • Handle and dispose excavated soil following the procedure shown in Figure 12-8. 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.	No additional mitigation measures are required.	Records on waste generated and hazardous chemicals used at the construction site should be properly kept and records produced when requested.	• At locations where excavated soil and extracted groundwater are generated and stored. • At locations where toxic chemical wastes are generated and stored. • At locations where hazardous chemicals/substances are used and stored.	• Monitoring records of the amount and type of toxic chemical waste generated, once a week • Inspection of hazardous chemical /substances storage conditions, once a week. • Environmental audit monthly during construction phase	CT, ECO	Investigation and corrective actions to be taken, when: • There are no/ poor records of toxic chemical waste amount and type; and • There is evidence of poor handling/ storage of toxic chemical waste and hazardous chemical

Environmental Parameters	Environmental Issues	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[16,17]
		• 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 12-8 • Discharge of extracted groundwater will be to an area approved for such disposal by the NEA and PUB and the proposed location as identified in Figure 12-8 and following the process set out in Figure 12-9. Based on the HLUS findings, there is a possibility of encountering historically contaminated soil due to the historical activities in the area. Therefore, it is recommended that the construction Contractor 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 will 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 will follow the procedure in Figure 12-8 • The wastewater from tunnelling activities should be stored and removed for treatment and disposal off-site by an approved Waste Management Contractor. • Contractor will need to seek approval from relevant authorities (e.g., PUB & NEA) as per						

Environmental Parameters	Environmental Issues	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[16,17]
		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 of. • 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 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 will be provided for all waste containers Spill trays will 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 will be treated to comply with the requirements under prevailing legislation. • 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 and PUB will be discharged into any watercourse or land.						

Environmental Parameters	Environmental Issues	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility	Triggers[16,17]
		• Ensure all activities involving repair, servicing, engine overhaul works, etc. will 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. • Provide emergency spill kits on site in the event of any chemical spillages. The emergency response team will also be competent in the use of these spill kits.						
Vectors	Accumulation of stagnant water, poor housekeeping and improper handling/ disposal of solid waste (especially food waste)	• Adhere to Control of Vector and Pesticide Act (CVPA) and ensure good housekeeping on-site. • Preparation and implementation of an effective vector control plan and measures as required under LTA's SHE Specifications and LTA's Guidebook in Vector Control at LTA Sites, as well as the NEA's Code of Practice for Environmental Control Officers. • Ensure water-bearing receptacles, gaps on grounds and equipment (e.g., openings at concrete barriers), as well as stockpiled areas are covered or sheltered, especially during the northeast monsoon season between November to January. • Scheduled daily housekeeping to ensure clearance of stagnant water and unwanted items are discarded properly. • Site entrance shall be paved to avoid ground depression. • Milled waste can be used to level the ground before laying steel plates. • Provide movable roof over shaft to prevent rainwater ingress. • Pump shall be deployed to clear water at areas where drainage is not possible, as well as for larger recessed surfaces. • Install pitched roof on top and/or seal up bottom of site container office. • After trees clearance, top of tree stumps has to be either remove thoroughly or patched up. • Pipette can be used for larvae-checking at the hard-to-reach parts of a tree. • Food disposal should be clearly allocated and disposed of on a daily basis to discourage rodents from establishing nests on site and to prevent cockroaches/ flies' infestation. • Store food in rodent proof storage containers/ cabinets with at least 60 cm clearance above ground level. • Thermal Fogging shall only be carried out when there is a Dengue outbreak or when high mosquito population is detected at construction worksite. Regular fogging is not encouraged as it may build up the mosquitoes' resistance over time.	Not Applicable.	• Inspection of potential mosquitoes breeding grounds (water ponding) • Inspection of rat/ rodent burrows • Inspection of cockroaches and flies' droppings	Within and/or at boundary of construction worksites.	• Daily inspection and housekeeping check across different zones and the Gravitraps, with each zone inspected at twice a week. • Weekly vector control and surveillance by an external NEA-licensed VCO/ VCT/ VCW. • Submission of Vector Control Plan upon contract award. • Submission of Vector Baseline Report to S.O. by the second week after the commencement of the contract or at the beginning of each construction stage. • Submission of Vector Service Report to S.O. after the end of each vector control service.	ECO/ VCO/ VCT/ VCW/ CT	Investigation and corrective actions (i.e., Stop Work Orders) to be taken, when: a. Worksite is found to have vector-breeding habitats. b. There is an occurrence of suspected dengue outbreak cases.

14.13.2 Operational Phase

The EMMP for operational phase of the project is described in table below.

