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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

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Volume 2 of 5

8 Hydrology and Surface Water Quality

This section provides an overview of the hydrology and surface water quality baseline environment within its study area of this Project.

8.1 Introduction

This section includes the assessment of baseline conditions of hydrology and surface water quality within the study area (same as defined in Section 6.1), as well as the evaluation of the potential impacts on them, arising from activities during the Projects' construction and operational phases. Based on the analysis of preliminary (e.g., visual observations during site reconnaissance and surveys, hydrology and surface water quality sampling and analysis, etc.) and secondary data (e.g., publicly available secondary data and data provided by the Client), baseline conditions have been established and presented. These findings were subsequently used to analyse the changes that might occur due to the impacts associated with construction and operational activities of the Project. Sensitive receptors were identified and classified according to the sensitivity categorization defined in Section 6.2.2) of this Report. As part of impact prediction, potential sources of impact from the Project that could affect the identified sensitive receptors and the minimum controls put in place to reduce them were also described for impact prediction. Based on the baseline survey, an impact evaluation (refer to Section 8.7) and EMMP development (refer to Section 14) were carried out.

The scope of work of the hydrology and water quality impact assessment is consisted of:

- To review the data provided by the Client and desktop research of publicly available data to understand the topographic and hydrographic characteristics of the Study Area;
- To conduct site reconnaissance survey for a better understanding of the Study Area's topography, hydrology, land cover and existing watercourses with their properties (i.e., locations, water flow conditions and bank characteristics);
- To identify the sampling locations for in-situ and ex-situ water quality analysis of existing watercourses located within the Study Area;
- To conduct hydrology and water quality impact analysis to assess the potential impacts of the Project during construction and operational phases;
- To propose mitigation measures to mitigate the potential impacts; and
- To propose EMMP to manage and monitor potential hydrological and water quality that could be impacted by the Project during construction and operational phases.

8.2 Methodology and Assumptions

This section details the methodology used to carry out baseline studies as well as impact assessment on hydrology and water quality.

8.2.1 Hydrology and Surface Water Quality Baseline Study

Hydrology and water quality baseline study was carried out by the combination of desktop research (i.e., review of publicly available secondary data, data provided by the Client, previous studies carried out within the Project Site or its vicinity) and field surveys (including the collection and analysis of primary data such as water quality and visual observations during site surveys). Subsequently, this data was collated, analysed and compared to the selected criteria, where applicable (refer to the Section 8.4). Following sub-sections detail the methodologies used for data collection and analysis of the collected baseline data.

8.2.1.1 Data Collection Methodology

8.2.1.1.1 Desktop Assessment (Secondary Data Collection)

Desktop research consisted of a review of secondary data (including existing topographic data, vegetation cover, existing land use and development activities, satellite images, etc.) which aided in determining the location of existing watercourses within the study area. The topographic survey data provided by the Client and surveyor, as well as catchment map (i.e., the source of water flow to existing reservoirs) from PUB website [W-1] were used to support the findings of the hydrological survey. The information, retrieved during the desktop research, comprised of publicly available data from government and technical agencies, existing available data (e.g., online satellite images), as well as published books, relevant articles, and other online sources. In addition, the baseline information for sampling locations as shown in Table 8-1 was referred to the secondary data from the concurrent study [R-78].

Table 8-1 Secondary data of baseline water quality from concurrent study [R-78]

S/N	Monitoring Location	Justification	Photo of Monitoring Location
WQ1	Upstream of Pang Sua Canal	To capture the water quality of water flowing into the Pang Sua Canal.	
WQ2	Upstream of Pang Sua Canal	To capture water quality of water in the upstream of Pang Sua Canal.	
WQ3	Midstream of Pang Sua Canal	To capture the water quality at midstream of Pang Sua Canal.	

8.2.1.1.2 Field Survey and Sampling Events (Primary Data Collection)

The activities performed as part of the field assessment included the following:

- To evaluate the accessibility of the watercourses through existing tracks;
- To verify the information collected from the available topographic surveys and satellite images;
- To identify and map out the location of existing watercourses within the study area;
- To determine the flow conditions and bank characteristics of the identified watercourses during dry and wet weather conditions; and
- To observe and record water quality indicators in existing watercourses within the study area (e.g., physical parameters such as colour, turbidity, odour, etc).

8.2.1.1.2.1 Hydrological Survey Methodology

The hydrological survey was conducted by casual exploration methods to identify and outline existing watercourses within the study area. The watercourse conditions, such as stream bank characteristics (e.g., natural bank or artificial bank), and flow velocity (e.g., indicative water depth, stagnant or continuous flow, estimated flow velocity) were identified based on visual observations and professional experience. A Global Positioning System (GPS) device was used to track the hydrological survey route. The GPS data was then synchronized with the photos taken on-site to identify the exact location of identified watercourses.

8.2.1.1.2.2 Surface Water Quality Survey Methodology

As mentioned in the sub-section above, major watercourses present in the study area were identified during hydrological site surveys. Subsequently, the sampling locations were selected at identified watercourses to collect surface water samples that would accurately represent the baseline surface water quality.

In order to get comprehensive data that is representative of baseline conditions of water quality and to capture the possible changes in water quality parameters over time and different events, identified watercourses were sampled during different weather and tide conditions. Dry weather conditions are defined as conditions after a continuous 48-hour period of no-rain, while wet weather conditions are defined as a rainfall event having more than ten (10) mm of rainfall, with water samples to be collected within three (3) hours after the rain stops. Two (2) dry weather ("normal conditions") and one (1) wet weather samples were collected from the sampling stations at inland watercourses with perennial flow, while only one (1) wet-weather sample was collected from the sampling station at watercourses with ephemeral flow. In addition to the inland watercourses, tidal-influenced watercourses were also sampled corresponding to lower water at receding time during Spring tide. Wet weather sampling were conducted at receding tide of the day.

The location of water quality stations within the Study Area was shown in Figure 8-1 and Table 8-2 summarized the rationale for the selection of each of the water quality sampling stations. Five (5) water quality stations were located at the upstream (i.e., WQ1, WQ2), midstream (i.e., WQ3, WQ4) and downstream (i.e., WQ5) of Pang Sua Canal. The location of stations WQ1 and WQ2 were selected to capture the water quality at the upstream of Pang Sua Canal which receiving water from upstream drains and surroundings residential area of the canal. Stations WQ3 and WQ4 were selected to capture the water quality of the midstream which receiving runoff from the residential area. Station WQ5 was selected to capture the water quality of downstream of Pang Sua Canal before flowing into Kranji Reservoir. Another ten (10) water quality stations (i.e., WQ6, WQ7, WQ8, WQ9A, WQ9, WQ10A, WQ10, WQ11A, WQ11 and WQ12) were sampled along Sungei Pang Sua as well as at the streams (i.e., Stream 1) and drains (i.e., E63 Drain, Drain 3 and Drain 6) which eventually discharge to Sungei Pang Sua. Three (3) water quality stations (i.e., WQ13, WQ14 and WQ15) were also sampled at the marine area near Sungei Pang Sua in order to capture the water quality from Sungei Pang Sua.

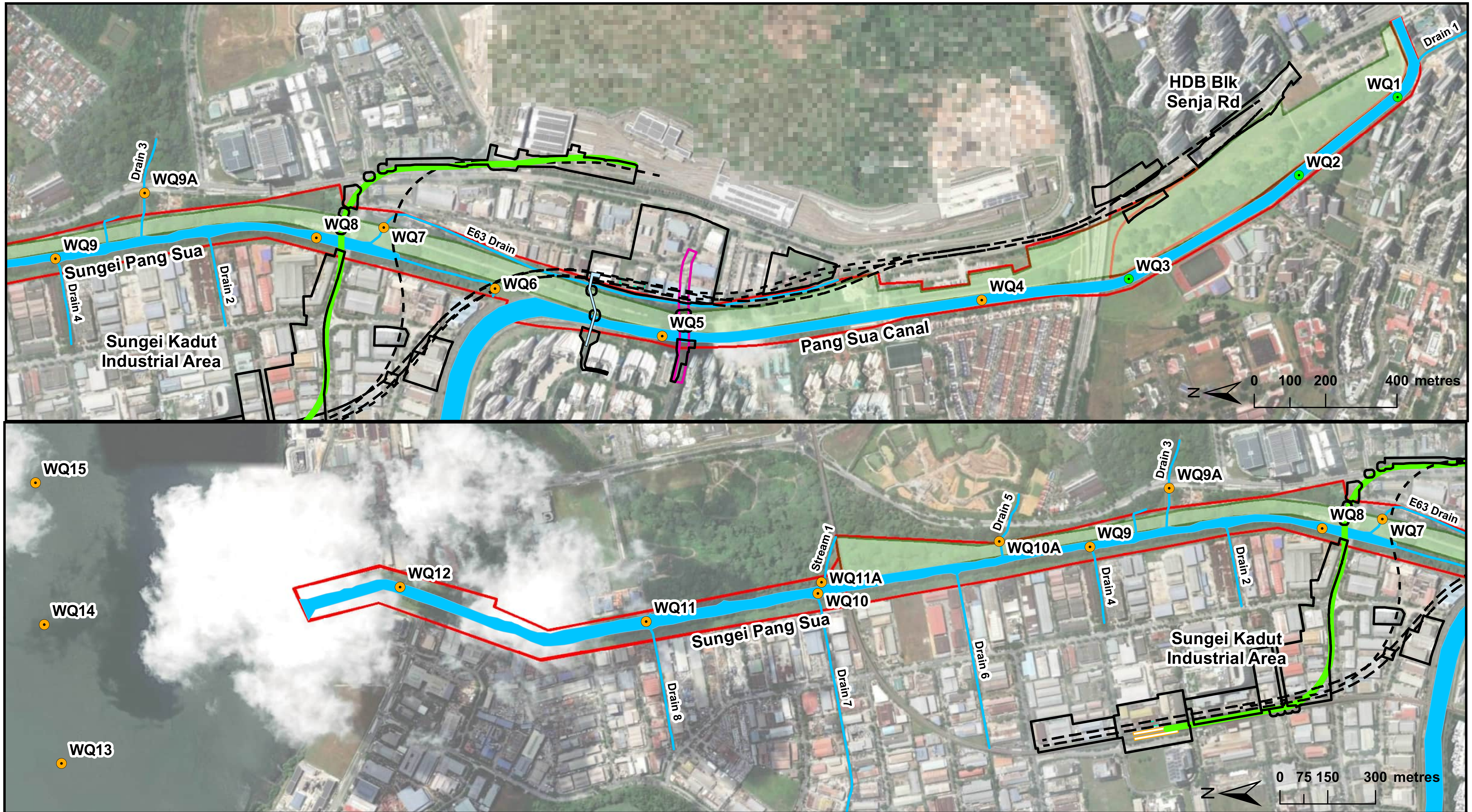
For this study, in-situ water quality parameters were measured using a calibrated multi-parameter digital sensor (YSI ProDSS) with United States Environmental Protection Agency (USEPA) approved testing methods for water quality parameters and include:

- Dissolved Oxygen (DO)
- pH
- Salinity
- Conductivity
- Temperature
- Total Dissolved Solids (TDS)
- Turbidity

The ex-situ parameters analysed by Marchwood Laboratory Services Pte Ltd (MLS) are listed as below:

- Biochemical Oxygen Demand (BOD5)
- Chemical Oxygen Demand (COD)
- Total Organic Carbon (TOC)
- Total Suspended Solids (TSS)
- Oil & Grease (Total)
- Total Nitrogen (TN)
- Ammonia (NH4-N)
- Nitrate (NO3-N)
- Total Phosphorus (TP)
- Orthophosphate (PO4-P)
- Enterococcus
- Chloride (Cl)

- Cyanide (CN)
- Arsenic (As)
- Barium (Ba)
- Calcium (Ca)
- Cadmium (Cd)
- Chromium (Cr)
- Copper (Cu)
- Iron (Fe)
- Lead (Pb)
- Zinc (Zn)
- Mercury (Hg)
- Chlorophyll-a
- Phenol



Legend

Water Quality Sampling Stations

- Existing Stations
- Proposed Stations
- Proposed Pedestrian Overhead Bridge
- Proposed Worksite Areas
- Potential Future Infrastructure
- Proposed DTL2e Tunnel Alignment
- Proposed Vehicular Bridge
- Watercourses
- Existing Vegetated Area
- Biodiversity Study Area

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

Qualified Person Endorsement : N/A

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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 WATER QUALITY SAMPLING LOCATIONS WITHIN/SURROUNDING THE STUDY AREA

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
SAG	HHL	JAG	8 -1	A	1 of 1

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SAG	MAY 2023	N/A	A3

Note: Source of basemap - OneMap

Table 8-2 Rationale for the selection of proposed water quality sampling locations with photos

S/N	Monitoring Location	Justification	Photo of Monitoring Location
WQ4	Midstream of Pang Sua Canal	To capture water quality of mixing discharge of culvert discharge from residential areas along the Pang Sua Canal.	
WQ5	Downstream of Pang Sua Canal	To capture water quality of water discharging at downstream of Pang Sua Canal before flowing into Kranji Reservoir.	
WQ6	Upstream of Sungei Pang Sua	To capture water quality at upstream of Sungei Pang Sua.	
WQ7	E63 Drain	To capture water quality at E63 Drain before discharging to Sungei Pang Sua.	
WQ8	Midstream of Sungei Pang Sua	To capture water quality at midstream of Sungei Pang Sua.	
WQ9A	Drain 3	To capture water quality of Drain 3 before discharge to Sungei Pang Sua.	
WQ9	Midstream of Sungei Pang Sua	To capture water quality at midstream of Sungei Pang Sua.	

S/N	Monitoring Location	Justification	Photo of Monitoring Location
WQ10A	Drain 6	To capture water quality at Drain 6 before discharge to Sungei Pang Sua.	
WQ10	Midstream of Sungei Pang Sua	To capture water quality of mixing water from midstream of Sungei Pang Sua and freshwater stream from nearby forest area.	
WQ11A	Stream 1	To capture water quality of a stream inside forested area before discharging to Sungei Pang Sua.	
WQ11	Downstream of Sungei Pang Sua	To capture water quality of mixing water from downstream of Sungei Pang Sua and nearby drain.	
WQ12	Downstream of Sungei Pang Sua	To capture water quality of mixing water before the river mouth of Sungei Pang Sua and nearby drain.	
WQ13	Marine area	To capture water quality of west coast of Sungei Pang Sua.	
WQ14	Marine area	To capture water quality at mixing water of sea and Sungei Pang Sua.	

S/N	Monitoring Location	Justification	Photo of Monitoring Location
WQ15	Marine area	To capture water quality of the mixing water at east coast near river mouth of Sungei Pang Sua and nearby drain outlet.	

8.2.1.2 Baseline Data Analysis and Assessment Methodology

The activities performed as part of the analysis and assessment of baseline data included the following:

- Analysis and manipulation of collected data by using various specialized software programmes;
- Evaluation of the accuracy of collected primary data and comparison and coupling with relevant available secondary data;
- Development of maps and figures for better understanding and comparison of data; and
- Comparison of data to selected criteria

8.2.1.2.1 Hydrological Baseline Bata Assessment

The elevation and slope maps of the study area were developed based on surveyed topographic survey data using GIS technique. In order to determine the exact locations of each of the identified watercourses, GPS data from surveys were synchronised with the photos taken on site. Catchment analysis was conducted based on surveyed topographic data, publicly available catchment map of Singapore developed by PUB [W-1], previously developed elevation and slope maps. Catchment delineation was conducted to identify the sub-catchment area and the main sources of water that feed each of the watercourses within the study area and also to understand how the runoff flows within the Site.

8.2.1.2.2 Surface Water Quality Baseline Assessment Criteria

The baseline water quality of the watercourses located within the Assessment Area was determined by comparing the selected parameters against the NEA Trade Effluent Discharge Limits [R-18]. This comparison could be used to determine whether the existing baseline water quality of the watercourses within the Assessment Area compiles with NEA limits or already exceeds these limits since the industrial areas were identified along the watercourses. To assess the water quality for few beneficial uses such as mangroves habitat, the baseline water quality was compared to Singapore's Marine Water Quality (SMWQ) Guideline [R-80]. To assess whether the surface water quality within the study area suitable for aquatic life or not or the surface water treatability for drinking purpose, the selected parameters were compared to international water quality criteria for aquatic life from other countries (i.e., Australia & New Zealand [R-12], Canada [R-13], Philippines [R-14], and Malaysia [R-16], as well as criteria set up by international organisations including ASEAN guidelines [R-17 & R-72], United Nations Economic Commission for Europe [R-9], World Health Organization [R-10] and USEPA [R-11]. The relevant limits and guidelines for water quality parameters were summarised in Table 8-3; however, where no guidelines exist, the monitored results would be considered as the baseline.

Table 8-3 Water quality guidelines and criteria

Parameter	NEA Trade Effluent Discharge Limits[1] W	NEA Trade Effluent Discharge Limits[1] CW	International Aquatic Life Criteria[2]	SG Marine Water Quality Guidelines[4]
pH	6 - 9		6 – 9*	7.5 - 8.5
Temperature (°C)	≤ 45		< 2°C above the maximum ambient temperature	≤ 1 °C increase over seasonal maximum ambient

Parameter	NEA Trade Effluent Discharge Limits[1] W	NEA Trade Effluent Discharge Limits[1] CW	International Aquatic Life Criteria[2]	SG Marine Water Quality Guidelines[4]
Dissolved Oxygen, DO (mg/L)	-		≥ 4 ≥ 5 (freshwater)*	≥ 4 (median)
Turbidity (NTU)	-		≤ 50	≤ 3.5 (any time)
Salinity (psu)	-		-	≤ ±5 % from background median
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)*	≤ 10 % increase over seasonal average
Oil & Grease (Total) (mg/L)	≤ 10	≤ 1	≤ 0.14	≤ 5.0 (any time)
Total Phosphorous, TP (mg/L)	-		Eutrophic limit: 0.075 mg/L	≤ 1.0 (any time)
Orthophosphate, PO_4-P (mg/L)	≤ 1.63 (equivalent to 5 as PO_4)	≤ 0.65 (equivalent to 2 as PO_4)	≤ 0.015	≤ 0.0065 (median) (equivalent to 0.02 as PO4)
Total Nitrogen, TN (mg/L)	-		Eutrophic Limit: 1.5 mg/L	-
Ammoniacal Nitrogen, NH_4-N (mg/L)	-		≤ 0.07 ≤ 0.3 (freshwater)*	≤ 0.03 (any time)
Nitrate, NO_3-N (mg/L)	-	≤ 4.52 (equivalent to 20 as NO3)	≤ 0.06	≤ 0.03 (any time)
***Enterococcus*[3] (CFU/100 mL)**	-		≤ 35	≤ 200 (95^{th} percentile)
Chloride, Cl (mg/L)	-	≤ 250	-	-
Cyanide, CN (mg/L)	≤ 0.1		≤ 0.007	-
Calcium, Ca (mg/L)	-	≤ 150	-	-
Chlorophyll-a (μg/L)	-		-	≤ 20.0 (median)
Arsenic (μg/L)	≤ 100	≤ 10	-	≤ 13.0 (median)
Barium (μg/L)	≤ 2,000	≤ 1,000	-	-
Cadmium, Cd (μg/L)	≤ 100	≤ 3	≤ 10	≤ 5.5 (median)
Chromium, Cr (μg/L)	≤ 1,000	≤ 50	-	≤ 4.4 (median)
Lead, Pb (μg/L)	≤ 100		Acute LOEL[5]: 82 Chronic LOEL[5]: 3.2	≤ 4.4 (median)
Iron, Fe (μg/L)	≤ 10,000	≤ 1,000	-	-
Zinc, Zn (μg/L)	≤ 1,000	≤ 500	-	≤ 15.0 (median)
Nickel, Ni (μg/L)	≤ 1,000	≤ 100	-	-
Copper, Cu (μg/L)	≤ 100		≤ 8.0	≤ 1.3 (median)
Mercury, Hg (μg/L)	≤ 50	≤ 1	≤ 0.16	≤ 0.4 (median)
Phenol (mg/L)	≤ 0.2	-	≤ 0.12	-

Parameter	NEA Trade Effluent Discharge Limits[1] W	CW	International Aquatic Life Criteria[2]	SG Marine Water Quality Guidelines[4]

Notes:
1. **NEA Trade Effluent Discharge Limits are for watercourse (W) and controlled watercourse (CW)**
2. **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]**
3. **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**
4. **The guideline limit values are selected based on stricter values of suitable beneficiary uses (i.e., seagrass/mangroves) which subjected to the study**
5. **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].**

8.2.1.2.3 Impact Assessment Methodology

The detailed prediction and evaluation methodologies for Project impacts on hydrology and surface water quality during construction and operational phases have been described in following sections.

8.2.1.2.3.1 Qualitative Impact Assessment

The potential impacts from Project on hydrology and surface water quality were assessed through qualitative approach based on primary and secondary data, technical experiences on previous projects and the understanding of the Project's activities of construction and operational phases. The potential sources of Project impacts and the potential environmental parameter affected, and associated Impacts were identified accordingly based on planned Project's activities. To collect primary and secondary data, the baseline condition of Assessment Area was studied through site reconnaissance and surveys as well as existing information provided by the Client. Subsequently, potential sensitive receptors were identified based on the baseline study. Each sensitive receptor was assessed, and each impact was evaluated its significance based on assessment criteria as provided in Section 6.4.

8.2.1.2.3.2 Quantitative Impact Assessment

The potential short term impacts during construction phase could cause significant riverbed change on Sungei Pang Sua based on planned Project's activities. Therefore, quantitative impact assessment was conducted using numerical modelling approach to assess the potential short-term impact on hydrology of Sungei Pang Sua. The impact during operational phase would be further assessed quantitatively if any significant change in riverbed of Sungei Pang Sua during construction phase from the simulated model result.

(i) Numerical Modelling Approach

MIKE 21 FM is a software used for hydrodynamics, sediment dynamics and water quality modelling. It is a modular product and includes simulation engines that are aimed at a very wide range of applications. These include modelling of tidal flows, storm surge, advection-dispersion, oil spills, water quality, mud transport, sand transport, harbour disturbance and wave propagation.

(ii) Model Setup

Flexible mesh was created for the whole model grid using MIKE Zero Mesh Generator. Coarse grid cell size is applied at the further offshore area while a finer grid cell size of less than 5m is used for Sungei Pang Sua. The bathymetry data within the Sungei Pang Sua were obtained from surveys and incorporated in the model (Figure 8-2). The boundary of the grid was generated from Global Tide Model (GTM). GTM utilised the latest 17 years' multi-mission measurements from TOPEX/Poseidon, Jason-1 and Jason-2 satellite altimetry for sea level residual analysis. Based on these measurements, harmonic constituents have been calculated. The major constituents in the tidal spectra were extracted as boundary. The provided constituents consider the semidiurnal M2, S2, K2, N2, diurnal S1, K1, O1, P1, Q1 and the shallow water constituent M4.