Table 14-15 Proposed EMMP for Operational Phase

Environmental Parameters	Environmental Issues	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility
Biodiversity	Minimisation of operational impacts to flora/vegetation	• Ensure noise levels are within approved limits (refer to Section 10 on Airborne Noise). • Ensure dust levels are within approved limits (refer to Section 9 on Air Quality). • Avoid fogging by implementing preventive measures for mosquito to remove sources of stagnant water or water-bearing receptacles	• Unused areas and/or areas which was cleared for works during the construction should be replanted. Adopt a native planting palette considering the existing and surrounding vegetation. • Execute in-fill planting or dense planting using native species and mangrove/back mangrove species, especially in areas with forest gaps or areas with bare or sparse undergrowth	-	-	-	Rail Operator/ EHS Officer
	Minimisation of operational impacts to fauna		• Bird-friendly building designs • Design and administrative measures	-	-	-	
Hydrology and Surface Water Quality	Permanent land use change Stormwater run-off contamination Improper management of liquid and solid wastes	a. Permanent Land Use Change • Geotechnical aspect of site's slope stability (such as ERSS) to be included in detailed design engineering for the operational stage. • Active, Beautiful, Clean Water (ABC) Water Design approach can be considered as part of the development to reduce the peak-flow of stormwater runoff as well. • Providing more softscape area should be considered in the design of the development to reduce generated peak flow of stormwater runoff from entering the public drain. • Provide more pervious areas to increase the seepage of surface water into the soil. b. Stormwater run-off contamination • Adequate drainage, piping and/or channelling of stormwater runoff to be assured through detailed design [such as Active, Beautiful, Clean (ABC) Water Design approach] for capture and treatment before discharge into watercourses. • Regular and dedicated procedures for the inspection and maintenance of stormwater collection, storage, and treatment infrastructure, such as pipes, oil water separation, silt screens, etc. • Regular and dedicated procedures for the management of stormwater collection, settling, testing and eventual discharge of 'clean' water to watercourses. c. Improper management of liquid and solid wastes • To prepare sufficient disposal bins surrounding of the Project to avoid improper disposal of waste. • To conduct regular inspection on wastes' storage system of the Project.	Not Applicable.	All parameters identified in Table 14-4. And any flooding issues should be recorded and inspected.	At the main outlets/drains of the Project site, as well as the sensitive watercourses in the vicinity of proposed Project (i.e., Sungei Pang Sua and Pang Sua Canal) during the first three (3) months of operational phase.	Monthly inspection for the water quality and hydrology, especially during heavy storm event for hydrological conditions during first three (3) months of operational phase	Rail Operator/ EHS Officer

Environmental Parameters	Environmental Issues	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility
		• To monitor the existing and proposed watercourses and its surroundings with CCTV surveillance regularly to ensure no contamination occurred. • To develop an emergency response plan and conduct adequate training to maintenance workers to cope the accidental water contamination. • Raising awareness of various stakeholders with community/stakeholder engagement (e.g., signage boards, warning signs, etc.).					
Air Quality	Air quality impact from dust nuisance from the emissions from vehicle exhaust due to increased traffic	No minimum control has been assumed.	No additional mitigation measures are required.	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Airborne Noise	Increased traffic in vicinity of the Project site.	No minimum control measures were proposed.	• Source noise control, speed limit on Choa Chu Kang North 7 and Choa Chu Kang Crescent.	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Ground-borne Vibration	Ground-borne Vibration from the operation of trains	• Train, track and tunnel design • Maintenance of vertical track alignment at the relevant longitudinal wavelengths • Maintenance of roughness of the railhead and wheel thread 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.	No additional mitigation measures are required.	Not Applicable	Not Applicable	Not Applicable	Rail Operator
Soil, Groundwater and Waste Management	More areas with impervious surfaces in the new development leading to decrease in infiltration of surface water/ stormwater into the soil.	Incorporate more pervious surfaces in the development plan.	No additional mitigation measures are required.	Not Applicable	Not Applicable	Not Applicable	Not Applicable
	• Heavy rain and stormwater wash-off pollutants built-up in the new development area and discharge to surrounding soil and groundwater • Discharge or leakage of waste and chemicals into the soil	• Ensure no trade effluent other than that of a nature or type approved by NEA Director-General will be discharged into any watercourse or land. • 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 will be provided for all chemical drum and potentially pollutive substances. Spill trays will be regularly maintained to prevent rain from washing out the pollutive substances. • Dispose all toxic waste chemicals to licensed TIW collectors for treatment • 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 will also be competent in the use of these spill kits.	No additional mitigation measures are required.	Records on waste generated and hazardous chemicals used at the Study Area should be properly kept and records produced when requested.	• At locations where toxic chemical waste are generated and store. • At locations where hazardous chemicals/ substances are used and stored	• Monitoring records of the amount and type of toxic chemical waste generated during first three (3) months of the operational phase • Inspection of hazardous chemical/substances storage conditions during first three (3) months of the operational phase	CT, EHS
Vectors	Accumulation of stagnant water, poor housekeeping and improper management of station facilities and/or waste disposal containers	• Rail operator to conduct periodic checks on the potential vector-breeding areas: – Ensure water tanks are properly covered – Ensure all drainage outlets are properly sealed	Not Applicable.	• Inspection of potential mosquitoes breeding grounds (water ponding)	At above-ground station buildings and the perimeters	• Daily housekeeping and cleaning • Clear roof gutters and place Bti insecticide once a month	Rail Operator

Environmental Parameters	Environmental Issues	Minimum Control Measures	Mitigation Measures	Monitoring Parameter	Monitoring Locations	Recommended Frequency of Monitoring	Site Responsibility
		– Clear fallen leaves and tree branches from drains, and seal up tree holes if any at the perimeter of the station/ bridge – Cover rarely-used gully traps and install anti-mosquito valves – Cover all containers storing water – Removed ununsed containers or unwanted receptables so they do not store water – Avoid using canvas or plastic sheets as they may trap water – Place sand granular insecticide in areas where stagnant water cannot be easily removed – Ensure all refuse bins are covered, recycling bins are not overflowing, and all damaged bulk bins are replaced. – Ensure all bins have working stoppers to prevent leakage of sullage water, and entry point for rats. – Remove food or refuse spillage • Engage and/or assign licensed personnel to: – Carry out fogging (only when there is a mosquito nuisance problem or disease outbreak) – Destroy vector breeding habitats (e.g., mosquito breeding grounds, rat/rodent burrows) if found, and perform treatment where necessary – Undertake vector control measures and vector surveillance regularly at the station and its perimeter. • Practice the 5-steps (B-L-O-C-K) of Mozzie Wipeout at least once a week for the station and around its perimeter, where applicable: – **B**reak up or loosen hardened soil of flower pots or plant boxes (if any) on alternate days – **L**ift and empty flowerpot plates (if any) where possible – **O**verturn pails and wipe their rims, so as to keep water storage containers or pails dry when not in use. – **C**hange water in vases – **K**eep roof gutters clear and place Bti insecticide once a month • Conduct daily housekeeping, cleaning and/or maintenance routine to ensure proper hygiene of the concerned public areas and litter/refuse bins.		• Inspection of rat/rodent burrows • Inspection of cockroaches and flies' droppings		• Periodic checks on potential vector-breeding areas (frequency not specified)	

15 Conclusions

This section will present the summary of conclusions and recommendations from the assessed potential environmental impacts. The unmitigated impact significance and potential residual impact significance of the assessed environmental aspects during construction and operational phases are summarised in Table 15-1 and Table 15-2 below.

A set of Environmental Monitoring and Management Plan (EMMP) has also been developed for each environmental parameter, which will be updated and implemented during construction and operational phases, to ensure the effectiveness of the proposed mitigation measures. The EMMP is described in Section 14 of this ES report.

Table 15-1 Summary of Potential Residual Impact Significance during Construction Phase

Environmental Parameters	EIS Section	Impact Significance with minimum controls	Residual Impact Significance with mitigation measures (if required)
Biodiversity	Section 7	Negligible to Moderate	Negligible to Minor
Hydrology and Surface Water Quality	Section 8	Minor to Moderate	Minor
Air Quality	Section 9	Moderate to Major	Minor
Airborne Noise	Section 10	Negligible to Major	Negligible to Major
Ground-borne Noise and Ground-borne Vibration	Section 11	Negligible to Major	Negligible to Moderate
Soil, Groundwater and Waste Management	Section 12	Negligible to Minor	Negligible to Minor[1]
Vectors	Section 13	Negligible to Minor	Negligible to Minor[1]
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.			

Table 15-2 Summary of Potential Residual Impact Significance during Operational Phase

Environmental Parameters	EIS Section	Impact Significance with minimum controls	Residual Impact Significance with mitigation measures (if required)
Biodiversity	Section 7	Negligible to Moderate	Negligible to Minor
Hydrology and Surface Water Quality	Section 8	Minor	Minor[1]
Air Quality	Section 9	Minor	Minor[1]
Airborne Noise	Section 10	Negligible	Negligible[1]
Ground-borne Noise and Ground-borne Vibration	Section 11	Minor	Minor[1]
Soil, Groundwater and Waste Management	Section 12	Negligible to Minor	Negligible to Minor[1]

Environmental Parameters	EIS Section	Impact Significance with minimum controls	Residual Impact Significance with mitigation measures (if required)
Vectors	Section 13	Negligible to Minor	Negligible to Minor[1]
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.			

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