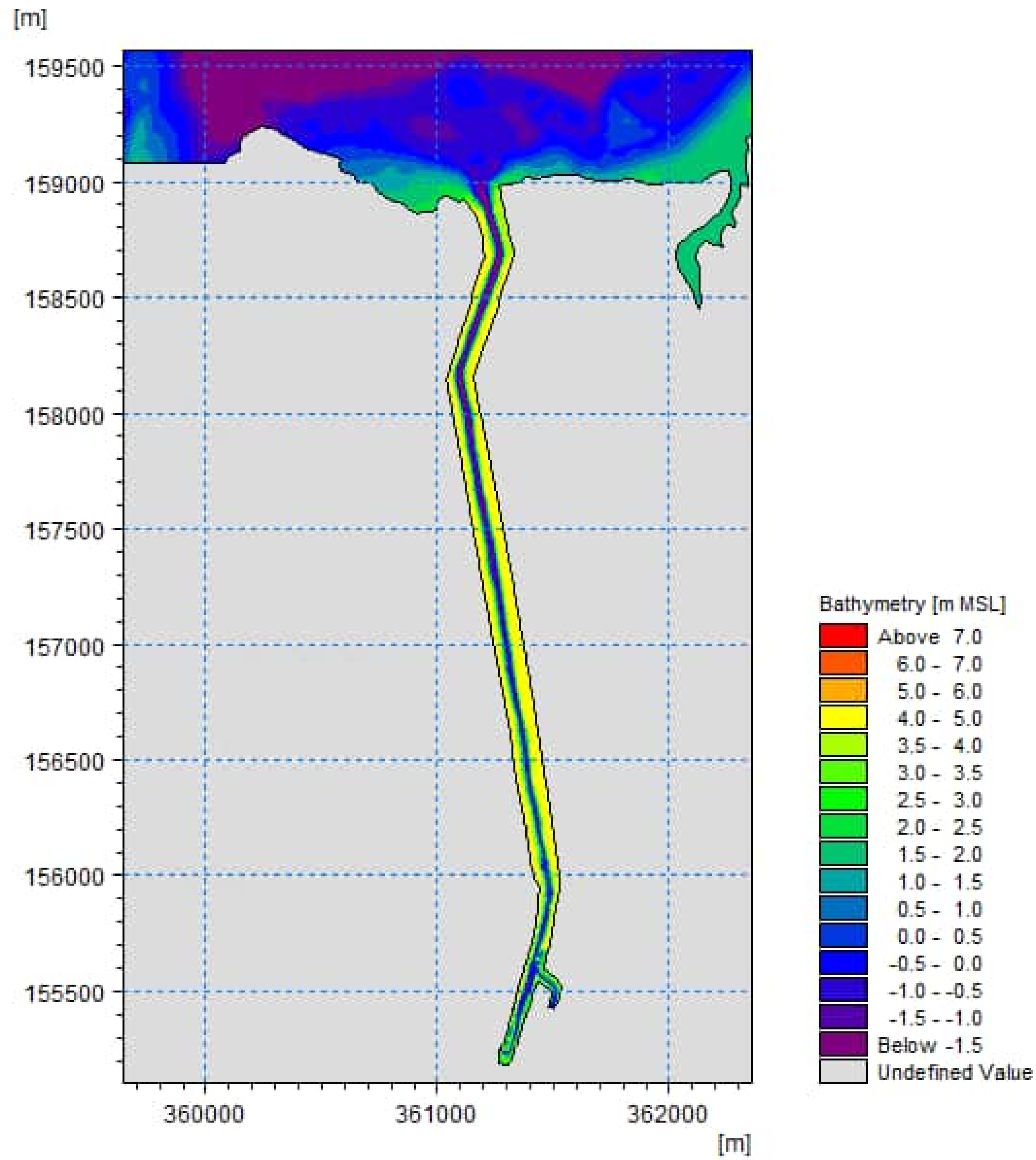


Figure 8-2 Model Bathymetry at the Assessment Area (positive values indicate the ground level is above mean sea level (MSL), while negative values indicate the ground level is below MSL)

(iii) Hydrodynamic Impact Assessment

Hydrodynamic impact assessment was conducted to assess potential changes in flow condition, i.e., current velocity and direction, in Sungei Pang Sua the impacts caused by the construction of the alignment. Based on the engineering inputs, due to tunnelling activity crossing Sungei Pang Sua, there might be few areas with localised settlement occur along Sungei Pang Sua. Maximum depth of the localised settlement is only 1cm-2cm from the existing riverbed. However, hydrodynamic modelling was still conducted to analyse potential changes in current within Sungei Pang Sua. This was used to assess the hydrodynamics impacts due to the settlement from alignment construction. The hydrodynamic modelling was developed for the scenarios for (1) the existing hydrodynamic condition as the baseline case, and (2) the construction phase, which forecasted the settlement of 10~20 mm at the upstream of Sungei Pang Sua. The production periods were 14-day NE monsoon season covering a tidal cycle in 2021. The model scenarios are tabulated in Table 8-4.

Table 8-4 Scenarios for hydrodynamic impact assessment

No.	Scenario	Simulation Period	Description
1	Baseline	14-day NE monsoon	Bathymetry within Sungei Pang Sua: as per survey results
2	Construction phase	14-day NE monsoon	Bathymetry within Sungei Pang Sua: settlement of 10~20 mm at the upstream of Sungei Pang Sua

Based on the model simulation results, quantitative methods to evaluate the impacts on the hydrodynamics include:

- Statistical 2D maps of mean flow speed for the conditions for the baseline scenario, construction phase, and the differences between the construction phase and the baseline scenario. Mean flow speed is the numerical statistical mean of the current speeds at any given point over the 14-day simulation period. The differences in mean flow speed are defined as:

$$\text{Differences in mean flow speed (m/s)} = \text{Mean flow speed in construction phase (m/s)} - \text{Mean flow speed in baseline (m/s)}$$

- Statistical 2D maps of maximum flow speed for the conditions for the baseline scenario, construction phase, and the differences between the construction phase and the baseline scenario. Maximum flow speed is the numerical statistical maximum of the flow speed at any given point over the 14-day simulation period. The differences in maximum flow speed are defined as:

$$\text{Differences in maximum flow speed (m/s)} = \text{Maximum flow speed in construction phase (m/s)} - \text{Maximum flow speed in baseline (m/s)}$$

(iv) Morphology Impact Assessment

Morphological assessment is usually conducted to understand riverbed morphology and its changes due to the Project. This assessment was conducted for the Project to determine the possible morphological changes after the occurrence of the localised settlement due to the construction of the alignment crossing over Sungei Pang Sua. Morphological modelling was developed for the construction scenario, which forecasted the localised settlement of 10 - 20 mm at the upstream of Sungei Pang Sua.

Based on the model simulation results, quantitative methods to evaluate the impacts on the morphological include:

- Changes in riverbed morphology; and
- Estimation the duration that the settlement at the upstream of Sungei Pang Sua would be back to the existing condition.

8.3 Potential Sources of Impacts

This section discusses the potential environmental impacts arising from the construction and operational phases of the projects.

8.3.1 Construction Phase

Nearby watercourses could be potentially exposed to hydrological flow change and water contamination due to the activities taking place during the project's construction phase. The sources that could potentially impact on the watercourses' quality and quantity include, but are not limited to, those listed in Table 8-5.

Table 8-5 Potential hydrology and water quality impacts during the construction phase

Activity	Potential Source of Impacts	Potential Environmental Parameter Affected and Associated Impacts
Land clearing, earthworks and excavation, main construction works (i.e., building demolition, ground improvement works, bridge construction, launch/retrieval shaft construction, tunnel boring works, road and utilities diversion, and site office, etc.)	• Run-off from exposed soil surface, earth work areas, soil stockpiles; • Stormwater/groundwater pumped out from excavated areas; • Release of grouting and cement materials; • Run-off from dust suppression spray; • Heavy rain during construction; • Altering existing drainage system within the study area; and • Change in land use due to proposed development (increase impervious surface and reduce seepage to soil).	Hydrology: • Increased stormwater peak flow contributions to the channel can lead to increased water level and subsequent flooding of surrounding areas adjacent to the watercourses due to the land use change from land clearing; • Altered dry weather flow which can lead to impact on downstream aquatic habitats and communities; • Stormwater run-off from exposed and unstable slopes may cause soil erosion and accretion; • Stream bed level change along Sungei Pang Sua due to ground settlement by tunnel boring works; • Increased water flow velocity and water level of watercourses due to changed land use, leading to erosion along the watercourses; and • Flooding risk due to alteration of existing drainage system. Water Quality: • Elevated levels of suspended solids leading to increased turbidity and sedimentation rates, solid waste, toxic material, etc; and • Increase in the levels of oil, grease, and other chemical substances.
Storage and disposal of liquid and solid wastes	• Improper handling, transfer, storage, and disposal of spoil and solid waste (e.g., excavated earth, construction debris). • Improper management of sewage effluents from on-site; and • Inappropriate discharge of domestic sewage and poor maintenance of the portable chemical toilet, storage tanks and septic tanks (e.g., overflow or overload).	Water Quality: • Stormwater contamination; • Elevated levels of suspended solids entering watercourses. The waste can also block the temporary drains leading to contamination of receiving watercourses; • Toxic waste generated at temporary work areas can lead to water quality contamination of nearby watercourses; and • Run-off increase in nearby watercourses and potentially contaminate the watercourses located adjacent to the construction sites.

Activity	Potential Source of Impacts	Potential Environmental Parameter Affected and Associated Impacts
Use and storage of chemical substances, and refuelling activities	• Improper handling, transfer, and storage of chemical substances; • Accidental spill and leaks; and • Fuel and lubricants spillage from maintenance of construction vehicles and mechanical equipment.	Water Quality • Stormwater contamination; and • Elevated levels of oil, grease and other chemical substances in the nearby watercourses.

8.3.2 Operational Phase

Watercourses can potentially be exposed to hydrological flow change and water contamination due to the activities taking place during the Project's operational phase. The sources that could potentially impact on watercourses' quality and quantity include but are not limited to those listed in Table 8-6.

Table 8-6 Potential hydrology and water quality impacts during the operational phase

Activity	Potential Source of Impacts	Potential Associated Impacts
Permanent land use change	• Heavy rain and stormwater wash-off pollutants built-up in the new development area and discharge to the surrounding watercourses; • Increase of runoff peak flow draining to the stream or drain during storm events due to the increase in urbanized area; and • Reduce the baseflow (sub-water discharge) due to the change in land use of the new development	Hydrology: • Increased stormwater peak flow contributions to the channel can lead to increased water level and subsequent flooding of surrounding areas adjacent to the stream/drain; • Stormwater run-off from exposed and unstable slopes may cause soil erosion and accretion; and • Increased flow velocity due to changed land use leading to erosion along the waterway. Water Quality: • Elevated suspended solids (e.g., silt and sediment) and pollutants (e.g., heavy metals and nutrients from human activities) in stormwater runoff.
Improper management of liquid and solid wastes	• Accidental spills and leaks (e.g., from maintenance activities or during storm event); and • Improper handling, transfer, and storage of solid and liquid wastes (e.g., rubbish collection and sewage disposal);	Water Quality: • Solid wastes generated from human activities can lead to elevated levels of suspended solids entering watercourses. The wastes can also block the watercourse and leading to contamination of receiving watercourses; and • Inappropriate discharge of liquid wastes to the watercourse results in contamination of nearby or downstream watercourses.

8.4 Hydrology and Water Quality Baseline Findings

This report is based on the site surveys and surface water samples collected till March 2022 (for detailed site visit programme refer to Table 6-3). The assessment and site surveys were mainly conducted by the following AECOM personnel:

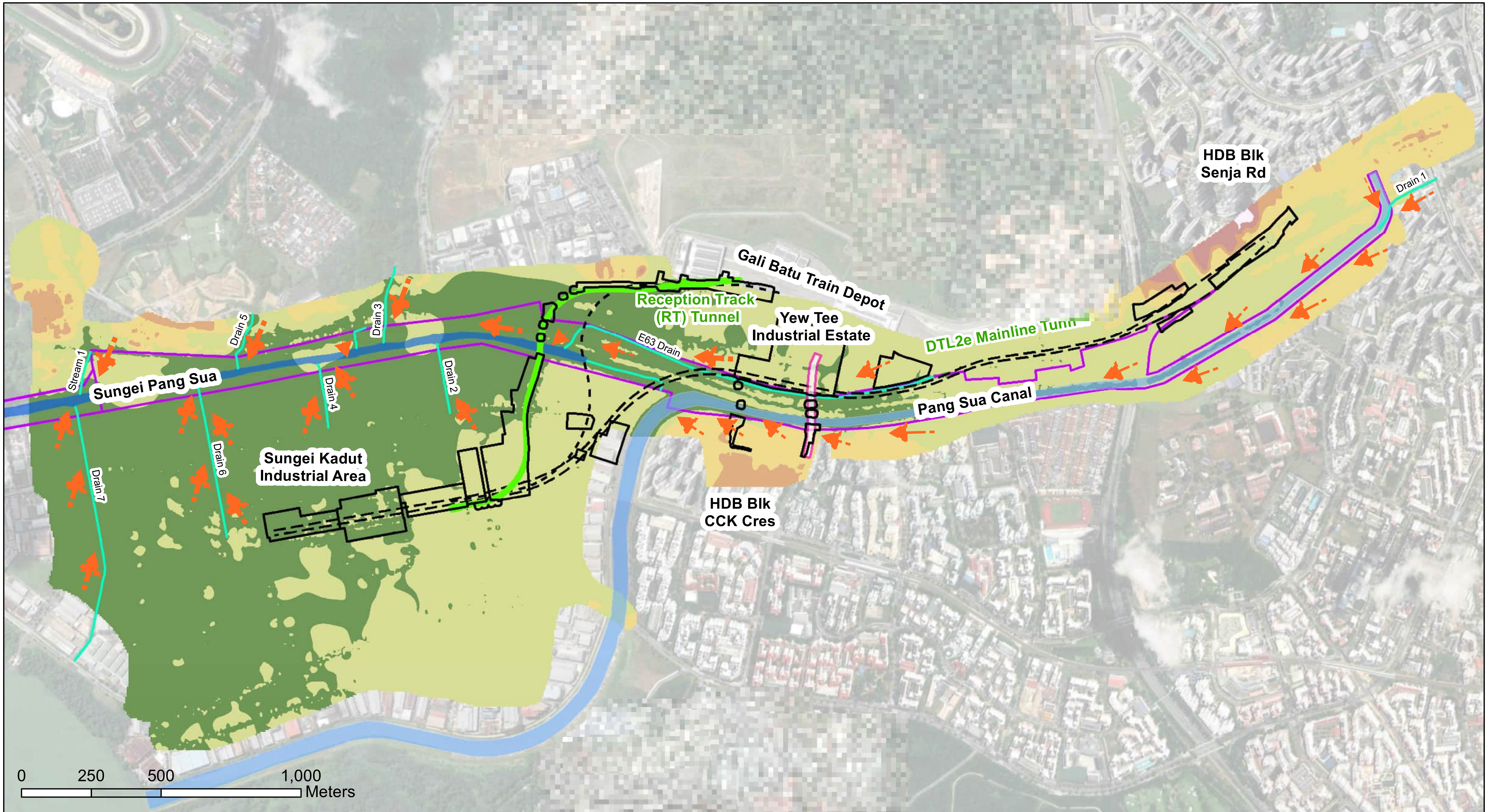
- Dr. Thanh Nguyen (Technical Reviewer of Hydrology and Surface Water Quality);
- Ms. Jacquelynn Chia (Hydrology and Surface Water Quality Specialist); and
- Mr. Grujica Sarenac (Hydrology and Surface Water Quality Specialist).

8.4.1 Hydrological Conditions

During site reconnaissance, Pang Sua Canal, Sungei Pang Sua, and marine area were identified as major watercourses within the Study Area. Their locations are shown in Figure 8-1. The baseline hydrological conditions in the study area were analysed based on site observations (refer to Table 8-7) and secondary data from concurrent study [R-78]. Photographic record (refer to Table 8-7) of each stream, drain, Sungei Pang Sua, and Pang Sua Canal were taken during every site survey. Topography of Study Area as summarized in Section 4.4 was used to generate the elevation and slope maps of the site using GIS. They were then overlaid with hydrological network as shown in Figure 8-3 and Figure 8-4 for baseline hydrological assessment.

As shown in Figure 8-3, the existing elevation along the proposed DTL2e Tunnel Alignment and above ground potential future infrastructure generally are in flat terrain (i.e., less than 10 mSHD) due to urban surroundings. Along the proposed alignment, highest elevation could be observed at north-eastern area near residential area at Senja Road. The low-lying areas along the proposed DTL2e alignment near Yew Tee Industrial Estate are mostly the watercourses such as Pang Sua Canal and drains. Besides, HDB blocks at Senja Road and Choa Chu Kang Crescent located at the south and centre of the Study Area has elevation up to 20.0 mSHD. The Sungei Kadut Industrial Area has relatively flat terrain with elevation below 5 mSHD. The significant steep slopes more than 30% were observed in the northern and southern of the Study Area as shown in Figure 8-4. Mild slopes (15 - 30%) were observed along Pang Sua Canal. The overall area of the Sungei Kadut Industrial Area and around Reception Track Tunnel almost has no significant slope variation (i.e., less than 15%) except that steep slope (more than 40%) observed at northern area of Reception Track Tunnel.

The baseline hydrological conditions in the watercourses within the Study Area were stated based on site observations (refer to Table 8-7). The Pang Sua Canal has low perennial water flow ranging from 0.2 to 0.6 m/s observed during dry weather and a higher flow velocity which more than 2 m/s after heavy storm throughout the canal. The surface runoff generally drains from drainage networks collecting surface runoff of Pang Sua Canal from surrounding residential areas along the Canal before drains into the Kranji Reservoir eventually. Sungei Pang Sua is a tidal-influenced stream and has a slow perennial flow (ranged from 0.04 to 0.3 m/s) even leading to almost stagnant condition in some areas. A few surface runoff discharge outlets which originated from urbanized area (i.e., E63 Drain, Drain 2, Drain 3, Drain 4, Drain 5, Drain 6, Drain 7 and Drain 8) and forest area (i.e., Stream 1) were observed along the Sungei Pang Sua. All the streams and drains within the Study Area did not have obvious smell based on site observation. The flow direction at marine area near to river mouth of Sungei Pang Sua normally was tidal influenced and varying and therefore, depended on the flood and ebb tides during spring and neap tidal periods.



Legend

- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Proposed Worksite Areas
- Proposed Vehicular Bridge
- Pang Sua Canal
- Sungei Pang Sua
- Streams and Drains
- Biodiversity Study Area
- Water Flow Direction

Elevation (mSHD)

- < 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- > 25

N

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

Qualified Person Endorsement : N/A

LTA Endorsement : N/A

Consultant : AECOM

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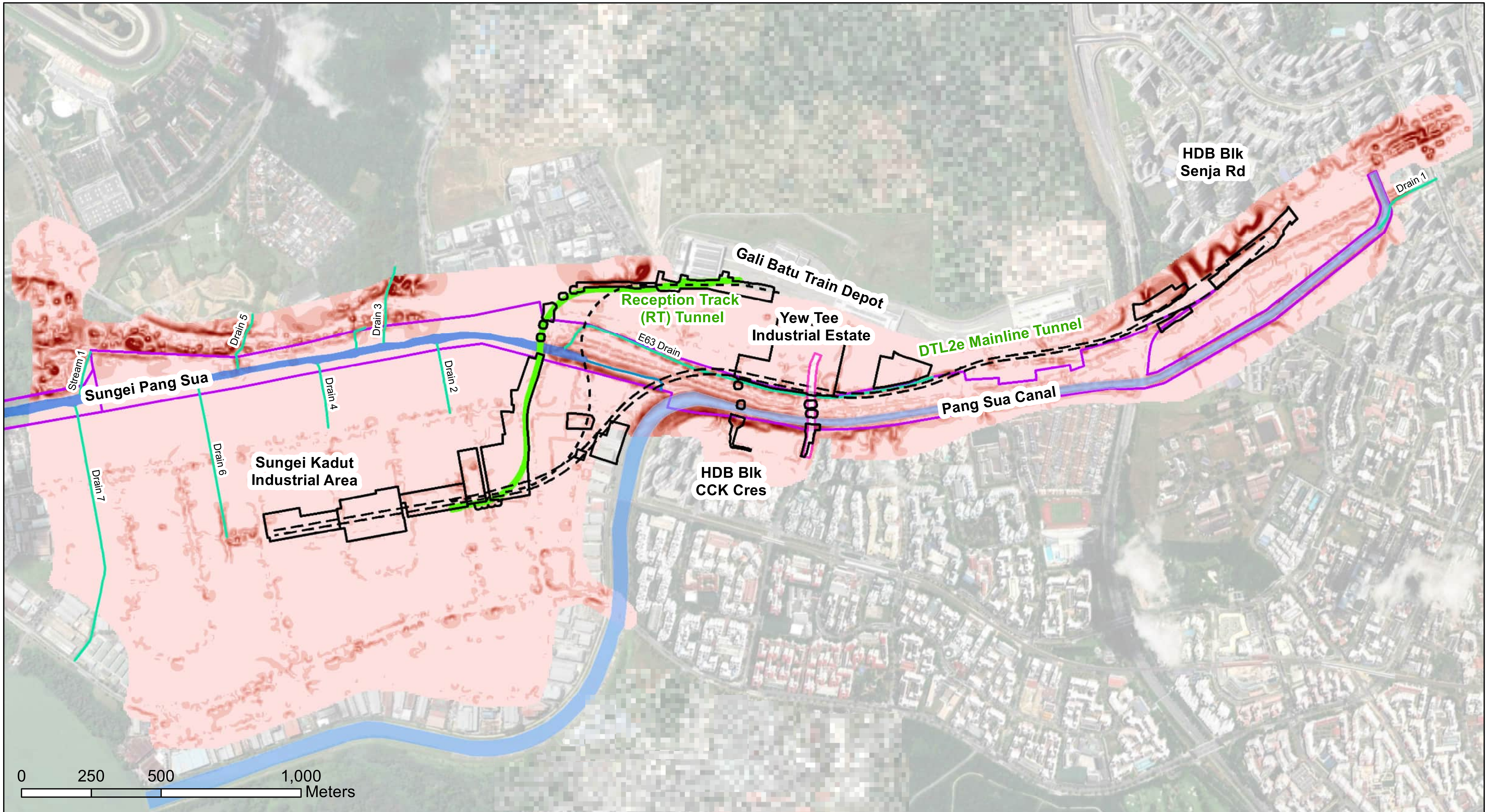
Project Title :
CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
ELEVATION MAP
OF THE STUDY AREA

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
SAG	HHL	JAG	8-3	A	1 of 1
	Drawn SAG	Date MAY 2023	CAD File Name :N/A		A3

Note: Source of basemap - Google Earth Map



Legend

- Proposed DTL2e Tunnel Alignment
- Potential Future Infrastructure
- Proposed Worksite Areas
- Proposed Vehicular Bridge
- Biodiversity Study Area
- Pang Sua Canal
- Sungei Pang Sua
- Streams and Drains

Slope (%)

- < 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- 35 - 40
- > 40

N

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

Qualified Person Endorsement : N/A

LTA Endorsement : N/A

Consultant : AECOM

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Project Title :
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Figure Title :
SLOPE MAP OF THE STUDY AREA

Designed	Checked	Approved	Drawn	Date	Figure No. :	Rev.	Sheet
SAG	HHL	JAG	SAG	MAY 2023	8-4	A	1 of 1

CAD File Name :N/A | A3

Note: Source of basemap - Google Earth Map

Table 8-7 Description of hydrological conditions of watercourses within the study area

Watercourses	Bank Characteristics	Water Flow Conditions	Photos
Pang Sua Canal	Wide concrete canal Estimated canal length within Biodiversity Study Area is approximately 3 km.	• Surface runoff originates from upstream drainage networks collecting surface runoff from surrounding residential areas before reaching the Study Area, and it drains into the Kranji Reservoir eventually. • Perennial flow **During dry weather condition (at surveyed time):** <u>Upstream (WQ1 and WQ2)</u>: • Slow water flow observed at approximately 0.2 - 0.6 m/s • Approximately 16 - 23 cm depth and an approximate width of 500 cm, at time of survey • Water in low turbidity and had no smell <u>Midstream (WQ3 and WQ4)</u>: • Slow water flow observed at approximately 0.25 - 0.6 m/s • Approximately 13 - 23 cm depth and width of 500 cm at time of survey • Water in low turbidity and had no smell <u>Downstream (WQ5):</u> • Slow dry weather flow at approximately 0.4 – 0.5 m/s • Approximately 18 - 22 cm depth and an approximate width of 500 cm, at time of survey • Water was clear and had no smell **During wet weather condition (at surveyed time):** <u>Upstream (WQ1 and WQ2)</u>: • Water flow observed at approximately 0.8 - 1.6 m/s • Approximately 25 m width and cover the entire depth of the canal at time of survey • Water was clear and had no smell <u>Midstream (WQ3 and WQ4)*</u>: • Water flow observed at approximately 1.56 m/s – above 2 m/s • Almost cover the entire depth of the canal at time of survey • Water was turbid <u>Downstream (WQ5)</u>: • Fast flowing water observed • Almost cover the entire depth of the canal at time of survey • Water was turbid and had no smell	Water Quality Station WQ1 (Upstream of Pang Sua Canal) During Dry Weather  During Wet Weather  Water Quality Station WQ2 (Upstream of Pang Sua Canal) During Dry Weather  During Wet Weather  Water Quality Station WQ3 (Midstream of Pang Sua Canal) During Dry Weather  During Wet Weather  Water Quality Station WQ4 (Midstream of Pang Sua Canal) During Dry Weather During Wet Weather

Watercourses	Bank Characteristics	Water Flow Conditions	Photos	
				
			Water Quality Station WQ5 (Downstream of Pang Sua Canal)	
			During Dry Weather 	During Wet Weather 
Sungei Pang Sua	The upstream of stream is concrete drain and covered with dense vegetation. The midstream is natural bank with dense vegetation (i.e., mangroves patches) and extended till its downstream. Estimated stream length within the within Biodiversity Study Area is approximately 3.8 km.	• Surface runoff originates from surrounding vegetation, discharges from industrial area along the stream before discharge to its river mouth. • Perennial flow **During dry weather condition (at surveyed time):** <u>Upstream (WQ6)</u>: • Almost stagnant flow • Approximately 63 cm depth and an approximate width of 400 cm, at the time of survey • Water was turbid and had no smell <u>Midstream (WQ7, WQ8, WQ9A and WQ9, WQ10A, WQ10, WQ11A)</u>: • WQ7: Slow water flow at approximately 0.04 – 0.1 m/s. At downstream of E63 drain (approximate 10 m width drain). Water was not clean but had no smell. • WQ8: Slow water flow observed at approximately 0.05 m/s. Water was clear and had no smell.	Water Quality Station WQ6 (Upstream of Sungei Pang Sua)	
			During Dry Weather 	During Wet Weather 
			Water Quality Station WQ7 (Downstream of E63 Drain)	
			During Dry Weather	During Wet Weather

Watercourses	Bank Characteristics	Water Flow Conditions	Photos
		• WQ9A: Slow water flow observed at approximately 0.015 m/s. Approximately 95 cm depth and an approximate width of 1.3 m, at time of survey. Water was clear and had no smell. • WQ9: Slow water flow observed at approximately 0.07 m/s. Water was clear and has no smell. • WQ10A: Slow water flow observed at approximately 0.02 m/s. Approximately 40 cm depth with width of approximately 200 cm, at time of survey. Water was slightly turbid and has no smell. • WQ10: Slow water flow observed at approximately 0.1 m/s. Water was slightly turbid and has no smell. • WQ11A: Water flow observed at approximately 0.15 m/s. Approximately 50 - 60 cm depth with width of approximately 60 - 70 cm, at time of survey. Water was clear and has no smell. Downstream (WQ11 and WQ12): • Slow water flow observed of approximately 0.08 - 0.1 m/s • Water was turbid and has no smell **During wet weather condition (at surveyed time):** Upstream (WQ6): • Almost stagnant flow • Approximately 68 cm depth and an approximate width of 400 cm, at the time of survey • Water was turbid and has no smell Midstream (WQ7, WQ8, WQ9A and WQ9, WQ10A, WQ10, WQ11A): • WQ7: Slow water flow at approximately 0.14 m/s. At downstream of E63 drain (approximate 10 m width drain). Water was turbid and has no smell. • WQ8: Slow water flow observed at approximately 0.1 m/s. Water was turbid and has no smell. • WQ9A: Slow water flow observed at approximately 0.04 m/s. Approximately 90 cm depth and an approximate width of 1.3 m, at time of survey. Water was turbid and has no smell. • WQ9: Slow water flow observed at approximately 0.09 m/s. Water was clear and has no smell. • WQ10A: Slow water flow observed at approximately 0.1 m/s. Approximately 110 cm depth with width of approximately 200 cm, at time of survey. Water was turbid and has no smell. • WQ10: Slow water flow observed at approximately 0.3 m/s. Water was turbid and has no smell. • WQ11A: Water flow observed at approximately 0.2 m/s. Approximately 60 cm depth with width of approximately 70 cm - 80 cm, at time of survey. Water was clear and has no smell. Downstream (WQ11 and WQ12):	  Water Quality Station WQ8 (Midstream of Sungei Pang Sua) During Dry Weather:  During Wet Weather:  Water Quality Station WQ9A (downstream of Drain 3) During Dry Weather:  During Wet Weather:  Water Quality Station WQ9 (Midstream of Sungei Pang Sua) During Dry Weather During Wet Weather

<table>
<tr><th>Watercourses</th><th>Bank Characteristics</th><th>Water Flow Conditions</th><th colspan="2">Photos</th></tr>
<tr><td rowspan="7"></td><td rowspan="7"></td><td rowspan="7">Slow water flow observed of approximately 0.1 - 0.2 m/s
Water was turbid and has no smell</td><td></td><td></td></tr>
<tr><td colspan="2">Water Quality Station WQ10A (Downstream of Drain 5)</td></tr>
<tr><td>During Dry Weather
</td><td>During Wet Weather
</td></tr>
<tr><td colspan="2">Water Quality Station WQ10 (Midstream of Sungei Pang Sua)</td></tr>
<tr><td>During Dry Weather
</td><td>During Wet Weather
</td></tr>
<tr><td colspan="2">Water Quality Station WQ11A (Downstream of Stream 1)</td></tr>
<tr><td>During Dry Weather</td><td>During Wet Weather</td></tr>
</table>

Watercourses	Bank Characteristics	Water Flow Conditions	Photos	
				
			Water Quality Station WQ11 (Downstream of Sungei Pang Sua)	
			During Dry Weather 	During Wet Weather 
			Water Quality Station WQ12 (Downstream of Sungei Pang Sua)	
			During Dry Weather 	During Wet Weather 
Marine area	Open sea area	Flow direction varies depend on flood and ebb tides during spring and neap tidal periods.	Water Quality Station WQ13	
			During Dry Weather	

Watercourses	Bank Characteristics	Water Flow Conditions	Photos
		During dry weather condition: Water flow and direction varied, depend on current propagation. Observed water was clean and has no smell	
			Water Quality Station WQ14
			During Dry Weather 
			Water Quality Station WQ15
			During Dry Weather 

Note:
***The discrepancy of hydrological result at WQ3 and WQ4 were due to different days of sampling during wet weather.**

8.4.2 Water Quality Conditions

Surface water samples were collected at eighteen (18) water quality stations strategically located along Pang Sua Canal, Sungei Pang Sua, and marine area as detailed in Table 8-8 and Table 8-9. The secondary data from concurrent study [R-78] was also used to support this study.

For all the sampling stations, surface water samples were collected during both dry and wet weather conditions, except WQ13, WQ14 and WQ15 of marine area which collected during Spring and Neap tides. The surface water quality results were summarised and presented in Table 8-11 and the ex-situ measurement result are tabulated in Appendix I. Photos showing dry and wet weather conditions at each of the sampling stations were presented in Table 8-10. Surface water quality results were assessed against NEA Trade Effluent Discharge limits, Singapore Marine Water Quality Guidelines and multiple international water quality criteria for aquatic life (as shown in Section 8.2.1.2.2). The relevant limits and guidelines for water quality parameters were summarised in Table 8-3; however, where no guidelines exist, the monitored results would be considered as the baseline. It should be noted that the surface water quality of any runoff generated from the Project's activities during both construction and operational phases should comply with the NEA guideline allowable limits.

Table 8-8 Water quality monitoring schedule for this study

Sampling Event / Sampling Location	Dry Weather							Wet Weather			
	8 Nov 2021	9 Nov 2021	21 Jan 2022	28 Jan 2022	7 Mar 2022	18 Mar 2022	21 Mar 2022	9 Nov 2021	2 Mar 2022	3 Mar 2022	31 Mar 2022
WQ4 (Pang Sua Canal)	√	S.C.	S.C.	S.C.	√	N.S.	N.S.	S.C.	√	N.S.	N.S.
WQ5 (Pang Sua Canal)	√	S.C.	S.C.	S.C.	√	N.S.	N.S.	S.C.	√	N.S.	N.S.
WQ6 (Sg. Pang Sua)	√	S.C.	S.C.	S.C.	S.C.	S.C.	√	S.C.	√	N.S.	N.S.
WQ7 (E63 Drain)	√	S.C.	S.C.	S.C.	S.C.	S.C.	√	S.C.	√	N.S.	N.S.
WQ8 (Sg. Pang Sua)	√	S.C.	S.C.	S.C.	S.C.	S.C.	√	S.C.	√	N.S.	N.S.
WQ9 (Sg. Pang Sua)	S.C.	√	S.C.	S.C.	S.C.	√	S.C.	S.C.	S.C.	S.C.	√
WQ9A (Drain 3)	S.C.	√	S.C.	S.C.	S.C.	√	S.C.	S.C.	S.C.	S.C.	√
WQ10 (Sg. Pang Sua)	S.C.	√	S.C.	S.C.	S.C.	√	S.C.	S.C.	S.C.	S.C.	√
WQ10A (Drain 6)	S.C.	√	S.C.	S.C.	S.C.	√	S.C.	√	S.C.	S.C.	√
WQ11 (Sg. Pang Sua)	√	S.C.	S.C.	S.C.	S.C.	S.C.	S.C.	S.C.	S.C.	√	N.S.
WQ11A (Stream 1)	S.C.	S.C.	S.C.	S.C.	S.C.	√	S.C.	S.C.	S.C.	S.C.	√
WQ12 (Sg. Pang Sua)	√	S.C.	S.C.	S.C.	S.C.	S.C.	S.C.	S.C.	S.C.	√	N.S.
WQ13	S.C.	S.C.	√	√	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Sampling Event / Sampling Location	Dry Weather							Wet Weather			
	8 Nov 2021	**9 Nov 2021**	**21 Jan 2022**	**28 Jan 2022**	**7 Mar 2022**	**18 Mar 2022**	**21 Mar 2022**	**9 Nov 2021**	**2 Mar 2022**	**3 Mar 2022**	**31 Mar 2022**
(Marine)											
WQ14 (Marine)	S.C.	S.C.	√	√	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
WQ15 (Marine)	S.C.	S.C.	√	√	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

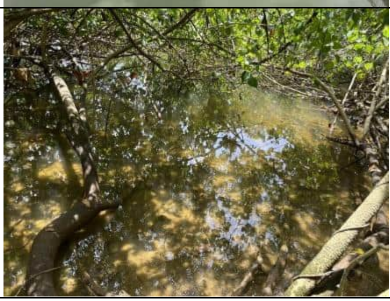
Note:
S.C. - Suboptimum Conditions: The sampling was not carried out due to restricting/ unfavourable conditions such as weather, timing, altered flow, etc.
N.S. - Not Sampled: The sampling was not carried out because the required sample(s) were already collected previously.

Table 8-9 Water quality monitoring schedule of baseline data from concurrent study [R-78]

Sampling Event / Sampling Location	Dry Weather		Wet Weather
	08 March 2021	**21 April 2021**	**13 April 2021**
WQ1 (Pang Sua Canal)	√	√	√
WQ2 (Pang Sua Canal)	√	√	√
WQ3 (Pang Sua Canal)	√	√	√

Table 8-10 Water quality photos at each sampling station

S/N	Photo of Monitoring Location	
	Dry Weather	Wet weather
WQ1		
WQ2		
WQ3		
WQ4		
WQ5		

S/N	**Photo of Monitoring Location**	
	Dry Weather	**Wet weather**
WQ6		
WQ7		
WQ8		
WQ9A		
WQ9		

S/N	**Photo of Monitoring Location**	
	Dry Weather	**Wet weather**
WQ10A		
WQ10		
WQ11A		
WQ11		
WQ12		

S/N	Photo of Monitoring Location	
	Dry Weather	Wet weather
WQ13		
WQ14		
WQ15		

Table 8-11 Surface water quality sampling results

Parameters		WQ1 (Upstream of Pang Sua Canal)	WQ2 (Upstream of Pang Sua Canal)	WQ3 (Midstream of Pang Sua Canal)	WQ4 (Midstream of Pang Sua Canal)	WQ5 (Downstream of Pang Sua Canal)	WQ6 (Upstream of Sungei Pang Sua)	WQ7 (E63 Drain)	WQ8 (Midstream of Sungei Pang Sua)	WQ9 (Midstream of Sungei Pang Sua)	WQ9A (Drain 3)	WQ10 (Midstream of Sungei Pang Sua)	WQ10A (Drain 6)	WQ11 (Downstream of Sungei Pang Sua)	WQ11A (Stream 1)	WQ12 (Downstream of Sungei Pang Sua)	WQ13 (Marine Area)	WQ14 (Marine Area)	WQ15 (Marine Area)	NEA Trade Effluent Discharge Limits[1]		International Aquatic Life Criteria[2]	SG Marine Water Quality Guidelines[6]
																				W	CW		
DO (mg/L)	Wet weather	7.9	7.8	8.3	8.0	7.9	7.5	7.5	7.3	3.1	5.5	2.9	7.9	3.8	4.5	4.8	Not Tested	Not Tested	Not Tested	-		≥ 4 ≥ 5 (freshwater)[9]	≥ 4 (median)
	Dry weather	9.0	9.2	9.2	11.1	11.5	1.9	2.5	2.7	3.6	5.0	3.0	5.5	2.7	4.3	2.9	8.2	7.0	7.6				
pH	Wet weather	9.1	8.3	8.1	7.3	7.4	7.7	7.7	7.7	7.2	7.3	7.4	9.0	8.0	7.5	7.9	Not Tested	Not Tested	Not Tested	6 - 9		6 - 9	7.5 - 8.5
	Dry weather	8.6	8.7	8.5	9.4	9.4	8.1	8.3	8.2	8.6	8.3	7.9	8.7	8.2	8.0	8.3	7.9	7.9	7.9				
Temperature (˚C)	Wet weather	30.0	29.7	29.1	25.9	26.0	26.6	26.2	26.3	29.1	28.8	29.0	28.1	29.3	26.9	28.1	Not Tested	Not Tested	Not Tested	≤ 45		< 2°C above the maximum ambient temperature	< 1°C above the maximum ambient temperature
	Dry weather	30.9	31.3	31.4	29.8	30.1	27.6	28.8	28.8	29.3	28.8	29.1	29.7	28.8	27.0	29.1	29.2	29.1	28.9				
TDS (mg/L)	Wet weather	90	52	66	36	39	60	72	100	7,687	5,037	7,137	213	4,473	1,595	1,580	Not Tested	Not Tested	Not Tested	-	≤ 1,000	≤ 1,000	-
	Dry weather	224	225	231	131	128	2,029	12,943	11,900	16,601	16,222	17,379	15,489	19,445	1,776	18,507	26,330	26,719	26,818				
Salinity (PSU)	Wet weather	0.06	0.04	0.05	0.02	0.03	0.04	0.05	0.07	6.7	4.3	6.2	0.2	3.7	1.3	1.2	Not Tested	Not Tested	Not Tested	-		-	≤ ±5 % from background median
	Dry weather	0.2	0.2	0.2	0.1	0.09	1.7	11.8	10.8	15.5	15.1	16.3	14.4	18.5	1.4	17.5	25.8	26.2	26.3				
Conductivity	Wet weather	151	87	110	56	62	96	113	157	12,743	8,305	11,818	347	7,304	2,544	2,576	Not Tested	Not Tested	Not Tested	-		-	-
	Dry weather	388	391	404	221	216	3,262	21,399	19,653	27,650	26,764	28,886	25,971	32,410	2,868	30,688	43,736	44,332	44,305				
Turbidity (NTU)	Wet weather	47	74	43	82	112	16	42	34	25	29	46	435	9	3	24	Not Tested	Not Tested	Not Tested	-		≤ 50	≤ 3.5 (any time)
	Dry weather	33	33	28	29	29	19	17	17	16	22	3	18	17	3	15	0.7	0.5	0.3				
TSS (mg/L)	Wet weather	40	70.0	45.0	71.7	118.0	6.6	26.7	18.6	28.3	105.0	51.7	40.9	13.7	12.3	7.2	Not Tested	Not Tested	Not Tested	≤ 50	≤ 30	≤ 10 % increase over seasonal average ≤ 50 (freshwater)[9]	≤ 10 % increase over seasonal average
	Dry weather	36.0	30.0	25.1	9.6	14.7	6.0	2.2	8.2	25.2	10.7	32.8	10.6	14.8	9.1	5.6	5.2	4.2	3.3				
BOD_5 (mg/L)	Wet weather	Not Tested	Not Tested	Not Tested	2.9	4.5	2.9	2.5	2.5	< 1	< 1	< 1	2.8	< 1	< 1	< 1	Not Tested	Not Tested	Not Tested	≤ 50	≤ 20	≤ 3 ≤ 5 (freshwater)[9]	-
	Dry weather	Not Tested	Not Tested	Not Tested	4.4	1.8	5.9	2.0	1.1	2.1	< 1	< 1	< 1	6.7	< 1	1.4	1.2	1.3	1.4				
COD (mg/L)	Wet weather	Not Tested	Not Tested	Not Tested	13.0	21.0	10.0	13.0	10.0	21.0	< 5	11.0	80.0	22.0	7.2	< 5	Not Tested	Not Tested	Not Tested	≤100	≤ 60	≤ 25 ≤ 30 (freshwater)[9]	-
	Dry weather	Not Tested	Not Tested	Not Tested	8.0	6.0	25.0	7.2	8.4	< 5	< 5	< 5	8.0	-	< 5	-	Not Tested	Not Tested	Not Tested				
TOC (mg/L)	Wet weather	2.8	4.2	6.6	2.3	2.8	2.6	3.8	3.7	3.6	3.0	3.4	3.5	5.9	3.6	3.2	Not Tested	Not Tested	Not Tested	-		-	-
	Dry weather	2.4	2.3	2.5	1.7	1.8	4.9	4.0	4.0	3.0	3.2	3.0	3.3	6.2	3.9	2.8	2.3	2.0	2.6				
Oil & grease	Wet weather	Not Tested	Not Tested	Not Tested	< 0.1	< 0.1	0.1	< 0.1	< 0.1	0.6	0.1	0.1	0.3	0.1	< 0.1	< 0.1	Not Tested	Not Tested	Not Tested	≤ 10	≤ 1	≤ 0.14	≤ 5.0 (any time)

Parameters		WQ1 (Upstream of Pang Sua Canal)	WQ2 (Upstream of Pang Sua Canal)	WQ3 (Midstream of Pang Sua Canal)	WQ4 (Midstream of Pang Sua Canal)	WQ5 (Downstream of Pang Sua Canal)	WQ6 (Upstream of Sungei Pang Sua)	WQ7 (E63 Drain)	WQ8 (Midstream of Sungei Pang Sua)	WQ9 (Midstream of Sungei Pang Sua)	WQ9A (Drain 3)	WQ10 (Midstream of Sungei Pang Sua)	WQ10A (Drain 6)	WQ11 (Downstream of Sungei Pang Sua)	WQ11A (Stream 1)	WQ12 (Downstream of Sungei Pang Sua)	WQ13 (Marine Area)	WQ14 (Marine Area)	WQ15 (Marine Area)	NEA Trade Effluent Discharge Limits[1]		International Aquatic Life Criteria[2]	SG Marine Water Quality Guidelines[6]
																				W	CW		
(total) (mg/L)	Dry weather	Not Tested	Not Tested	Not Tested	< 0.1	< 0.1	0.3	0.1	0.1	< 0.1	0.3	< 0.1	0.1	0.2	0.3	< 0.1	< 0.1	< 0.1	< 0.1				
TN (mg/L)	Wet weather	3.5	2.2	1.5	0.7	0.8	0.4	0.6	0.6	1.1	1.2	1.1	1.7	3.9	1.3	0.8	Not Tested	Not Tested	Not Tested	-		Eutrophic Limit: 1.5 mg/L	
	Dry weather	1.2	1.0	1.2	0.8	0.7	1.6	1.1	1.4	1.5	1.5	1.3	1.6	2.5	1.2	1.7	0.7	0.6	0.5				
NH_4-N (mg/L)	Wet weather	0.3	0.2	0.1	< 0.01	< 0.01	< 0.01	0.02	0.04	0.5	0.3	0.4	0.4	2.5	0.4	0.3	Not Tested	Not Tested	Not Tested	-		≤ 0.07 ≤ 0.3 (freshwater)[9]	≤ 0.03 (any time)
	Dry weather	0.1	0.1	0.1	0.09	0.06	0.5	0.5	0.6	0.6	0.6	0.3	0.6	0.9	0.4	0.6	0.2	0.2	0.2				
NO_3-N (mg/L)	Wet weather	2.0	2.1	1.3	0.3	0.2	0.2	0.2	0.2	0.3	0.5	0.4	0.5	0.5	0.7	0.3	Not Tested	Not Tested	Not Tested	-	≤ 4.52 (equivalent to 20 as NO3)	≤ 0.06	≤ 0.03 (any time)
	Dry weather	0.6	0.6	0.6	0.5	0.5	0.1	0.3	0.3	0.4	0.5	0.4	0.6	< 0.005	0.6	0.4	0.3	0.2	0.1				
TP (mg/L)	Wet weather	0.05	0.05	0.04	0.04	0.06	0.04	0.04	0.05	0.1	0.07	0.09	0.03	0.1	0.1	0.09	Not Tested	Not Tested	Not Tested	-		Eutrophic limit: 0.075 mg/L	≤ 1.0 (any time)
	Dry weather	0.3	0.3	0.2	0.06	0.06	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.06	0.06	0.06				
PO_4-P (mg/L)	Wet weather	0.03	0.01	0.02	0.02	0.02	0.03	0.03	0.04	0.09	0.05	0.09	0.02	0.10	0.06	0.08	Not Tested	Not Tested	Not Tested	≤ 1.625 (equivalent to 5 as PO4)	≤ 0.65 (equivalent to 2 as PO4)	≤ 0.015	≤ 0.0065 (equivalent to 0.02 as PO4)
	Dry weather	0.2	0.2	0.1	0.06	0.05	0.10	0.09	0.1	0.1	0.1	0.1	0.05	0.08	0.09	0.1	0.06	0.06	0.05				
Enterococcus (CFU/100 ml)	Wet weather	16,000	14,000	7,000	11,000	8,600	16,000	11,000	13,000	910	870	410	34,000	2,900	1,400	1,200	Not Tested	Not Tested	Not Tested	-		≤ 35	≤ 200 (95th percentile)[5]
	Dry weather	1,990	2,015	2,125	1,180	1,320	4,000	1,910	375	385	155	160	1,810	12,100	260	240	11	10	7				
Chlorophyll-a (µg/L)	Wet weather	Not Tested	Not Tested	Not Tested	0.9	1.5	0.3	0.5	0.6	0.2	0.2	0.2	2.4	1.5	0.4	0.5	Not Tested	Not Tested	Not Tested	-		-	≤ 20.0 (median)
	Dry weather	Not Tested	Not Tested	Not Tested	1.5	1.4	< 0.1	0.5	0.1	4.1	1.7	7.0	2.1	0.5	1.7	0.2	8.0	4.5	10.2				
Cadmium (µg/L)	Wet weather	Not Tested	Not Tested	Not Tested	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	Not Tested	Not Tested	Not Tested	≤ 100	≤ 3	≤10	≤ 0.7 (median)
	Dry weather	Not Tested	Not Tested	Not Tested	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5				
Chromium (µg/L)	Wet weather	Not Tested	Not Tested	Not Tested	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.6	Not Tested	Not Tested	Not Tested	≤ 1,000	≤ 50	-	≤ 4.4 (median)
	Dry weather	Not Tested	Not Tested	Not Tested	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.8	< 0.5	< 0.5	< 0.5	1.1	< 0.5	1.5	4.8	5.1	5.2				
Copper (µg/L)	Wet weather	Not Tested	Not Tested	Not Tested	1.9	2.2	2.2	1.9	1.7	1.4	1.5	1.3	2.9	3.1	0.9	1.1	Not Tested	Not Tested	Not Tested	≤ 100		≤ 8.0	≤ 1.3 (median)
	Dry weather	Not Tested	Not Tested	Not Tested	0.7	0.7	1.7	1.2	1.2	0.8	1.2	< 0.5	< 0.5	1.0	< 0.5	2.1	2.1	1.3	1.0				
Zinc (µg/L)	Wet weather	Not Tested	Not Tested	Not Tested	2.5	< 0.5	16.5	0.7	2.3	16.2	7.4	11.0	27.5	4.5	2.4	4.9	Not Tested	Not Tested	Not Tested	≤ 1,000	≤ 500	-	≤ 15.0 (median)
	Dry weather	Not Tested	Not Tested	Not Tested	< 0.5	< 0.5	10.6	4.1	11.4	8.3	8.2	6.3	4.2	12.0	0.6	1.4	7.9	4.2	3.4				
Lead (µg/L)	Wet weather	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	Not Tested	Not Tested	Not Tested	≤ 100		Acute LOEL: 82 Chronic LOEL: 3.2	≤ 4.4 (median)
	Dry weather	0.3	0.3	0.3	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5				

Parameters		WQ1 (Upstream of Pang Sua Canal)	WQ2 (Upstream of Pang Sua Canal)	WQ3 (Midstream of Pang Sua Canal)	WQ4 (Midstream of Pang Sua Canal)	WQ5 (Downstream of Pang Sua Canal)	WQ6 (Upstream of Sungei Pang Sua)	WQ7 (E63 Drain)	WQ8 (Midstream of Sungei Pang Sua)	WQ9 (Midstream of Sungei Pang Sua)	WQ9A (Drain 3)	WQ10 (Midstream of Sungei Pang Sua)	WQ10A (Drain 6)	WQ11 (Downstream of Sungei Pang Sua)	WQ11A (Stream 1)	WQ12 (Downstream of Sungei Pang Sua)	WQ13 (Marine Area)	WQ14 (Marine Area)	WQ15 (Marine Area)	NEA Trade Effluent Discharge Limits[1]		International Aquatic Life Criteria[2]	SG Marine Water Quality Guidelines[6]
																				W	CW		
Iron (µg/L)	Wet weather	Not Tested	Not Tested	Not Tested	31.3	46.4	23.2	75.0	73.7	7.8	7.2	6.6	62.6	6.9	13.7	< 0.5	Not Tested	Not Tested	Not Tested	≤ 10,000	≤ 1,000	-	-
	Dry weather	Not Tested	Not Tested	Not Tested	17.1	19.2	36.6	12.6	8.6	9.8	9.6	13.9	10.4	9.3	10.6	< 0.5	7.8	7.1	7.7				
Mercury (µg/L)	Wet weather	Not Tested	Not Tested	Not Tested	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	Not Tested	Not Tested	Not Tested	≤ 50	≤ 1	≤ 0.16	≤ 0.4 (median)
	Dry weather	Not Tested	Not Tested	Not Tested	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1				
Nickel (µg/L)	Wet weather	Not Tested	Not Tested	Not Tested	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	1.1	< 0.5	1.0	0.9	< 0.5	< 0.5	< 0.5	Not Tested	Not Tested	Not Tested	≤ 1,000	≤ 100	-	-
	Dry weather	Not Tested	Not Tested	Not Tested	< 0.5	< 0.5	< 0.5	0.6	1.5	1.5	0.7	1.3	0.6	1.8	< 0.5	1.3	1.6	1.5	1.4				
Arsenic (µg/L)	Wet weather	Not Tested	Not Tested	Not Tested	2.5	3.4	1.2	19.0	19.6	33.1	6.3	23.4	0.8	10.6	1.4	31.7	Not Tested	Not Tested	Not Tested	≤ 100	≤ 10	-	≤ 13.0 (median)
	Dry weather	Not Tested	Not Tested	Not Tested	2.4	1.7	4.3	77.2	9.1	6.6	12.2	7.5	5.6	4.0	1.7	3.3	4.3	3.9	3.9				
Cyanide (mg/L)	Wet weather	Not Tested	Not Tested	Not Tested	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.01	< 0.005	< 0.005	Not Tested	Not Tested	Not Tested	≤ 0.1		≤ 0.007	-
	Dry weather	Not Tested	Not Tested	Not Tested	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.02	< 0.005	0.01	0.01	< 0.005	< 0.005				
Barium (µg/L)	Wet weather	Not Tested	Not Tested	Not Tested	6.8	9.3	15.5	12.1	12.8	37.7	39.3	38.7	37.45	101	45.9	28.3	Not Tested	Not Tested	Not Tested	≤ 2,000	≤ 1,000	-	-
	Dry weather	Not Tested	Not Tested	Not Tested	13.6	12.6	50.3	31.8	32.1	23.3	35.1	29.2	47.9	38.7	67.1	17.0	Not Tested	Not Tested	Not Tested				
Chloride (mg/L)	Wet weather	Not Tested	Not Tested	Not Tested	< 10	< 10	< 10	< 10	13.5	3,986	2,239	3,328	717	378	686	2,001	Not Tested	Not Tested	Not Tested	-	≤ 250	-	-
	Dry weather	Not Tested	Not Tested	Not Tested	11	12	45	1,086	6,613	7,707	3,959	7,276	1,805	-	1,294	-	Not Tested	Not Tested	Not Tested				
Phenol (mg/L)	Wet weather	Not Tested	Not Tested	Not Tested	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	0.026	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	Not Tested	Not Tested	Not Tested	≤ 0.2	-	≤ 0.12	-
	Dry weather	Not Tested	Not Tested	Not Tested	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	-	< 0.025	-	Not Tested	Not Tested	Not Tested				
Calcium (mg/L)	Wet weather	Not Tested	Not Tested	Not Tested	7.9	9.3	15.7	17.7	17.9	44.3	28.5	42.3	47.9	69.3	32.8	78.8	Not Tested	Not Tested	Not Tested	-	≤ 150	-	-
	Dry weather	Not Tested	Not Tested	Not Tested	27.2	26.7	19.1	59.4	167.9	198.5	126.1	187.5	85.9	-	115.4	-	Not Tested	Not Tested	Not Tested				

Note:
1. NEA Trade Effluent Discharge Limits are for watercourses and controlled watercourses.
2. The sources of water quality criteria for aquatic life include ASEAN Guideline, United Nations Economic Commission for Europe, World Health Organization, United States Environmental Protection Agency, Australian & New Zealand, Canada, Philippines, and Malaysia
3. Red values mean data exceeding the NEA limits; Blue values mean data exceeding aquatic life criteria; Purple values mean data exceeding SG Marine Quality Guidelines; Green values mean data exceeding the limits of at least 2 guidelines.
4. < 0.1 means lower than 0.1 mg/L of level of detection limit.
5. 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
6. The value limits are referred to stricter value where applicable for sensitive receptors such as corals, seagrass/mangroves, recreational and others.
7. "- " indicates no sampling for the location due to not suitable weather/tide condition or pending result from laboratory.
8. Not Tested indicates the water quality station did not test for the respective water quality parameter which might due to limited information from concurrent study/tidal condition/some of parameters only to focus along the Pang Sua Canal and Sungei Pang Sua instead of sea area.
9. Referenced from limits under Class I: Potable Water of ASEAN Strategic Plan of Action on Water Resources Management [R-72] and only applicable for water along Pang Sua Canal which to discharge water to reservoir and further treatment for drinking water purpose.

All surface water quality sampling results were compared against NEA guideline for trade effluent. The water quality along Pang Sua Canal (i.e., WQ1, WQ2, WQ3, WQ4 and WQ5) was compared against the NEA guidelines for controlled watercourses, while the water quality stations along Sungei Pang Sua and the marine area were compared against the NEA guideline for uncontrolled watercourses. In addition to the NEA criteria for trade effluent regulations, the surface water quality of watercourses in a natural ecosystem was compared to international water quality criteria for aquatic life in order to assess its appropriateness to support aquatic life. The surface water quality was also compared to the respective limits of international aquatic life criteria and Singapore Marine Water Quality (SMWQ) Guideline.

8.4.2.1 Pang Sua Canal

As shown in Figure 8-5, surface water temperature across all water quality stations (i.e., WQ1, WQ2, WQ3, WQ4 and WQ5) along Pang Sua Canal during dry and wet weather conditions do not vary significantly ranged from 25.9 to 31.4 ˚C, which below the NEA guideline limit of 45˚C.

The pH observed along the Canal during dry and wet weathers were within the pH ranges for both NEA trade effluent (i.e., pH 6 to 9) and water quality criteria for aquatic life (i.e., pH 6.5 to 9). Sometimes (either dry or wet days), the pH value of water in the perennial Canal was slightly elevated above pH 9 (i.e., both NEA guideline and criteria for aquatic life), possibly due to the wash-off of the concrete surface from surrounding urbanized area (possible from the nearby construction site), where chemicals washed away from concrete could lead to the increased pH. The residential area might have also contributed to the elevated pH value by discharging wash waters containing high alkali compounds such as detergent chemicals during dry weather.

The measured dissolved oxygen (DO) for all water quality stations along the Canal ranged from 9.0 to 11.5 mg/L during dry weather, and 7.8 to 8.3 mg/L during wet weather. All water quality stations met the water quality criteria for aquatic life (i.e., > 4.0 mg/L).

The conductivity of water, salinity and total dissolve solids (TDS) are strongly dependent on the number of ions available to participate in the conduction process. These parameters positively correlated to salinity which is a measure of amount of salts dissolved in water. The salinity, TDS and conductivity of the water found within the study were low during dry weathers and wet weather which confirmed prevalence of freshwater, given that the seawater generally has salinity of around 35 PSU [P-55], conductivity of around 3.31x106 µS/m [P-53] and TDS of around 35,000 mg/L [W-88].

The turbidity along Pang Sua Canal ranged from 28 to 33 Nephelometric Turbidity Units (NTU) during dry weather, and 43 to 112 NTU during wet weather. The turbidity value found in each water quality stations along Pang Sua Canal showed an increase in trend during wet weather compared to dry weather. The turbidity level at midstream and downstream of Pang Sua Canal (i.e., WQ2, WQ4 and WQ5) exceeded the criteria for aquatic life (i.e., 50 NTU). This might be due to flushing from surrounding urban surface (including the nearby construction site) which carried high concentration of suspended particles during wet weather.

As shown in Figure 8-5 and Table 8-11, total suspended solids (TSS) ranged from 9.6 to 36.0 mg/L during dry weather and ranging from 40 to 118 mg/L) during wet weather. Similar with turbidity, higher TSS was observed along Pang Sua Canal during wet weather compared to dry weather. The TSS along the Canal during wet weather and the upstream of the Canal (i.e., WQ1 and WQ2) during dry weather exceeded NEA trade effluent limit (i.e., 30 mg/L). And some of water quality stations at freshwater canal (i.e., WQ2, WQ4 and WQ5) exceeded international aquatic life criteria (i.e., 50 mg/L). This might be due to the runoff from the surrounding residential areas or nearby construction site, where the paved surface of surrounding urbanized area has less tendency to trap any TSS from surface runoff before it reaches to the watercourses.

Total organic carbon (TOC) along Pang Sua Canal ranged from 1.7 to 6.6 mg/L during dry and wet weather. By comparing to criteria for drinking source water from Canada (i.e. 4 mg/L, [R-12]), indicated relatively low TOC during dry weather and slightly high TOC found at upstream and midstream of the Canal during wet weather.

Comparing the water quality criteria for aquatic life, the detected total nitrogen (TN) along upstream of Pang Sua Canal (i.e., WQ1 and WQ2) during wet weather were above the eutrophic limit of TN (i.e., 1.5 mg/L). This indicated the potential of eutrophication at the upstream of the Canal. Exceedance TN might due to the stormwater runoff from residential areas and nearby construction worksites (e.g., fertilizer from vegetation, food waste, etc.) as well as the vegetated area along the Canal (e.g., decomposed organic nitrogen). NH_4-N along the Canal was ranged from < 0.01 to 0.3 mg/L during dry and wet weather conditions, which only the upstream of the Canal (i.e., WQ1) was exceeded aquatic life criteria of 0.3 mg/L for freshwater during wet weather. NO_3-N along the Canal was ranged from 0.2 to 2.1 mg/L during dry and wet weather. The NO_3-N found along the Canal was below the NEA guideline limit (i.e., 4.52 mg/L) but exceeded the aquatic life criteria (i.e., 0.06 mg/L).

Total phosphorus (TP) along the Canal varied during dry and wet weather. The TP level ranged from 0.06 to 0.3 mg/L during dry weather and ranged from 0.04 to 0.06 mg/L during wet weather. Compared with water quality criteria for aquatic life, the TP level at upstream (i.e., WQ1 and WQ2) and midstream (i.e., WQ3) of Pang Sua Canal exceeded the eutrophication limit (i.e., 0.075 mg/L) during dry weather. During wet weather, TP levels at all water quality stations were below the eutrophication limit. The concentration of orthophosphate (PO_4-P) along Pang Sua Canal was ranged from 0.05 mg/L to 0.2 mg/L during dry weather and ranged from 0.01 to 0.03 mg/L during wet weather. PO_4-P levels at all stations along the Canal were exceeded the aquatic life criteria (i.e., 0.015 mg/L) except upstream of Canal (i.e., WQ2) during wet weather. The relevant phosphorus data showed eutrophication potential in Pang Sua Canal and the source of phosphorus compounds might be came from urbanized area (e.g., fertilizer from tree plantation, food wastes, etc.) which outside of the Study Area and from the decomposed vegetation within the Study Area.

Enterococcus counts along the Canal ranged from 1,180 to 2,125 CFU/100 ml during dry weather and ranged from 7,000 to 16,000 CFU/100 ml during wet weather. There are no available *Enterococcus* guidelines for freshwater aquatic life, but comparing with the NEA Recreational Water Quality Guidelines [W-89] on *Enterococcus* (200 CFU/100 ml), the *Enterococcus* concentrations along the Canal were significantly high. This indicated possible human or animal faecal pollution in the Canal. However, it should be noted that the criterion is for marine water and none of the watercourses is expected to hold any recreational activities involving direct human contact. During wet weather, the *Enterococcus* counts along the Canal were higher than *Enterococcus* counts observed during dry weather and this might be due to the stormwater runoff carrying faecal contaminants from surrounding residential and/or vegetated area.

During dry weather, 0.3 µg/L of lead (Pb) concentration was found at the upstream (i.e., WQ1 and WQ2) and midstream (i.e., WQ3) of Pang Sua Canal, but the concentrations were within the NEA guideline limits (100 µg/L) and aquatic life criteria (82 µg/L of acute LOEL and 3.2 µg/L of chronic LOEL). This indicates low Pb pollution found at the Canal during dry weather.

Both in-situ and ex-situ water quality parameters showed relatively high pH, TSS and nutrient (i.e., nitrogen and phosphorus) concentrations in the watercourses, indicating poor water quality for survival of aquatic life. This aligned with biodiversity findings in Section 7 and indicated Pang Sua Canal has supported poor aquatic life at the time of survey.

8.4.2.2 Sungei Pang Sua

As shown in Figure 8-5, temperature of watercourse has no significant variation across all water quality stations along Sungei Pang Sua during dry and wet weather conditions and it ranged from 26.2 to 29.7 ˚C, which below the NEA limit of 45˚C.

The pH sampled along Sungei Pang Sua was ranged from pH 7.3 to 9.0 during dry and wet weather conditions. Based on water quality results shown in Table 8-11, the pH values of water samples collected along Sungei Pang Sua and the marine area meet all the guidelines of NEA, aquatic life and SMWQ, except for the downstream of Drain 6 (i.e., WQ10A) during dry and wet weather (i.e., pH 8.7 and 9.0) which exceeded the SMWQ guideline limit range (i.e., pH 7.5 to 8.5). The conditions of slightly higher pH values might be due to the surface runoff generated from surrounding urbanized area (i.e., residential and industrial areas).

The conductivity of water is strongly dependent on the number of ions available to participate in the conduction process. This parameter is positively correlated to TDS, which measures the total amount of organic and inorganics present in the watercourses, and salinity, which measures the amounts of salts dissolved in water. As shown in Table 8-11, the average salinity, conductivity and TDS measured along Sungei Pang Sua (i.e., WQ6 to WQ12) and the marine area (i.e., WQ13 to WQ15) were comparatively higher than the freshwater stream (i.e., WQ11A) during dry and wet weather conditions. This implies that the surface water along the Sungei Pang Sua is brackish water (impacted by marine water and the tidal cycles), given that the seawater generally has salinity of around 35 PSU [P-55], conductivity of around 3.31x106 µS/m [P-53] and TDS of around 35,000 mg/L [W-88]. The elevated conductivity, TDS and salinity for Sungei Pang Sua and the marine area during dry and/or wet weather were due to the tidal influenced flow from marine area. Furthermore, it could be observed that the salinity, conductivity and TDS varied significantly between dry and wet weather conditions at upstream (i.e., WQ6) and downstream (i.e., WQ12) of Sungei Pang Sua. More specifically, the beforementioned parameters are noticeably high during dry weather conditions, except for WQ6. This implies that the flow velocity in Sungei Pang Sua was low and nearly stagnant during dry day; hence, there was no turbulence to dilute the brackish water.

The DO at all water quality stations along Sungei Pang Sua during dry and wet weathers were above 4.0 mg/L of the aquatic life criteria and/or 4.0 mg/L of SMWQ Guideline, except some of stations along Sungei Pang Sua (i.e., WQ6 to WQ9, WQ10, WQ11 and WQ12). In general, decomposition of organic matter from vegetation resulted by the low flow velocity of the watercourse surrounded by vegetation, could usually result in depletion of DO in the watercourse. This seems to be valid for lower DO observed along Sungei Pang Sua during dry weather, ranging from 1.9 to 5.5 mg/L. Slightly lower DO was also found at WQ12 downstream of Sungei Pang Sua during dry weather. It might be due to the decomposed organic matters occurred along Sungei Pang Sua and led to lower DO level.

The turbidity at almost all the water quality stations along Sungei Pang Sua at upstream (i.e., WQ6), midstream (i.e., WQ8 and WQ9, WQ10) and downstream (i.e., WQ11 and WQ12) of the Sungei Pang Sua, E63 Drain, Drain 3 (i.e., WQ9A) and Drain 6 (i.e., WQ10A) exceeded SMWQ guideline limit (i.e., ≤ 3.5 NTU) during both dry and/or wet weather which possible due to runoff generated from the urbanized areas (i.e., residential and industrial areas) and vegetated area. For marine area, the measured turbidity has not exceeded the aquatic life criteria (i.e., ≤ 50 NTU) and SMWQ guideline limit (i.e., ≤ 3.5 NTU).

The measured TSS at water quality stations along Sungei Pang Sua and marine areas was within 50 mg/L of NEA guideline limit for uncontrolled watercourse, except Drain 3 (i.e., WQ9A) and midstream of Sungei Pang Sua (i.e., WQ10) during wet weather. The exceedance TSS at Drain 3 and midstream of Sungei Pang Sua was probably because of stormwater flushing from further upstream consists of high concentration of sediments. This was consistent with the muddy runoff during wet weather as shown in the site photo in Table 8-10.

BOD_5 at all water quality stations was relatively low and met criteria of NEA guideline (i.e., 20 mg/L for controlled watercourse and 50 mg/L for other watercourse), ranging from 1.1 mg/L to 6.7 mg/L during dry and wet weather. Except the water quality stations at the upstream (i.e., WQ6) and downstream (i.e., WQ11) of Sungei Pang Sua, all the stations at rest locations of Sungei Pang Sua were within the criteria for aquatic life (i.e., 3 mg/L) during dry and wet weather. For COD, the water quality stations along the Sungei Pang Sua were ranged from < 5 to 80 mg/L during both dry and wet weather, which within the guideline limits of NEA (i.e., 100 mg/L for other watercourse). For Drain 6 (i.e., WQ10A), 80 mg/L of COD level was exceeded the aquatic life criteria (i.e., 25 mg/L) during wet weather.

The TOC of all water quality stations along Sungei Pang Sua and marine area ranged from 2.0 to 6.2 mg/L during dry weather, while the TOC of all water quality stations during wet weather were ranged from 2.6 to 5.9 mg/L. Since there are no available TOC guidelines for aquatic life, the results were compared with the criteria for drinking source water from Canada [i.e., 4 mg/L, (R-81)]. Comparatively with the TOC criteria, the elevated TOC level at WQ6 (i.e., during dry weather) and WQ11 (during dry and wet weather) might be due to the surface runoff comprised of high concentration of organic carbon in the soil organic matters or the excess TOC might come along with the surface runoff from nearby urbanized area or vegetated area.

The oil & grease (total) measured at all the water quality stations along Sungei Pang Sua and marine area were within the NEA guideline limit (i.e., 10 mg/L for other watercourse) and SMWQ guideline limit (i.e., 5.0 mg/L). The oil & grease (total) along Sungei Pang Sua (i.e., WQ6, WQ9A, WQ9, WQ10A and WQ11) and freshwater Stream 1 (i.e., WQ11A) during dry weather as well as WQ10A at Drain 6 were found slightly higher than the aquatic life criteria (i.e., 0.14 mg/L). The exceedance of oil & grease (total) might be due to the surface runoff discharge from upstream urbanized area and nearby industrial area.

The TN measured at all the water quality stations along Sungei Pang Sua and marine area ranged from 0.4 to 3.9 mg/L during wet weather while ranged 0.5 to 2.5 mg/L during dry weather. Excess concentration of TN was found at upstream (i.e., WQ6) and downstream (i.e., WQ11 and WQ12) of Sungei Pang Sua as well as Drain 6 (i.e., WQ10A) during dry and/or wet weather conditions. For NH_4-N, basically all the water quality stations along Sungei Pang Sua and marine area were exceeded aquatic life criteria (i.e 0.07 mg/L) and/or SMWQ guideline limit (i.e., 0.03 mg/L), except the upstream of Sungei Pang Sua (i.e., WQ6) and E63 drain (i.e., WQ7) which sampled during dry weather. The NO_3-N concentration along Sungei Pang Sua was exceeded the SMWQ guideline (i.e., 0.0068 mg/L) and/or water quality criteria for aquatic life (i.e., 0.03 mg/L) during dry and wet weather. Excess nutrient concentrations indicate eutrophication potential and might be came from surface runoff generated from upstream urbanized areas, fertilizer residuals from nearby residential area, discharges from nearby industrial area and the decomposition of organic matters of vegetated areas.

The TP measured at all the water quality stations ranged from 0.03 to 0.2 mg/L during dry and wet weather. All the stations exceeded eutrophic limit (i.e., 0.075 mg/L) of aquatic life criteria during dry and/or weather, except the water quality stations at the upstream (i.e., WQ6) and midstream (i.e., WQ8) of Sungei Pang Sua, E63 Drain (i.e., WQ7), Drain 3 (i.e., WQ9A) and Drain 6 (i.e., WQ10A) during wet weather. The concentrations of PO_4-P measured at all the water quality stations were exceeded the aquatic life criteria (i.e., 0.015 mg/L) and SMWQ guideline (i.e., 0.0065 mg/L) during both dry and wet weather. Excess phosphorous concentrations might come from surface runoff generated from upstream urbanized areas, fertilizer residuals from nearby residential area, discharges from nearby industrial area and the decomposition of organic matters of vegetated areas.

The *Enterococcus* counts measured at all the water quality stations ranged from 7 to 34,000 CFU/100 ml during dry and wet weather. All the water quality stations exceeded the aquatic life criteria (i.e., 35 CFU/100 ml) and/or SMWQ Guideline (i.e., 200 CFU/100 ml). The NEA Recreational Water Quality Guidelines [W-89] requires *Enterococcus* to be below 200 CFU/100 ml, indicating possible human or animal faecal pollution in the watercourses. However, it should be noted that none of the watercourses within the Study Area are expected to hold any recreational activities that involved direct human contact.

For heavy metal, chromium measured at marine area exceeded the water SMWQ guideline limit (i.e., 4.4 µg/L) during dry weather. The concentration of copper measured at Sungei Pang Sua (i.e., WQ6, WQ7, WQ8, WQ9, WQ11 and WQ12), E63 Drain (i.e., WQ7), Drain 3 (i.e., WQ9A), Drain 6 (i.e., WQ10A) and marine area (i.e., WQ13) exceeded the SMWQ guideline limit (i.e., 1.3 µg/L) during dry and/or wet weather. For zinc, the water quality station at upstream (i.e., WQ6) and midstream (i.e., WQ9) of Sungei Pang Sua and Drain 6 (i.e., WQ10A) were exceeded the SMWQ guideline (i.e., 15 µg/L) during wet weather. Based on SMWQ guideline, the elevated arsenic concentration was found at the downstream of E63 Drain (i.e., WQ7) during both dry and wet weather as well as the midstream (i.e., WQ8, WQ9 and WQ10) and downstream (i.e., WQ12) of Sungei Pang Sua during wet weather. Another heavy metal parameter such as cyanide was found at the downstream (i.e., WQ11 and WQ12) of Sungei Pang Sua and marine area (i.e., WQ13) during dry and/or wet weather. The elevated heavy metals was possibly generated from the surface runoff from nearby industrial area near to downstream of Sungei Pang Sua.

Other parameters such as chlorophyll-a, phenol, calcium and the heavy metals of cadmium, lead, iron, mercury, nickel and barium measured at all water quality stations were within all the respective limits of NEA guideline, aquatic life criteria and/or SMWQ guideline.

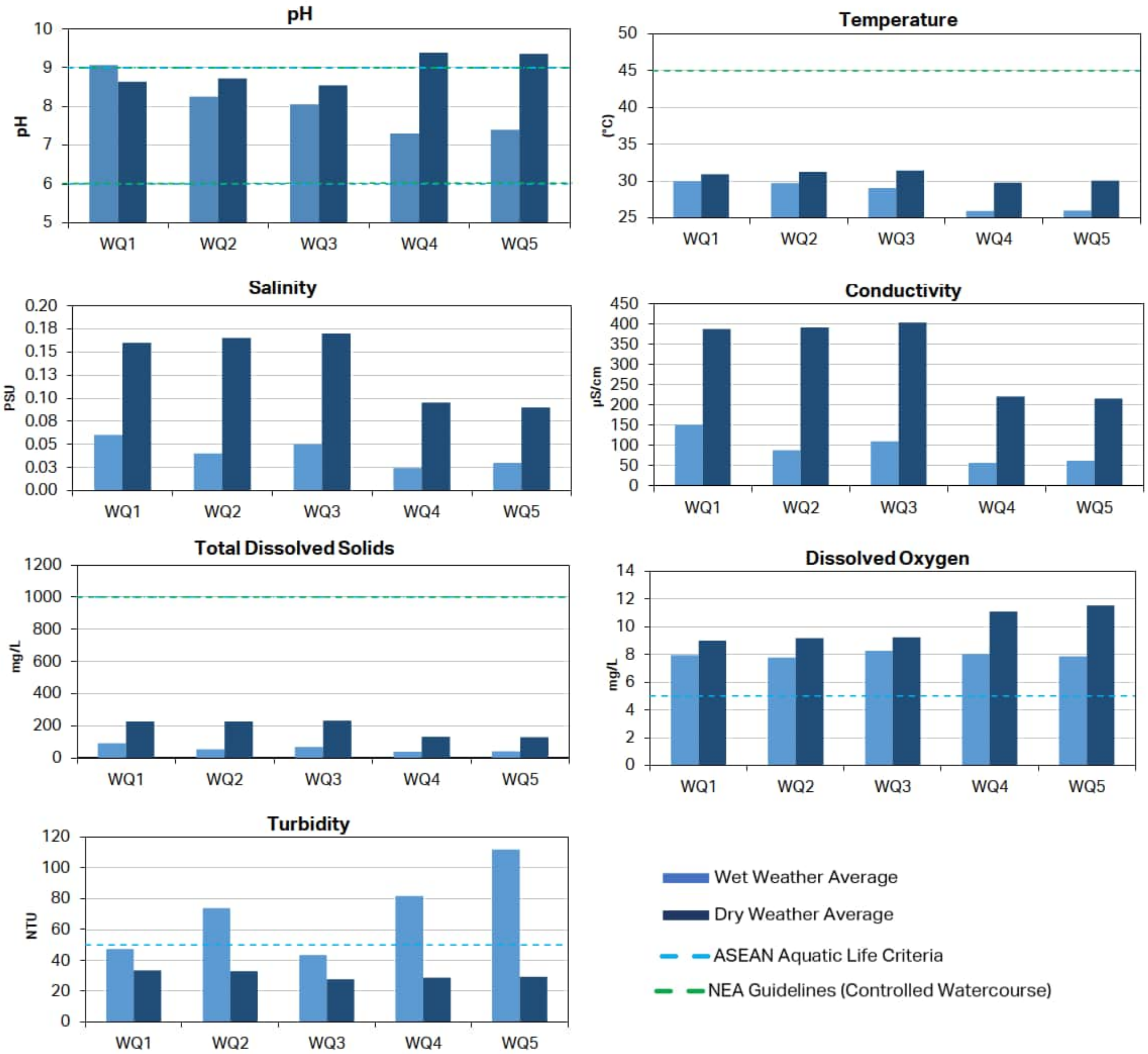


Figure 8-5 Average monitoring results of In-situ parameters along Pang Sua Canal during dry and wet weather conditions

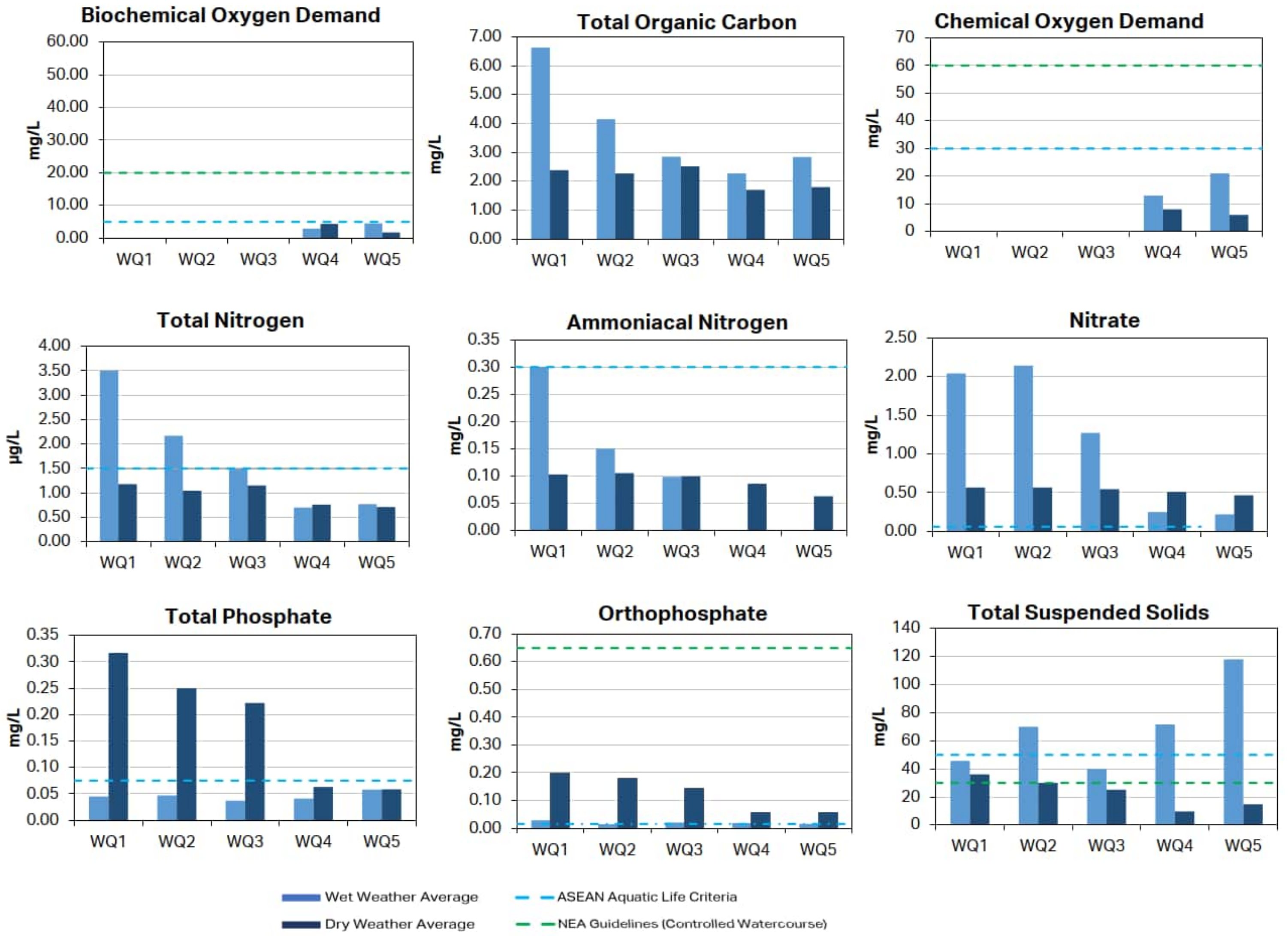


Figure 8-6 Average monitoring results of Ex-situ parameters along Pang Sua Canal during dry and wet weather conditions (part 1)

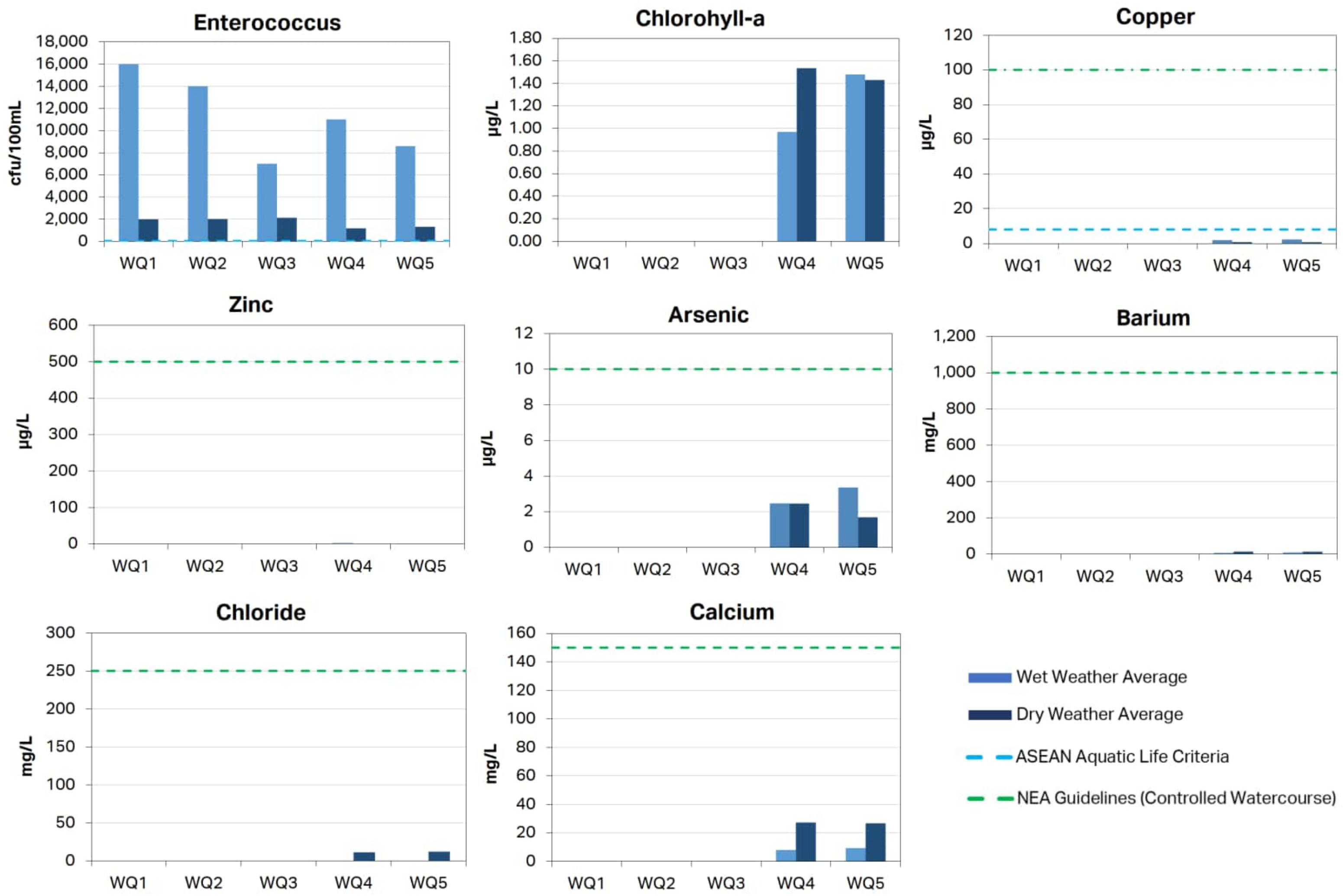


Figure 8-7 Average monitoring results of Ex-situ parameters along Pang Sua Canal during dry and wet weather conditions (part 2)

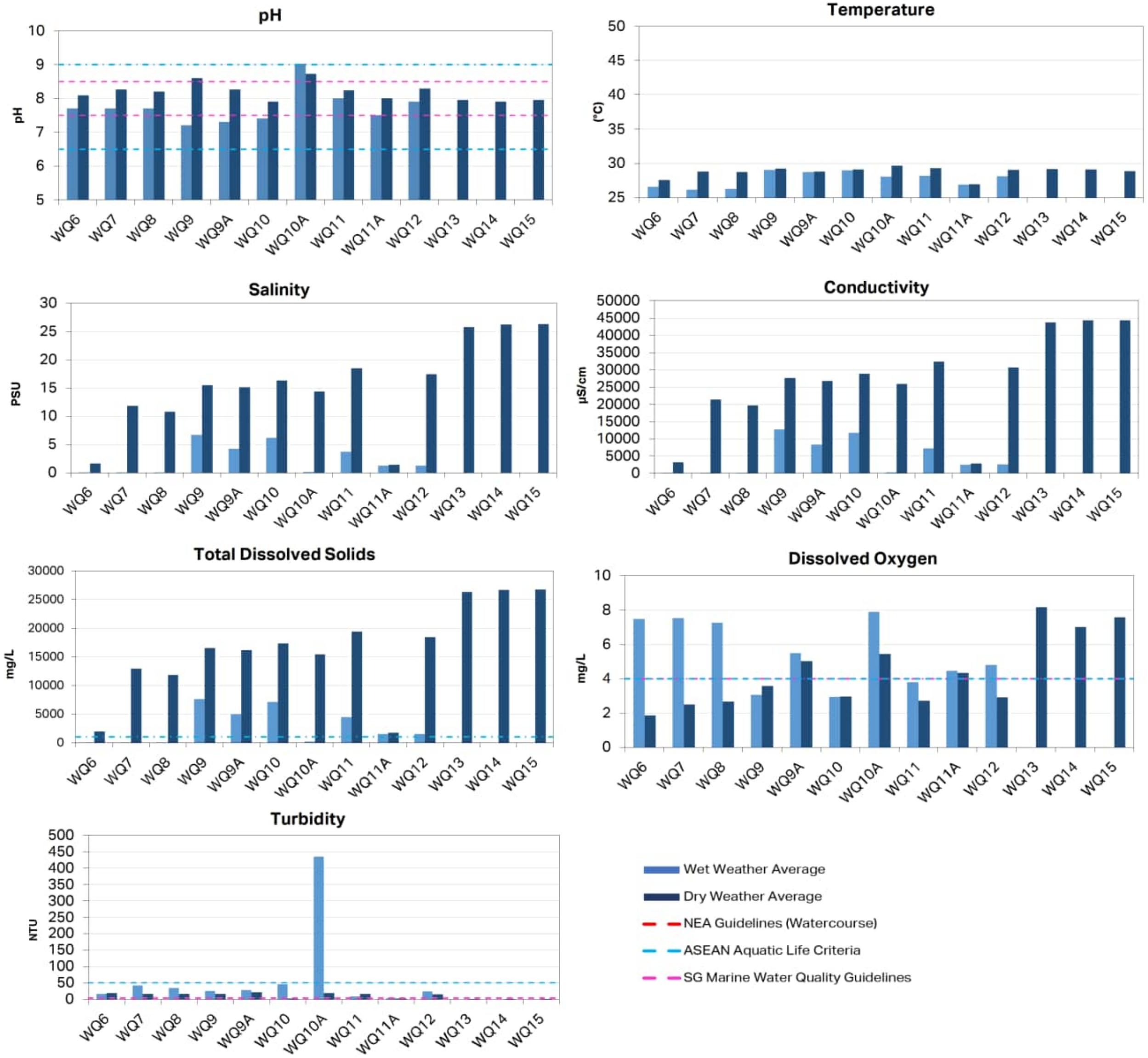

pH
Temperature
(°C)
Salinity
PSU
Conductivity
µS/cm
Total Dissolved Solids
mg/L
Dissolved Oxygen
mg/L
Turbidity
NTU
WQ6 WQ7 WQ8 WQ9 WQ9A WQ10 WQ10A WQ11 WQ11A WQ12 WQ13 WQ14 WQ15
Wet Weather Average
Dry Weather Average
NEA Guidelines (Watercourse)
ASEAN Aquatic Life Criteria
SG Marine Water Quality Guidelines

Figure 8-8 Average monitoring results of In-situ parameters along Sungei Pang Sua during dry and wet weather conditions

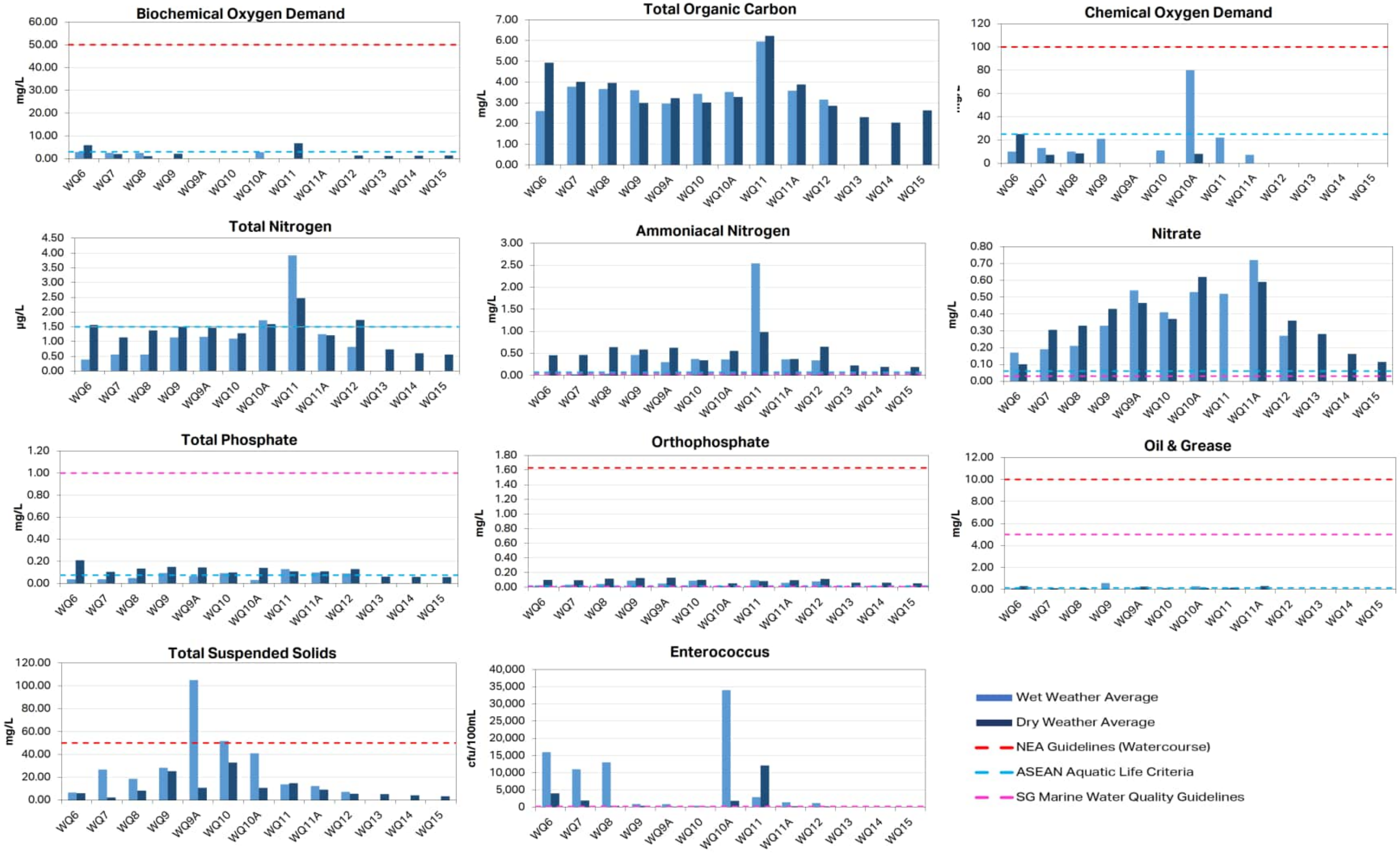


Figure 8-9 Average monitoring results of Ex-situ Parameters along Sungei Pang Sua during dry and wet weather conditions (part 1)

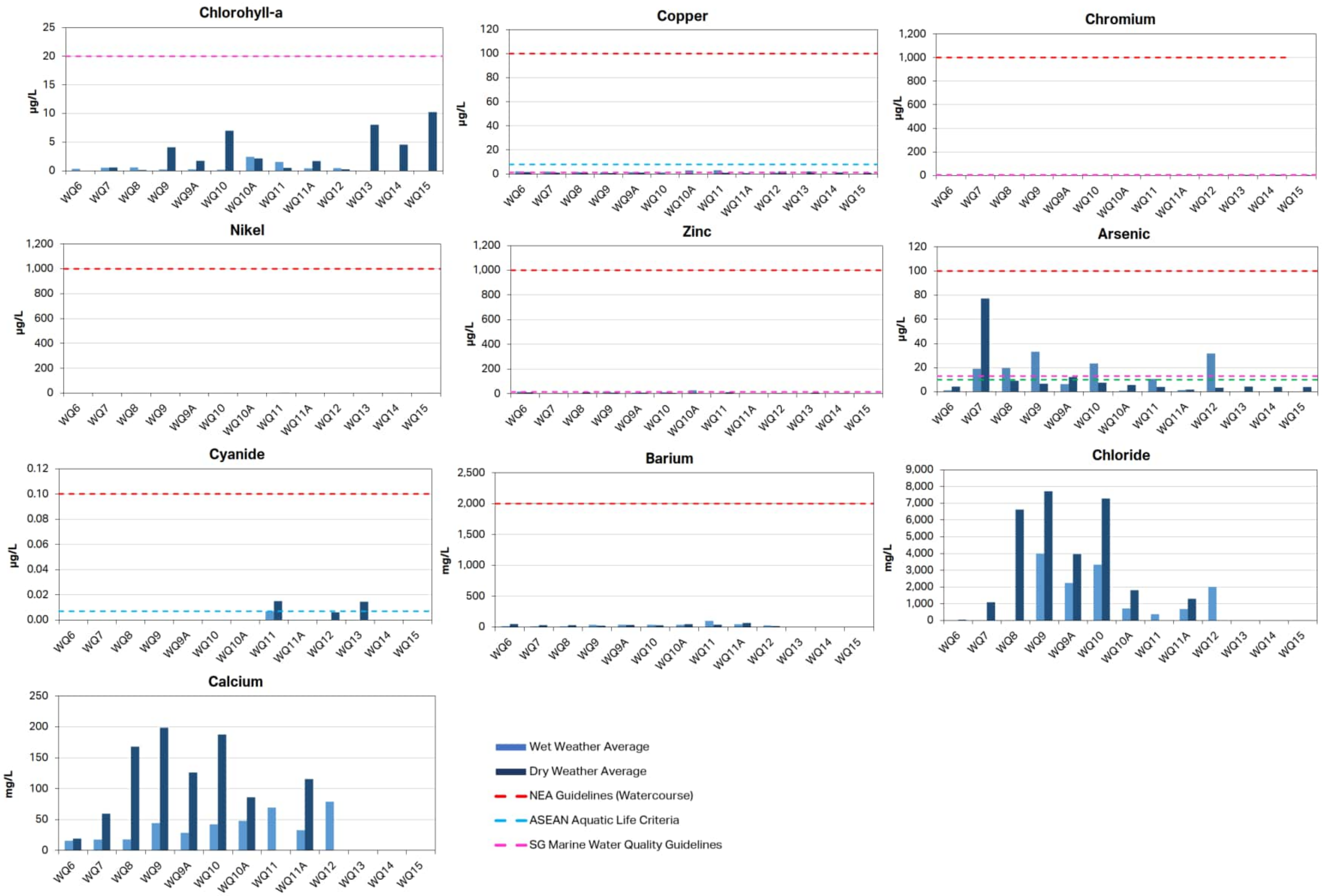


Figure 8-10 Average monitoring results of Ex-situ Parameters along Sungei Pang Sua during dry and wet weather conditions (part 2)

8.5 Identification of Sensitive Receptors

Receptor screening for hydrology and water quality was conducted within Study Area and its surroundings for both construction and operational phases. The criteria detailed in Table 6-2 was used to determine the sensitivity of the hydrology and water quality receptors presented in Table 8-12 and Table 8-13.

8.5.1 Construction Phase

During construction phase, the human and ecology receptors are identified and classified based on sensitivity classification (Table 6-2) as shown in Table 8-12.

Table 8-12 Classification of hydrology and water quality sensitive receptors identified for construction phase

Sensitive Receptor	Environmental Parameter	Receptor Description	Receptor Classification
Human Receptors			
On-site construction workers	Hydrology Water Quality	Regular activities of on-site workers may be disrupted due to localised flooding within the Project Site Construction workers will not use water within Project Site (i.e., from stormwater drainage or canal or streams) for any beneficial purpose (i.e., drinking and industrial purposes, irrigation) Construction workers may come in direct contact with surface water during various pre-construction and construction activities (e.g., washing, cleaning, etc.)	Priority 2
Off-site resident and visitors in the vicinity of the Study Area	Hydrology Water Quality	Changes in baseline hydrology of the Project Site may cause changes in hydrological cycle in the surrounding area which can obstruct regular activities of the visitors outside of Project Site Water within/nearby Project Site's drains, streams and canal will flow into the sea and reservoir (as described in Section 4.4) and hence is not expected to be eventually used directly for drinking purposes Off-site resident and visitors may be exposed to surface water from the Project Site indirectly, by coming in contact (e.g., dermal contact, inhalation of water particles)	Priority 2
Habitats and biocenosis of Pang Sua Canal	Hydrology Water Quality	Based on the biodiversity baseline study findings (refer to Section 7.3.1), habitats and biocenosis of Pang Sua Canal are identified to be of low ecological value Habitats and biocenosis of Pang Sua Canal are not highly dependent of the quantity and quality of water and would not likely be disturbed due to the changes in hydrology and water quality The surface water eventually will be discharged into Kranji Reservoir and to be treated for drinking supply	Priority 1
Ecological Receptors			
Habitats and biocenosis of Sungei Pang Sua	Hydrology Water Quality	Based on the biodiversity baseline study findings (refer to Section 7.3.1), habitats and biocenosis of Sungei Pang Sua are identified to be of high ecological value Habitats and biocenosis of Sungei Pang Sua are highly dependent of the quantity and quality of water and would most likely be disturbed by changes in hydrology and water quality The surface water eventually will be discharge to marine area	Priority 1

8.5.2 Operational Phase

During operational phase, the human and ecology receptors are identified and classified based on sensitivity classification (Table 6-2) as shown in Table 8-13.

Table 8-13 Classification of hydrology and water quality sensitive receptors identified for operational phase

Sensitive Receptor	Environmental Parameter	Receptor Description	Receptor Classification
Human Receptors			
Maintenance workers and visitors of the proposed development	Hydrology Water Quality	The permanent land use change may cause flooding risk to the urbanized area such as residential areas or other development. Possible pathways for exposure of the receptors to water quality contamination which derived from accidental leakages/spill of solid and liquid wastes from human activities such as maintenance works.	Priority 2
Visitors and residents in the vicinity of the proposed development	Hydrology Water Quality	The permanent land use change may cause flooding risk to the urbanized area such as residential areas or other development. Off-site residents and visitors may be exposed to water from the Study Area indirectly, by coming in contact (e.g., dermal contact, inhalation of water particles) with downstream watercourse (i.e., Pang Sua Canal and Sungei Pang Sua)	Priority 2
Habitats and biocenosis of Pang Sua Canal	Hydrology Water Quality	Based on the biodiversity baseline study findings (refer to Section 7.3.1), habitats and biocenosis of Pang Sua Canal are identified to be of low ecological value Habitats and biocenosis of Pang Sua Canal are not highly dependent of the quantity and quality of water and would not likely be disturbed due to the changes in hydrology and water quality The surface water eventually will be discharged into Kranji Reservoir and to be treated for drinking supply	Priority 1
Ecological Receptors			
Habitats and biocenosis of Sungei Pang Sua	Hydrology Water Quality	Based on the biodiversity baseline study findings (refer to Section 7.3.1), habitats and biocenosis of Sungei Pang Sua are identified to be of high ecological value Habitats and biocenosis of Sungei Pang Sua are highly dependent of the quantity and quality of water and would most likely be disturbed by changes in hydrology and water quality The surface water eventually will be discharge to marine area	Priority 1

8.6 Minimum Control Measures

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

8.6.1 Construction Phase

Table 8-14 has a non-exhaustive list of minimum controls for each potential impact identified in Section 8.3.1 for construction phase.

Table 8-14 Minimum controls during the construction phase applicable to hydrology and water quality impact assessment

Potential Source of Impacts	Environmental Parameter Potentially Affected	Minimum Control
Temporary Land Use Change	Hydrology	• Runoff within, upstream of, and adjacent to the work site will be effectively drained away without causing flooding in the vicinity; • Potential increase of peak-flow due to the change in the land use at the worksite can be mitigated by providing detention tanks or ponds within the Study Area. Detention tanks or ponds can capture stormwater during heavy storm events to reduce the peak runoff; • 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; and • 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.
Solid & Toxic Wastes Generation **(During site clearing, earthworks and general construction activities at launch/retrieval shafts, cut and cover areas, e.g., clearing and preparation, trench excavation, backfill, soil mixing, compaction, spoil handling and transport, building of permanent**	Water Quality	• Development of a Standard Operation Procedure (SOP) for safe handling, transfer, storage and disposal of solid and toxic wastes such as demolition waste, and other construction wastes; • 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; • ECM measures include but are not limited to minimisation of formation of bare soil, coverage of all bare/erodible surfaces, slope stability, concrete cut-off drains, silt fences/traps along the perimeter cut-off drain, turbidity curtains for works adjacent to watercourses, etc.; • Implementation of CCTV including SIDS at the public drain to monitor the surface run-off 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); • Provision of enclosed bins and waste disposal facilities cleared up as often as necessary to prevent build-up. Housekeeping

Potential Source of Impacts	Environmental Parameter Potentially Affected	Minimum Control
structures, utilities diversion, etc.)		checks will be carried out once a day to ensure all litter is cleared from site; • Hazardous substances and toxic wastes should be stored on hard stand, under shelter with a kerb around the storage area; • 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; and • Appropriate disposal of any waste listed in the Environmental Public Health (General Waste Collection) Regulations by licensed waste operator/collector.
Improper Management of Chemical Substances **(Use, storage and disposal of chemical substances; refuelling activities)**	Water Quality	• Development of SOP for safe handling, transfer and storage of toxic waste; housekeeping checks once a day to ensure all toxic wastes 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; and • Appropriate disposal of toxic waste as per required in the Environmental Public Health (Toxic Industrial Waste) Regulations by licensed waste operator/collector.
Liquid Effluent Generation and Stormwater Runoff **(Construction wastewater and stormwater runoff resulting from site clearance, excavation, etc.)**	Water Quality	• 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; • Reduce, reuse, and recycle hierarchy principle to be applied to wastewater onsite; • Regular audits on environmental management procedures will be carried out onsite; • No hazardous liquids to be sent to the detention pond; • 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

Potential Source of Impacts	Environmental Parameter Potentially Affected	Minimum Control
		Waste Management Contractor. Hazardous liquids to be handled as Hazardous Waste; • Containment pond/kerbs will be of impervious material and be designed with sufficient capacity to hold volumes of wastewater produced on-site, as well as allowance for stormwater run-off and potential fire-fighting wastewater; • Surface Water Drainage, to be endorsed by a QECP and submitted to PUB; • Implementation of the ECM plan before the start of any construction work; • Effective ECM and monitoring implemented as recommended in the Code of Practice on Surface Water Drainage to ensure that discharge into stormwater drainage system does not contain TSS in concentrations greater than the prescribed limits under the Sewerage and Drainage (Surface Water Drainage) Regulations; • ECM measures include but are not limited to minimisation of formation of bare soil, coverage of all bare/erodible surfaces, concrete cut-off drains, silt fences/traps along the perimeter cut-off drain, turbidity curtains for works adjacent to water bodies (canals, drains, streams), etc. • Implementation of CCTV including a SIDS at the public drain to monitor the surface run-off discharges from the sites as per the PUB circular on Preventing Muddy Waters from the Construction Sites (October 2015); • Runoff within, upstream of, and adjacent to the work site will be effectively drained away without causing flooding in the vicinity; • ECM tanks/ponds will be designed in sufficient capacity to hold the turbid stormwater prior to treatment at the ECM facility; • Temporary storage volumes should be provided for overflow situations of untreated wastewater. Temporary storage with sufficient capacity will capture any expected additional volumes to ensure untreated wastewater is not released to watercourses unless it complies with Singapore NEA Guidelines on trade effluent discharge concentrations; • A responsible person (e.g., ECO) to be assigned to oversee the efficient operation of the containment pond/kerbs where ‘Good Housekeeping’ practices would be adhered to. Also, the area would be carefully managed to avoid spills, leaks, and odour issues, with the containment pond/kerbs checked at least daily to ensure proper functionality; • Daily record volume of wastewater, as well as volumes of sludge and other produced wastes; • Contractor will need to seek for approval from relevant authorities (i.e., PUB & NEA) as per PUB Sewerage and Drainage (Trade Effluent) Regulations if the wastewater will be discharged to public sewer or NEA’s Trade Effluent Discharge Limits to controlled watercourse if the treated trade effluent will be discharged 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;

Potential Source of Impacts	Environmental Parameter Potentially Affected	Minimum Control
		• 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; • The containment pond/kerbs, as well as wastewater generating areas on-site, to be equipped with spill clean-up kits; • 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; • Adequate drainage, cut-off drains sump pit, road kerb, piping and toe wall for channelling of construction process wastewater streams (e.g., wash water, etc.) and stormwater runoff separately to be assured 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 will include oil-water separators to capture inadvertent spills or leaked oils or greases; • Implement a construction EMMP and ensure full preparation of associated plans and procedures including the following: • EMMP to include SOPs, an Emergency Response Plan (ERP), an inventory of wastewater streams, training of staff as well as an inspection, maintenance and audit schedule; and • Full development of EMMP Wastewater Management Procedures to include dedicated management and monitoring procedures that covers all eventualities related to the proper operation of the containment pond/kerbs, or any other wastewater discharge location/equipment. • Regular and dedicated procedures for the inspection and maintenance of wastewater (i.e., trade effluent) collection, storage, and treatment infrastructure, such as pipes, oil water separators, silt screens, etc.; • Regular and dedicated procedures for the management of stormwater collection, settling, testing and eventual discharge of 'clean' water to watercourses; • A training programme for all on-site workers, including sub-contractors, in relation to their obligations for ensuring proper water quality management; • ECM measures include but are not limited to minimisation of formation of bare soil, coverage of all bare/erodible surfaces, concrete cut-off drains, silt fences/traps along the perimeter cut-off drain, turbidity curtains for works adjacent to watercourses (canals, drains, streams), etc.; • Adequate drainage and piping for channelling of stormwater run-off to be assured through detailed design for capture and treatment before discharge into 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; • Regular and dedicated procedures for the inspection and maintenance of stormwater collection, storage, and treatment

Potential Source of Impacts	Environmental Parameter Potentially Affected	Minimum Control
		infrastructure, such as pipes, oil water separation, silt screens, etc.; and • Regular and dedicated procedures for the management of stormwater collection, settling, testing and eventual discharge of 'clean' water to surface waters.
Storage and Disposal of Domestic Liquid and Construction Solid Wastes	Water Quality	• Provision of portable toilets and on-site septic tank; • Regular cleaning of the portable toilets and clearing of sanitary waste; • Appropriate location of toilet facilities away from any nearby watercourses; • Inspections and audits to ascertain the hygienic conditions onsite; • Training of workers on the best practices to contribute in environmental protection; • Appropriate disposal of any waste listed in the Environmental Public Health (General Waste Collection) Regulations by licensed waste operator/collector; • Manholes should always be adequately covered and temporarily sealed; • All raw materials such as sand, gravel and cement shall be stored under a shelter. The storage areas shall be curbed and served by proper drainage, and all sullage water from the material stockpile areas shall not be discharged into drain / waterway; • All sewage and sullage water shall be discharged into a public sewer; • 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; • Coverage of temporary/open storage of excavated materials; • All vehicles should run via wheel washing process before leaving the site to ensure no earth, mud, debris, etc., is deposited on roads; and the wastewater hence generated should be stored and removed for treatment and disposal off-site by an approved Waste Management Contractor; and • 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.

8.6.2 Operational Phase

Table 8-15 has a non-exhaustive list of minimum controls for each potential impact identified in Section 8.3.2 for operational phase.

Table 8-15 Minimum controls during the operational phase applicable for hydrology and water quality impact assessment

Potential Source of Impact	Environmental Parameter Potentially Affected	Minimum Control
Permanent land use change (Altered Stormwater runoff)	Hydrology	• 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; and • Provide more pervious areas to increase the seepage of surface water into the soil.
Stormwater run-off contamination	Water Quality	• Adequate drainage, piping and/or channelling of stormwater runoff to be assured through detailed design [such as Active, Beautiful, Clean Water (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.; and • Regular and dedicated procedures for the management of stormwater collection, settling, testing and eventual discharge of 'clean' water to watercourses.
Improper management of liquid and solid wastes	Water Quality	• 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; • 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; and • Raising awareness of various stakeholders with community/stakeholder engagement (e.g., signage boards, warning signs, etc.)

8.7 Prediction and Evaluation of Hydrology and Surface Water Quality Impacts

During construction phase, potential hydrology and water quality impact on the sensitive receptors such as on-site construction workers, the off-site residents and visitors at vicinity of the Study Area, and the habitat and biocenosis of Pang Sua Canal and Sungei Pang Sua as detailed in Section 8.5.1 were assessed qualitatively using the risk matrix method that has been presented in Section 6.4. Sungei Pang Sua was also assessed quantitatively using modelling software and detailed assessment has been presented in Section 8.7.1.2.

For operational phase, the sensitive receptors such as maintenance workers and visitors of the proposed developments, nearby visitors and residents of the proposed development as well as the habitat and biocenosis of Pang Sua Canal and Sungei Pang Sua as detailed in Section 8.5.2 were assessed qualitatively using the risk matrix method that has been presented in Section 6.4.

8.7.1 Construction Phase

8.7.1.1 Qualitative Impact Assessment

As described in Section 8.3.1, major sources of impacts on hydrology and water quality during construction phase are temporary land use change, solid & toxic waste generation, liquid effluent generation, stormwater runoff contamination and improper management of chemical substances. Temporary land use change (due to construction activities) will mostly impact the existing hydrological conditions of the site, while the rest of the impact sources will mostly have an impact on water quality. Following sub-sections present the impact prediction and evaluation on hydrology and water quality during construction phase.

8.7.1.1.1 Hydrology

8.7.1.1.1.1 Temporary Land Use Change

Land use modification due to land clearing during construction phase may affect existing hydrological conditions of the Study Area. The proposed construction activities include site clearance and excavation, the vegetation coverage in the worksite areas will be reduced. Such changes may increase stormwater surface runoff and reduce the time of runoff propagation over the land. Subsequently this could lead to significant increase of water levels and possible flooding of surrounding areas during the heavy storm events. Hence, the catchment area and existing hydrological conditions could be affected significantly and would cause Medium impact intensity on the human receptors such as on-site construction workers as well as the nearby off-site residents and visitors. The human receptors have been categorized as Priority 2 sensitive receptors, impact consequence would be Low based on Impact Consequence Matrix (refer to Table 6-7). Since the flooding could be happened during storm event only and sufficient capacity of detention tanks would be designed based on PUB's Code of Practice on Surface Water Drainage [R-7] to capture the stormwater to reduce its peak runoff during storm event, the likelihood for this source of impact would be Rare and the impact significance was assessed to be Minor based on Impact Significance Matrix (Table 6-9).

The land use change will cause dry weather flow alteration and stormwater peak flow increase during construction phase and ecology in the watercourses within and surroundings of the Project might potentially be affected by proposed land use change. The potential impact would bring Medium impact intensity on the habitat and biocenosis of Pang Sua Canal. Given that Priority 1 sensitivity of Pang Sua Canal, the impact consequence would be Medium based on the Impact Consequence Matrix (refer to Table 6-7). However, by applying the minimum controls such as considering earth retaining stabilization structures in detailed design and installation of detention tanks/ponds, it would bring Rare likelihood of occurrence of the impact during construction phase The impact significance on habitat and biocenosis of Pang Sua Canal was assessed to be Minor based on Impact Significance Matrix Table 6-9). The proposed construction footprint will locate at the upstream of Sungei Pang Sua and the stream consisted of high ecological value based on biodiversity findings (refer to Section 7.3.1). The land use change due to the proposed construction footprint would cause Medium impact intensity to the biodiversity living along Sungei Pang Sua. Given that the habitat and biocenosis along Sungei Pang Sua is Priority 1 sensitive receptor, the impact consequence would be Medium based on the Impact Consequence Matrix (refer to the Table 6-7). The hydrology of Sungei Pang Sua is dominantly influenced by tidal flows, so the likelihood of hydrological change on Sungei Pang Sua would be Rare and the impact significance was assessed to be Minor based on Impact Significance Matrix (Table 6-9).

8.7.1.1.2 Water Quality

8.7.1.1.2.1 Solid & Toxic Waste Generation

The building demolition, utility diversion, land clearance, earthworks and the main construction including station boxes, MRT superstructure, potential future infrastructure, pedestrian linkbridges and proposed vehicular bridge would generate contaminated soils, rocks, organic solvents, and others solid and toxic wastes. Human receptors such as on-site construction workers and nearby off-site residents and visitors could have adverse health issue if the solid and toxic wastes spill into the watercourses and human receptors contact with the contaminated water during construction phase. Thus, solid and toxic wastes generation from the construction works would cause Medium intensity to the on-site construction workers and nearby off-site residents and visitors. The human receptors have been categorized as Priority 2 sensitive receptors and the impact consequence would be Low based on the Impact Consequence Matrix (refer to Table 6-7). The quantity of the wastes stored on the site (e.g., chemical waste, construction debris, etc.) is expected to be limited and the wastes should be regularly removed by the licensed waste management contractors. Thus, after implementation of such minimum controls, it would bring Rare likelihood of occurrence of the impact on the on-site construction workers and nearby off-site residents and visitors. The impact significance was assessed to be Minor based on Impact Significance Matrix (refer to Table 6-9).

The ecology in the watercourses within and surroundings of the Project might potentially be affected by the water quality contamination due to solid and toxic wastes generation from the construction activities. Any improper handling, transfer and storage of solid and toxic wastes at the proposed worksites would cause Medium impact intensity on the habitat and biocenosis of Pang Sua Canal. The impact consequence for habitat and biocenosis of Pang Sua Canal would be Medium based on the Impact Consequence Matrix (refer to Table 6-7). However, by considering the minimum controls as described in Table 8-14, it would bring Rare likelihood of occurrence of the impact on the habitat and biocenosis of Pang Sua Canal. The impact significance was assessed to be Minor based on the Impact Significance Matrix as shown in Table 6-9. The construction worksites will locate near to the upstream of Sungei Pang Sua and the stream consisted of high ecological value based on biodiversity findings (refer to Section 7.3.1), so any solid and toxic wastes generated from the construction worksite would cause Medium impact intensity to the biodiversity living along Sungei Pang Sua. Given that the habitat and biocenosis of Sungei Pang Sua is Priority 1 sensitive receptor, the impact consequence would be Medium based on the Impact Consequence Matrix (refer to Table 6-7). Due to some of worksites located near to the stream bank of Sungei Pang Sua, the potential water quality contamination would likely to occur throughout the construction phase with Occasional likelihood, the impact significance was assessed to be Moderate based on Impact Significance Matrix (Table 6-9).

8.7.1.1.2.2 Improper Management of Chemical Substances

During maintenance of construction vehicles or mechanical equipment, the chemical substances such as fuel and lubricants may accidentally spill and leak to the surrounding streams or drains. Given the relatively small quantities of such potential spills, the impact intensity on the human receptors such as on-site construction workers and nearby off-site residents and visitors would be Medium. Since the human receptors have been categorized as Priority 2 sensitive receptors, the impact consequence would be Low based on the Impact Consequence Matrix (Table 6-7). As the chemical wastes will be managed based on developed standard operating procedure and disposed by licensed waste operator based on Environmental Public Health (Toxic Industrial Waste) Regulations (refer to Table 8-14), the likelihood of the impact occurrence on on-site construction workers and nearby off-site residents and visitors was considered as Rare, and the impact significance was assessed to be Minor (based on Impact Significance Matrix of Table 6-9).

The ecology in the watercourses within and surroundings of the construction worksite might also potentially be affected by the water quality contamination due to improper management of chemical substances from the construction activities. The potential water quality contamination would bring Medium impact intensity on habitat and biocenosis of Pang Sua Canal. Based on the Impact Consequence Matrix (refer to Table 6-7), the impact consequence for habitat and biocenosis of Pang Sua Canal would be Medium due to Priority 1 sensitivity. By providing appropriate storage area for the chemical substances and proper disposal of chemical wastes such minimum controls as described in Table 8-14, the potential impact would bring Rare likelihood of occurrence of the impact on habitat and biocenosis of Pang Sua Canal and the impact significance was assessed to be Minor based on Impact Significance Matrix (Table 6-9). The construction worksites will locate near to the upstream of Sungei Pang Sua and the stream consisted of high ecological value based on biodiversity findings (refer to Section 7.3.1), so any potential spill due to improper management of chemical substances from the construction worksites would lead Medium impact intensity to the biodiversity living along Sungei Pang Sua. Given that the habitat and biocenosis of Sungei Pang Sua is Priority 1 sensitive receptor, the impact consequence would be Medium based on the Impact Consequence Matrix (refer to the Table 6-7). Due to some of worksites located near to the stream bank of Sungei Pang Sua, the potential water quality contamination would likely to occur throughout the construction phase with Occasional likelihood. The impact significance on habitat and biocenosis of Sungei Pang Sua was assessed to be Moderate based on Impact Significance Matrix (Table 6-9).

8.7.1.1.2.3 Liquid Effluent and Stormwater Runoff Generation

During construction phase, the liquid effluents generated from the construction activities commonly include extracted groundwater, sanitary discharges, and stormwater runoff from exposed and unstable slopes. The elevated suspended solids of liquid effluents will lead to increased turbidity and sedimentation rates. Such potential impact would bring Medium impact intensity on the human receptors such as on-site construction workers and nearby off-site residents and visitors. Since the human receptors have been categorized as Priority 2 sensitive receptors, the impact consequence would be Low (refer to Table 6-7). By considering the minimum controls (Table 8-14) such as regular and dedicated procedures for the inspection and maintenance of wastewater management would be developed and put in place accordingly for construction activities, the likelihood of the impact occurrence on on-site construction workers and nearby off-site residents and visitors was considered to be Rare, and the impact significance would be Minor (based on Impact Significance Matrix of Table 6-9).

The stormwater runoff generated from excavated areas or land clearing will potentially increase the levels of suspended solids, nutrients, oils and greases, change in runoff volume and salinity, etc. on the nearby watercourses of Project worksite if not properly managed during construction phase. The potential water quality contamination would bring Medium impact intensity on habitat and biocenosis of Pang Sua Canal. The impact consequence for habitat and biocenosis of Pang Sua Canal would be Medium based on the Impact Consequence Matrix (refer to Table 6-7). With considering no direct construction into the Canal (e.g., column construction for proposed pedestrian linkbridge and proposed vehicular bridge) and applying the minimum controls as described in Table 8-14, the potential impact would bring Rare likelihood of occurrence on habitat and biocenosis of Pang Sua Canal. The impact significance on habitat and biocenosis of Pang Sua Canal was assessed to be Minor based on Impact Significance Matrix (refer to Table 6-9). The construction worksites will locate near to the upstream of Sungei Pang Sua and the stream consisted of high ecological value based on biodiversity findings (refer to Section 7.3.1), so potential liquid runoff and stormwater runoff generated from the construction worksite would cause Medium impact intensity to the biodiversity living Sungei Pang Sua. Given that the habitat and biocenosis of Sungei Pang Sua is Priority 1 sensitive receptor, the impact consequence would be Medium based on the Impact Consequence Matrix (refer to Table 6-7). Due to some of worksites located near to the stream bank of Sungei Pang Sua, the potential water quality contamination would likely to occur throughout the construction phase with Occasional likelihood, and the impact significance was assessed to be Moderate based on Impact Significance Matrix (Table 6-9).

8.7.1.1.2.4 Storage and Disposal of Domestic Liquid and Construction Solid Wastes

During construction phase, the domestic and construction wastes normally would be generated from construction activities. Water contamination may occur due to improper storage, handling, transfer and disposal of the wastes would bring Medium impact intensity on the on-site construction workers and nearby off-site residents and visitors. Since the human receptors have been categorized as Priority 2 sensitive receptors, the impact consequence would be Low based on the Impact Consequence Matrix (refer to Table 6-7). With regular inspection and audit on hygienic conditions of construction worksite, the occurrence likelihood of the potential impact on on-site construction workers and nearby off-site residents and visitors is considered to be Rare, and the impact significance was assessed to be Minor based on Impact Significance Matrix of Table 6-9.

The ecology in the watercourses within and surroundings of the Project might potentially be affected by the water quality contamination due to improper storage and disposal of domestic liquid and construction solid wastes. The potential water quality contamination would bring Medium impact intensity on habitat and biocenosis of Pang Sua Canal. The impact consequence for habitat and biocenosis of Pang Sua Canal would be Medium based on the Impact Consequence Matrix (refer to Table 6-7). By providing best training practices on the workers in order to contribute in environmental protection and storing the stockpiles properly with erosion blanket coverage, the potential impact would bring Rare likelihood of occurrence of the impact on habitat and biocenosis of Pang Sua Canal and the impact significance was assessed to be Minor based on Impact Significance Matrix (refer to Table 6-9). The construction worksites will locate near to the upstream of Sungei Pang Sua and the stream consisted of high ecological value based on biodiversity findings (refer to Section 7.3.1), the improper management and disposal of domestic and construction wastes would cause Medium impact intensity to the biodiversity living along Sungei Pang Sua. Based on the Impact Consequence Matrix (refer to Table 6-7), the impact consequence would be Medium, given that the habitat and biocenosis of Sungei Pang Sua is Priority 1 sensitive receptor. Due to some of worksites located near to the stream bank of Sungei Pang Sua, the potential water quality contamination would likely to occur with Occasional likelihood even applied the minimum controls throughout the construction phase, the impact significance was assessed to be Moderate based on Impact Significance Matrix (Table 6-9).

Table 8-16 Summary of impact evaluation during construction phase

Potential Source of Impact	Receptor Sensitivity	Impact Intensity	Consequence	Likelihood	Significance
Temporary Land Use Change (Hydrology)	On-site construction workers (Priority 2)	Medium	Low	Rare	Minor
	Off-site residents and visitors in the vicinity of the Study Area (Priority 2)	Medium	Low	Rare	Minor
	Habitat and biocenosis of Pang Sua Canal (Priority 1)	Medium	Medium	Rare	Minor
	Habitat and biocenosis of Sungei Pang Sua (Priority 1)	Medium	Medium	Rare	Minor
Solid & Toxic Wastes Generation (Water Quality)	On-site construction workers (Priority 2)	Medium	Low	Rare	Minor
	Off-site residents and visitors in the vicinity of the Study Area (Priority 2)	Medium	Low	Rare	Minor
	Habitat and biocenosis of Pang Sua Canal (Priority 1)	Medium	Medium	Rare	Minor
	Habitat and biocenosis of Sungei Pang Sua (Priority 1)	Medium	Medium	Occasional	Moderate
Improper Management of Chemical Substances (Water Quality)	On-site construction workers (Priority 2)	Medium	Low	Rare	Minor
	Off-site residents and visitors in the vicinity of the Study Area (Priority 2)	Medium	Low	Rare	Minor
	Habitat and biocenosis of Pang Sua Canal (Priority 1)	Medium	Medium	Rare	Minor
	Habitat and biocenosis of Sungei Pang Sua (Priority 1)	Medium	Medium	Occasional	Moderate
Liquid Effluent	On-site construction workers	Medium	Low	Rare	Minor

Potential Source of Impact	Receptor Sensitivity	Impact Intensity	Consequence	Likelihood	Significance
Generation and Stormwater Runoff (Water Quality)	(Priority 2)				
	Off-site residents and visitors in the vicinity of the Study Area (Priority 2)	Medium	Low	Rare	Minor
	Habitat and biocenosis of Pang Sua Canal (Priority 1)	Medium	Medium	Rare	Minor
	Habitat and biocenosis of Sungei Pang Sua (Priority 1)	Medium	Medium	Occasional	Moderate
Storage and Disposal of Domestic Liquid and Construction Solid Wastes (Water Quality)	On-site construction workers (Priority 2)	Medium	Low	Rare	Minor
	Off-site residents and visitors in the vicinity of the Study Area (Priority 2)	Medium	Low	Rare	Minor
	Habitat and biocenosis of Pang Sua Canal (Priority 1)	Medium	Medium	Rare	Minor
	Habitat and biocenosis of Sungei Pang Sua (Priority 1)	Medium	Medium	Occasional	Moderate

8.7.1.2 Quantitative Impact Assessment

8.7.1.2.1 Hydrodynamic Impact

Figure 8-11 presents the simulated statistical mean flow speed during the NE simulation period. It shows the simulated results for the baseline case, the construction phase case, and the differences between the above two cases. Based on the simulation results for the baseline case and the construction phase after the settlement, the Sungei Pang Sua is characterized with low flow speed at the upstream area, and relatively high flow speed at the middle stream and the downstream (tidal entrance area). The mean flow speed is typically below 0.005 m/s at the upstream of the Sungei Pang Sua, while the mean flow speed ranges of 0.06 to 0.1m/s at the middle stream and the downstream of Sungei Pang Sua. The simulated flow speeds are consistent with the site observations which are presented in Section 8.4.

During the construction period, the mean flow speed shows the similar regime as the baseline conditions. The difference plot shows that no changes in mean flow speed is observed within the Sungei Pang Sua between the baseline and construction phase.

Figure 8-12 present the simulated statistical maximum flow speed during the NE simulation period. It shows the simulated results for the baseline case, the construction phase case and the differences between the two cases. In general, the maximum flow speed shows the similar flow regime as the mean flow speed, with low flow speed at the upstream area, and relatively high flow speed at the middle stream and the downstream.

Based on the simulation results, the maximum flow speed at the upstream of the Sungei Pang Sua is up to 0.03m/s, while the maximum flow speed at the middle stream and downstream could be up to 0.3m/s. During the construction period, the maximum flow speed shows the similar regime as the baseline conditions. The difference plot shows that no changes in maximum flow speed is observed within the Sungei Pang Sua between the baseline and construction phase.

Overall, it is expected that there are **No Impacts** on the mean and maximum flow speeds during the construction phase.

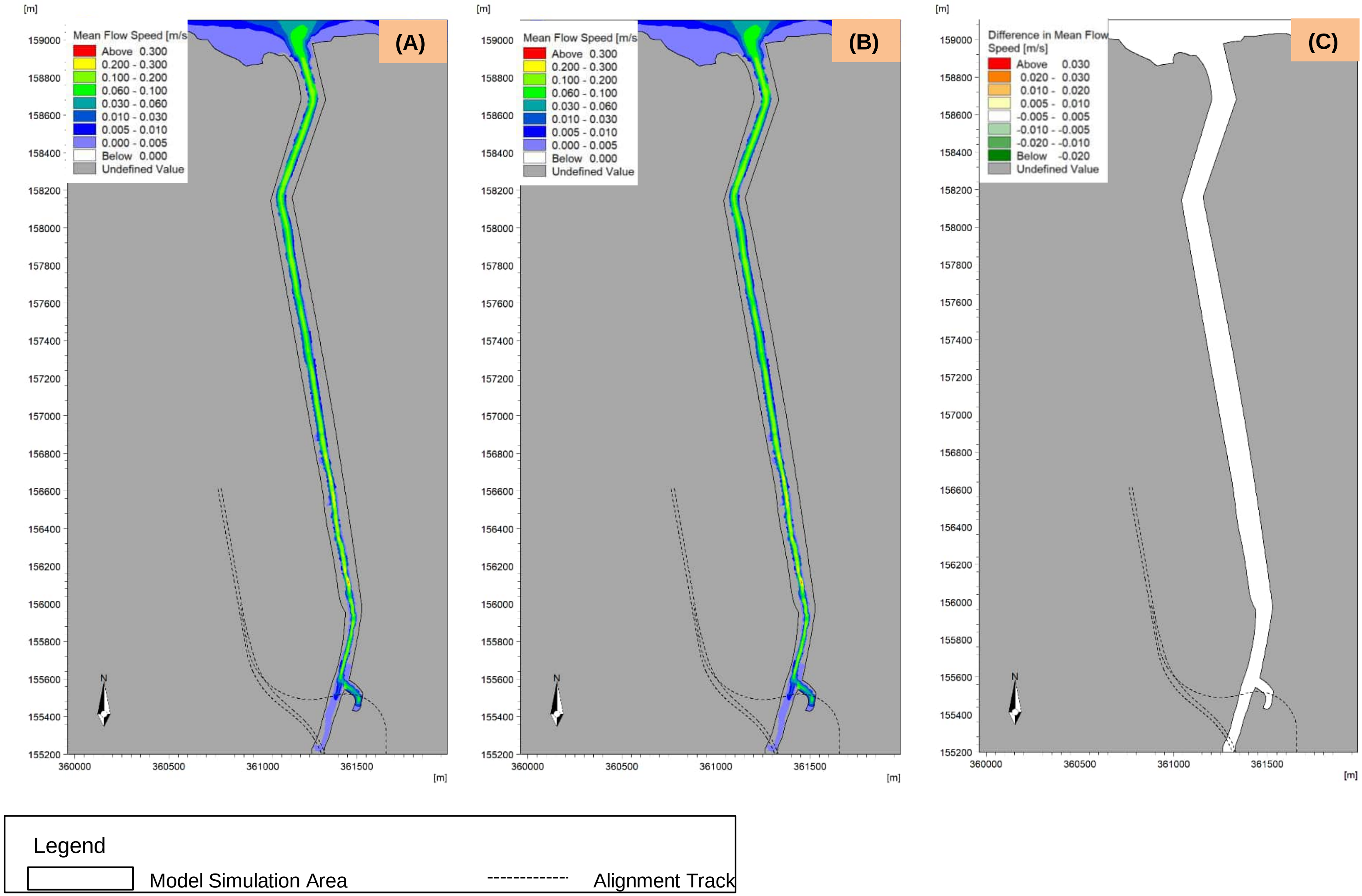


Figure 8-11 Simulated mean flow speed for (A) baseline and (B) construction phases, and (C) the differences in the mean flow speed between construction and baseline phase

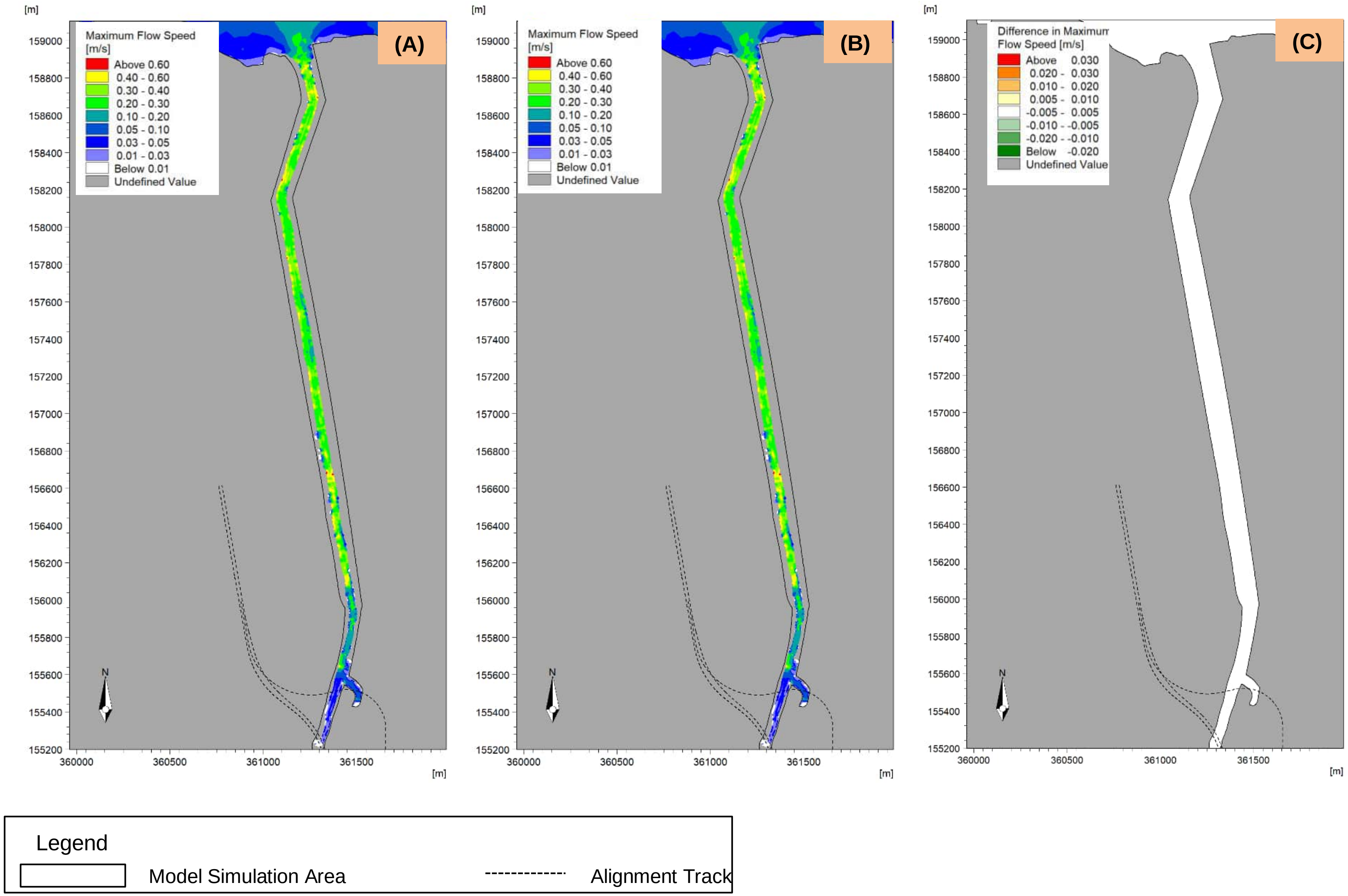


Figure 8-12 Simulated maximum flow speed for (A) baseline and (B) construction phase, and (C) the differences in the maximum flow speed between construction and baseline phase

8.7.1.2.2 Morphological Impact

The morphology simulation results show the sedimentation occur at the settlement area naturally. It is estimated that after 2 years, the riverbed at the settlement area will be level up as similar to the baseline condition. The morphological model only simulated the sedimentation process of the suspended sediments. In the actual condition, the falling leaves, the crashed branches and the detritus in Sungei Pang Sua will flow and settle down at the settlement area, whereas, the riverbed level might be back to the baseline condition earlier than 2 years' time.

8.7.2 Operational Phase

As described in Section 8.3.2, the major sources of impacts on hydrology and water quality during operational phase are altered stormwater runoff, stormwater runoff contamination and improper management of liquid and solid wastes. The potential source of altered stormwater runoff will mostly impact the existing hydrological conditions of the site, while the rest of the impact sources will mostly impact on water quality. The sources of impacts will be assessed the risk matrix method that has been presented in Section 6.4. Following sub-sections present the impact prediction and evaluation on hydrology and water quality during operational phase.

8.7.2.1 Hydrology

8.7.2.1.1 Altered Stormwater Runoff

Higher percentage of urbanised areas is known to have an impact on the water runoff, both in quantity and quality. Hence, it is expected that the proposed future land use of operational footprint might have the potential impact on the hydrology, especially during storm events. Increased runoff flow peak is expected in such events which could consequently lead to elevated water depths in drainage system and potentially cause flooding to the surrounding areas. It was assessed that the impact intensity on the human receptors such as maintenance workers and visitors of the proposed development as well as the nearby off-site residents and visitors would be Medium. Since the human receptors have been categorized as Priority 2 sensitive receptors, the impact consequence would be Low (refer to Table 6-7). The detention system would be provided and designed as per requirement of PUB's COP on Surface Water Drainage [R-7] to capture the stormwater during heavy storm events to reduce the peak runoff from the baseline condition, the nearby watercourses would not be significantly impacted. Given Rare likelihood of the impact occurrence for maintenance workers and visitors within the proposed development as well as nearby off-site residents and visitors, the impact significance was assessed to be Minor based on Impact Significance Matrix (Table 6-9).

The ecology in the watercourses within and surroundings of the operational footprint might also potentially be affected by dry weather flow alteration and stormwater peak flow increase during operation of the Project. As the proposed land use change of operational footprint might not significantly affect the existing land use of Pang Sua Canal, the impact intensity on the habitat and biocenosis of Pang Sua Canal would be Low. Given that the habitat and biocenosis of Pang Sua Canal is Priority 1 sensitive receptor, the impact consequence would be Low based on the Impact Consequence Matrix (refer to Table 6-7). Since more softscape area would be considered in the design of the development to reduce the run-off coefficient which will help to reduce the peak flow and reduce flood risk at downstream area, it would bring Rare likelihood of occurrence and the impact significance was assessed to be Minor during operational phase based on Impact Significance Matrix (Table 6-9). For Sungei Pang Sua, it consisted of high ecological value based on biodiversity findings (refer to Section 7.3.1), so the land use change of operational footprint would cause Medium impact intensity to the biodiversity living along the stream. Given that the habitat and biocenosis of Sungei Pang Sua is Priority 1 sensitive receptor, the impact consequence would be Medium based on the Impact Consequence Matrix (refer to Table 6-7). The hydrology of Sungei Pang Sua is dominantly influenced by tidal flowing, so the likelihood occurrence of hydrological change on Sungei Pang Sua would be Rare. The impact significance was assessed to be Minor based on Impact Significance Matrix (Table 6-9).

8.7.2.2 Water Quality

8.7.2.2.1 Stormwater Runoff Contamination

With the minimum controls such as regular and dedicated procedures for stormwater management, wastewater and solid waste management practice will be implemented, impact intensity of stormwater runoff contamination on the human receptors such as maintenance workers and visitors within the proposed development and nearby off-site residents and visitors would be Medium. Since the human receptors have been categorized as Priority 2 sensitive receptors, the impact consequence would be Low (refer to Table 6-7). By applying the minimum controls (refer to Table 8-15) such as regular and dedicated procedures for the inspection and maintenance of stormwater management, the likelihood of the stormwater runoff contamination on maintenance workers and visitors within the proposed development as well as nearby off-site residents and visitors would be Rare, and the impact significance was assessed to be Minor (based on Impact Significance Matrix of Table 6-9).

The stormwater runoff from future drainage system within the operational footprint and the planned runoff discharge via holes in the structures of proposed above ground potential future infrastructure and vehicular bridge may flow directly into the watercourses such as Pang Sua Canal and Sungei Pang Sua. The stormwater runoff may consist of elevated sediment and silt before flow into the watercourses and will contaminate the water of the watercourses. The potential contamination would bring Medium impact intensity on the habitat and biocenosis of Pang Sua Canal. The impact consequence for habitat and biocenosis of Pang Sua Canal was assessed to be Medium based on the Impact Consequence Matrix (refer to Table 6-7). However, by considering the minimum controls as described in Table 8-15, it would bring Rare likelihood of occurrence of the impact, the impact significance on habitat and biocenosis of Pang Sua Canal would be Minor based on Impact Significance Matrix (refer to Table 6-9). The operational footprint is located at the upstream of Sungei Pang Sua and the stream consisted of high ecological value based on biodiversity findings (refer to Section 7.3.1). The stormwater runoff contamination from the operational footprint would cause Medium impact intensity to the biodiversity living along Sungei Pang Sua. Given that the habitat and biocenosis of Sungei Pang Sua is Priority 1 sensitive receptor, the impact consequence would be Medium based on the Impact Consequence Matrix (refer to Table 6-7). By providing the minimum controls such as proper management of stormwater collection, settling and testing before discharging the stormwater into Sungei Pang Sua as described in Table 8-15, it would bring Rare likelihood of the potential water quality contamination throughout the operational phase. The impact significance was assessed to be Minor based on Impact Significance Matrix (Table 6-9).

8.7.2.2.2 Improper Management on Liquid and Solid Wastes

During operational phase, the surface water in the Project and surroundings watercourses are potentially to be contaminated due to inappropriate disposal and storage of liquid and solid wastes. It would cause Medium impact intensity on the human receptors such as maintenance workers and visitors within the proposed development and nearby off-site residents and visitors as human's health might be jeopardised due to the potential impact. Since the human receptors have been categorized as Priority 2 sensitive receptors, the impact consequence would be Low (refer to Table 6-7). By considering to provide regular inspection on wastes storage system and well-monitored of proposed watercourses of the operational footprint such minimum controls (refer to Table 8-15), Rare likelihood of the impact occurrence would be expected on the maintenance workers and visitors within the proposed development as well as the nearby off-site residents and visitors. The impact significance on the human receptors was assessed to be Minor based on Impact Significance Matrix (Table 6-9).

The ecology in the watercourses within and surroundings of the operational footprint would be impacted if the liquid and solid wastes within operational footprint are not managed properly. Any improper handling, transfer and storage of liquid and solid wastes would cause Medium impact intensity on the habitat and biocenosis of Pang Sua Canal. The impact consequence for habitat and biocenosis of Pang Sua Canal would be Medium based on the Impact Consequence Matrix (refer to Table 6-7). However, by considering the minimum controls as described in Table 8-15, it would bring Rare likelihood of occurrence of the impact, the impact significance on habitat and biocenosis of Pang Sua Canal was assessed to be Minor based on Impact Significance Matrix (refer to Table 6-9). The operational footprint is located at the upstream of Sungei Pang Sua and the stream consisted of high ecological value based on biodiversity findings (refer to Section 7.3.1). The water quality contamination due to improper management and handling of liquid and solid wastes would cause Medium impact intensity to the biodiversity living along Sungei Pang Sua. Given that the Priority 1 sensitivity of habitat and biocenosis of Sungei Pang Sua, the impact consequence would be Medium based on the Impact Consequence Matrix (refer to Table 6-7). By applying the the minimum controls as described in Table 8-15 such as dedicated inspection procedure on wastes' storage system of the Project and regular monitoring on the watercourses, it would bring Rare likelihood of the occurrence on Sungei Pang Sua throughout the operational phase. The impact significance was assessed to be Minor based on Impact Significance Matrix (Table 6-9).

Table 8-17 Summary of impact evaluation during operational phase

Potential Source of Impact	Receptor Sensitivity	Impact Intensity	Consequence	Likelihood	Significance
Altered Stormwater Runoff (Hydrology)	Maintenance workers and visitors of the proposed development (Priority 2)	Medium	Low	Rare	Minor
	Visitors and residents in the vicinity of the proposed development (Priority 2)	Medium	Low	Rare	Minor
	Habitat and biocenosis of Pang Sua Canal (Priority 1)	Low	Low	Rare	Minor
	Habitat and biocenosis of Sungei Pang Sua (Priority 1)	Medium	Medium	Rare	Minor
Stormwater Runoff Contamination (Water Quality)	Maintenance workers and visitors of the proposed development (Priority 2)	Medium	Low	Rare	Minor
	Visitors and residents in the vicinity of the proposed development (Priority 2)	Medium	Low	Rare	Minor
	Habitat and biocenosis of Pang Sua Canal (Priority 1)	Medium	Medium	Rare	Minor
	Habitat and biocenosis of Sungei Pang Sua (Priority 1)	Medium	Medium	Rare	Minor
Improper Management of Liquid and Solid Wastes (Water Quality)	Maintenance workers and visitors of the proposed development (Priority 2)	Medium	Low	Rare	Minor
	Visitors and residents in the vicinity of the proposed development (Priority 2)	Medium	Low	Rare	Minor
	Habitat and biocenosis of Pang Sua Canal (Priority 1)	Medium	Medium	Rare	Minor
	Habitat and biocenosis of Sungei Pang Sua (Priority 1)	Medium	Medium	Rare	Minor

8.8 Recommended Mitigation Measures

In this section, mitigation measures were proposed to further minimise the adverse impacts on the environment where impact significance were assessed to be Moderate or Major during both construction and operational phases. For operational phase, as the impact significance on all sensitive receptors was assessed to be Minor, thus no mitigation measure to be proposed for operational phase.

8.8.1 Construction Phase

8.8.1.1 Minimise

The proposed construction activities of the Project were assessed to have Moderate impact significances on habitat and biocenosis of Sungei Pang Sua although with implemented minimum controls.

It is recommended that all the discharges from the construction worksites to Sungei Pang Sua 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]. The water quality of the discharge should be monitored regularly throughout whole construction stage to ensure the water quality meets the guidelines.

8.9 Residual Impacts

A residual impact assessment has been undertaken assuming the mitigation measures recommended in the previous section are implemented. With the implementation of the recommended mitigation measure in conjunction with the identified minimum controls, the residual impact intensity on water quality could be reduced to **Minor** during construction phase.

Table 8-18 Summary of water quality residual impacts and its mitigation measures during construction phase

Activity	Receptor Sensitivity	Impacts	Impact Significance (with minimum controls)	Mitigation Measures	Significance of Residual Impact (with mitigation measures)
Land clearing, earthworks and excavation activities; Storage and disposal of solid, liquid and toxic wastes; and Use and storage of chemical substances, and refuelling activities.	Habitat and biocenosis of Sungei Pang Sua (Priority 1)	Contaminants from the construction worksite will direct deteriorate the water quality especially total suspended solids (TSS).	Moderate	Discharge from potential future infrastructure worksite should comply with NEA Trade Effluent Discharge Limits and monitored regularly, especially TSS parameter.	Minor

8.10 Cumulative Impacts with Other Concurrent Projects

This section focuses on assessing cumulative impacts of the construction and operational activities from identified concurrent developments as described in Section 3.5.2 on the watercourses. It should be noted that as the details of construction and operational activities were not available at the time of writing this report, only qualitative cumulative impact assessment was carried out.

8.10.1 Construction Phase

It was assumed that all the concurrent developments would comply with the construction standards and hence their impact on hydrology and surface water quality for the watercourses was not expected to be significant.

8.10.2 Operational Phase

It was assumed that all the concurrent developments would comply with the operation standards and hence the hydrology and surface water quality impact for the watercourses was not expected to be significant.

8.11 Summary of Key Findings

While the hydrological baseline study aimed to identify watercourses present in the Study Area including their location, water flow conditions and bank characteristics, the water quality surveys determined the water quality of the surface watercourses.

The baseline hydrological conditions in the Study Area were analysed based on site observations. The Pang Sua Canal has perennial flow with water flow ranging from 0.2 to 0.6 m/s observed during dry weather and the water flow could be more than 2 m/s during heavy storm throughout the canal. The surface runoff generally originated from drainage networks collecting surface runoff from surrounding residential areas along the Canal before drains into the Kranji Reservoir eventually. Sungei Pang Sua is a tidal-influenced stream and has perennial flow with slow water flow (i.e., ranged from 0.04 to 0.3 m/s) and even could be in almost stagnant condition at some areas. A few surface runoff discharge outlets (i.e., E63 Drain, Drain 2, Drain 3, Drain 4, Drain 5, Drain 6, Drain 7 and Drain 8) which originated from urbanized area and forest area (i.e., Stream 1) were observed along the Sungei Pang Sua. All the streams and drains within the Study Area did not have any obvious smell based on site observation. The flow direction at marine area near to river mouth of Sungei Pang Sua normally was tidal influenced and varying and therefore, depended on the flood and ebb tides during spring and neap tidal periods.

In order to get comprehensive data that is representative of baseline conditions of water quality and to capture the possible changes in water quality parameters over time and different events, the identified watercourses were sampled during dry and wet weather conditions. Five (5) water quality stations were located at the upstream (i.e., WQ1, WQ2), midstream (i.e., WQ3, WQ4) and downstream (i.e., WQ5) of Pang Sua Canal. The location of stations WQ1 and WQ2 were selected to capture the water quality at the upstream of Pang Sua Canal which receives water from upstream drains and surrounding residential areas along the canal. Stations WQ3 and WQ4 were selected to capture the water quality of the midstream which receiving runoff from the residential area. Station WQ5 was selected to capture the water quality of downstream of Pang Sua Canal before flowing into Kranji Reservoir. Another ten (10) water quality stations (i.e., WQ6, WQ7, WQ8, WQ9A, WQ9, WQ10A, WQ10, WQ11A, WQ11 and WQ12) were sampled along Sungei Pang Sua as well as at the streams (i.e., Stream 1) and drains (i.e., E63 Drain, Drain 3 and Drain 6) which eventually discharge to Sungei Pang Sua. Three (3) water quality stations (i.e., WQ13, WQ14 and WQ15) were also sampled at the marine area near Sungei Pang Sua in order to capture the water quality from Sungei Pang Sua. The surface water samples were tested for the physical and chemical parameters relevant for sustenance of aquatic life including temperature, pH, salinity, conductivity, total dissolved solids (TDS), dissolved oxygen (DO), turbidity, total suspended solids (TSS), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total organic carbon (TOC), oil & grease (total), total phosphorous (TP), orthophosphate (PO_4-P), total nitrogen (TN), nitrate (NO_3-N), ammoniacal nitrogen (NH_4-N), *Enterococcus*, chlorophyll-a, cadmium, chromium, copper, zinc, lead, iron, mercury, nickel, arsenic, cyanide, barium, chloride, phenol and calcium. The data results of the water quality stations were compared with respective NEA discharge guideline of Singapore, international criteria for aquatic life and Singapore Marine Water Quality (SMWQ) guideline accordingly.

From the results of the hydrological and water quality baseline assessment, it could be inferred that the Pang Sua Canal was generally perennial (fed from stormwater), however, the water quality results indicate poor water quality for survival of aquatic life. This also aligns with biodiversity findings in Section 7.3, which shows that only Pang Sua Canal supported poor aquatic life at the time of survey. For perennial Sungei Pang Sua, the water quality of the environment was mostly affected by the tidal influence and its surrounding urbanised areas (i.e., industrial area). Despite high nutrients, turbidity with some heavy metals contamination and lower DO found along the watercourse, the mangroves along Sungei Pang Sua still support certain flora and fauna species of conservation significance as described in biodiversity findings from Section 7.3.

Based on the assessment of the hydrology and water quality related impacts on the various sensitive receptors, the activities of construction and operational phases were assessed qualitatively to cause Minor to Moderate impacts on human receptors and the habitat and biocenosis of Sungei Pang Sua and Pang Sua Canal during construction and operational phases, even with implemented minimum controls. In terms of quantitative impact assessment, it was assessed that there will be no impacts on the hydrodynamics of Sungei Pang Sua and that the upstream riverbed level is expected to be brought back to the baseline condition within 2 years' time during the construction phase. As a mitigation measure, it was recommended that all the discharges from the construction worksites to Sungei Pang Sua 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. With such mitigation measure, the residual water quality impact on habitat and biocenosis of Sungei Pang Sua could be reduced to **Minor**.

For the cumulative impacts from concurrent developments identified in the vicinity of the Project during both construction and operational phases, it was assumed that all the concurrent developments would comply with the construction and operation standards and hence their impact on hydrology and surface water quality for the watercourses was not expected to be significant.

Table 8-19 Summary of Hydrology and Surface Water Quality Impact Assessment

Sensitive Receptors and Phases	Impact Significance with minimum controls	Residual Impact Significance with mitigation measures (if required)
Construction Phase		
On-site construction workers (Priority 2)	Minor	**Minor**
Off-site residents and visitors in the vicinity of the Study Area (Priority 2)	Minor	**Minor**
Habitat and biocenosis of Pang Sua Canal (Priority 1)	Minor	**Minor**
Habitat and biocenosis of Sungei Pang Sua (Priority 1)	Moderate	**Minor**
Operational Phase		
Maintenance workers and visitors of the proposed development (Priority 2)	Minor	**Minor**
Visitors and residents in the vicinity of the proposed development (Priority 2)	Minor	**Minor**
Habitat and biocenosis of Pang Sua Canal (Priority 1)	Minor	**Minor**
Habitat and biocenosis of Sungei Pang Sua (Priority 1)	Minor	**Minor**

9 Air Quality

9.1 Introduction

This section presents the air quality impact assessment for the construction and operational phases of the Project following the general ES methodology described in Section 6. Air quality impact tends to impact sensitive receptors such as schools, medical institutions, residential areas and natural areas located in the vicinity of the Project Site. Therefore, the Study Area for air quality is well beyond the Project Site and is focused largely on the sensitive receptors (see Section 6.2.1). In line with the applicable legislation detailed in Section 5, the key steps for conducting the air quality impact assessment are as follows:

- Review existing baseline monitoring data and conduct baseline air monitoring at representative locations to evaluate the current air quality in the Study Area;
- Identify and classify sensitivity of the area around the construction or operational footprint;
- Understand the proposed activities during construction and operational phases;
- Conduct an impact assessment to qualitatively assess air quality impacts during construction and operation of the Project;
- Evaluate qualitative air quality impacts against nominated assessment criteria;
- Specify mitigation measures to be implemented;
- Determine the overall significance of the residual air quality impacts after implementation of mitigation measures; and
- Recommend a suitable monitoring and management plan.

9.2 Methodology and Assumptions

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

9.2.1 Study Area and Screening of Air Sensitive Receptors

The Study Area for air quality impact assessment during construction phase is recommended as 350 m and 50 m from the construction footprint (i.e., demolition, earthworks, construction works, trackout) of the proposed development for human and ecological receptors, respectively (in accordance with UK IAQM guidance [R-35]). For operational phase the Study Area is recommended as 250 m around the project/ operational footprint (e.g., stations, vehicle bridge, overhead bridge, potential future infrastructure, etc.). The 250 m Study Area for operational phase covers the proposed intermediate station and interchange station and the existing major operational roads outside or nearby the Project Site.

During the scoping phase for this ES, an initial screening of receptors in the Study Area was conducted as per Section 6.2.2 and detailed in Section 9.3, in order to determine the areas which are sensitive to potential construction and operational impacts detailed in Section 9.4.

9.2.2 Air Quality Baseline Study

Baseline air quality monitoring includes primary data collection in the form of baseline ambient air quality monitoring to understand baseline air quality. Of the criteria pollutants generally measured as part of ambient air monitoring, such as CO, O_3, NO_2, SO_2, PM_{10} and $PM_{2.5}$, this baseline monitoring only focuses on PM_{10}, $PM_{2.5}$ and NO_2, since these are the major pollutants that are likely to have the significant impact on the ambient air quality as a result of the project during construction and operational phase. The purpose of the baseline monitoring is to understand what the natural conditions of these air quality parameters are, so that in the event that a repeat monitoring event is to be conducted during the construction and/or operational phases in the future, this monitoring data can be used as a reference of the existing baseline prior to any disturbance.

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

9.2.2.1 Secondary Data Collection (Review of Background Data)

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

9.2.2.1.1 NEA Long Term Ambient Air Quality

NEA carries out routine monitoring of ambient air quality through the Telemetric Air Quality Monitoring and Management System (TAQMMS). This system comprises 22 monitoring stations (refer to Figure 9-1) which are located around Singapore and linked into a Central Control System (CCS). The air quality monitoring stations are distributed amongst urban, industrial, suburban, coastal, and roadside locations. General NEA ambient air monitoring results for Singapore over the period 2016 – 2020 have been presented and compared with Singapore Long Term Ambient Air Quality Targets in Section 9.5.2.1.1. Air pollution control in Singapore is governed by legislation listed in Section 5.

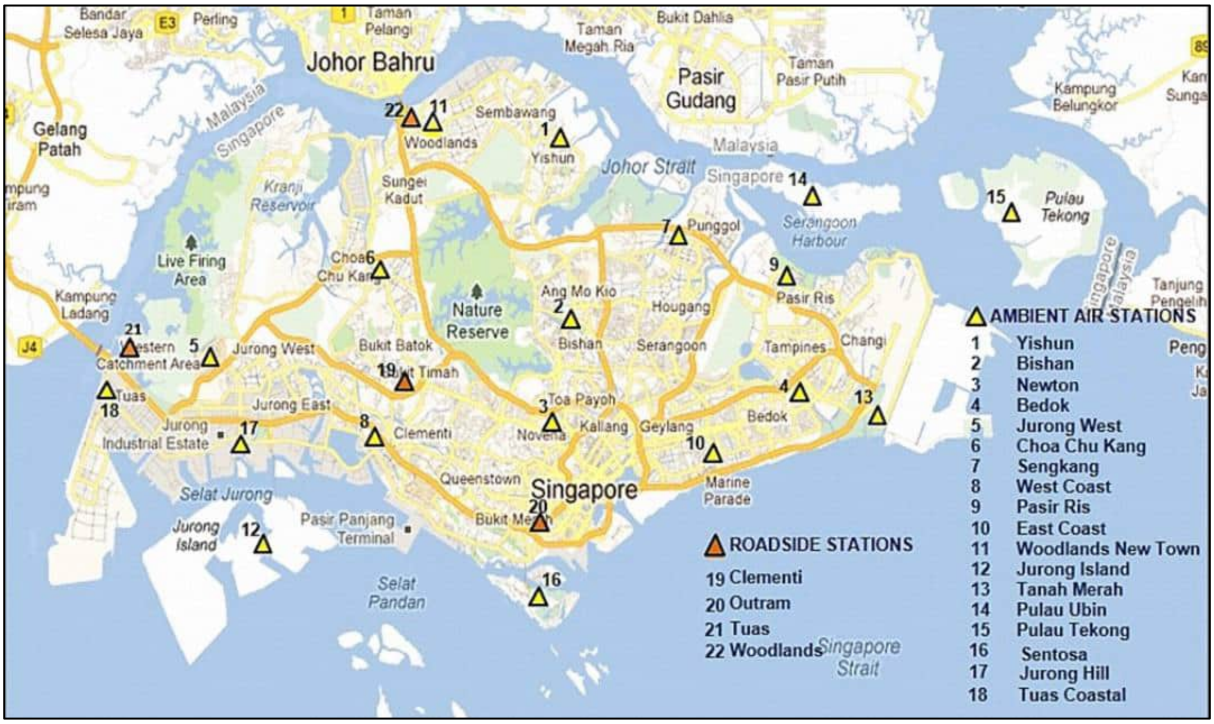


Figure 9-1 NEA ambient air quality monitoring stations in Singapore [R-75]

9.2.2.1.2 Hourly Pollution Standards Index (PSI) and 24-hour PM_{10} and $PM_{2.5}$ Concentrations

The PSI is an index used to provide accurate and easily understandable information about daily levels of air quality. The concentration levels of particulate matter (PM_{10}), fine particulate matter ($PM_{2.5}$), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), and carbon monoxide (CO) monitored by air monitoring locations located in different parts of Singapore are used to determine the PSI. The PSI value gives an indication of the air quality as shown in Table 9-3. The 24-hr $PM_{2.5}$ and PM_{10} PSI readings were available on data.gov.sg for the

North Region of Singapore. These data were collected during the same period of primary data collection period and discussed in Section 9.5.2.1.2.

Hourly 24-hr PM_{10} and $PM_{2.5}$ concentration readings were available on data.gov.sg for the Western and Northern Regions of Singapore. These data were collected during the same period of primary data collection period and discussed in Section 9.5.2.1.2.

Table 9-1 General air quality descriptor based on PSI value [W-102]

PSI Value	Air Quality Descriptor
0 – 50	Good
51 – 100	Moderate
101 -200	Unhealthy
201 – 300	Very unhealthy
Above 300	Hazardous

9.2.2.1.3 Other Parameters (Rainfall, Temperature, Wind Speed)

Rainfall, temperature, and wind speed can significantly affect the distribution of pollutants. The weather monitoring station recorded rainfall, temperature and wind speed data for the past 5 years have been collected and the results are discussed in Section 9.5.2.1.3.

Bukit Panjang is the nearest monitoring station to the Study Area, located approximately 800 m from the Study Area. However, this monitoring location only recorded rainfall data. Hence, only rainfall data was presented for Bukit Panjang. Collection of temperature and wind speed was conducted for the next nearest weather monitoring locations which have these data available, i.e., Tengah and Admiralty located approximately 5 km and 7 km from the Study Area respectively. It should be noted that Tengah has stopped recording temperature and wind speed since August 2017 and May 2020 respectively.

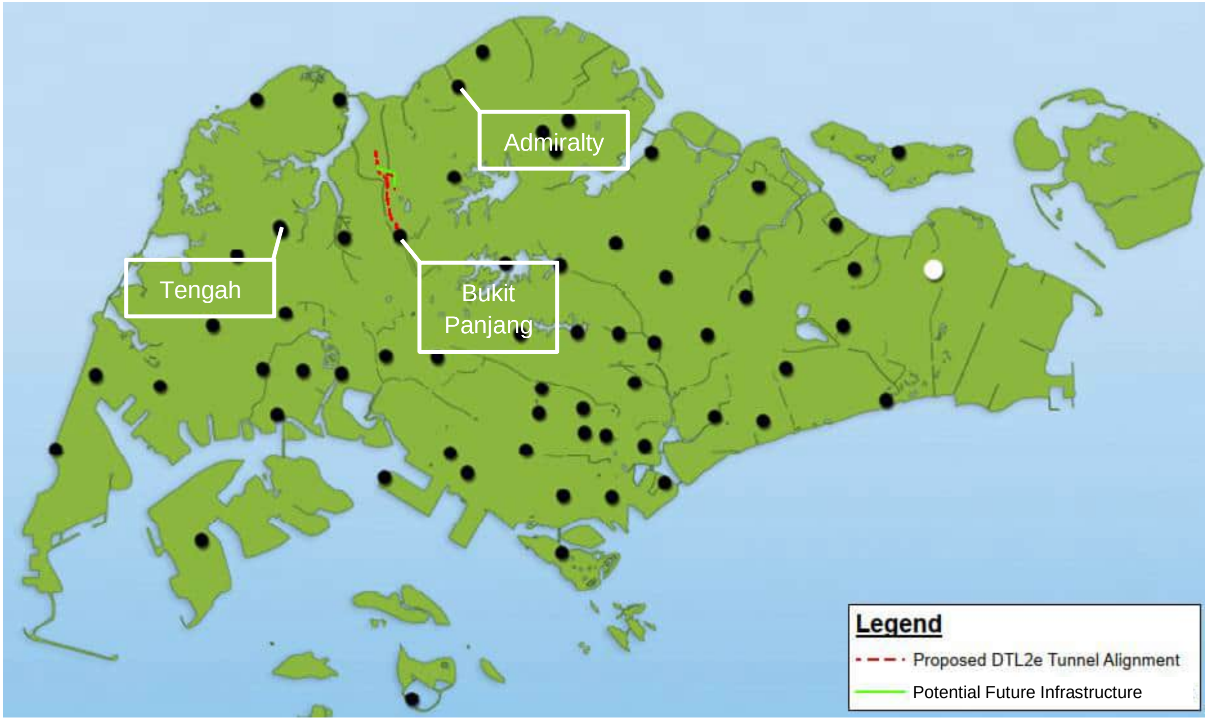


Figure 9-2 NEA weather monitoring stations in Singapore [W-65]

9.2.2.1.4 Secondary Data from Concurrent Study Air Quality Monitoring [R-92]

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

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

Air quality monitoring was conducted from 2 – 9 September 2022 and 9 – 16 September 2022, 19 – 26 September 2022, and 26 September – 3 October 2022. The air monitoring location for the concurrent study [R-92] is presented in Table 8-1 and Figure 8-3. The results for concurrent study air quality monitoring [R-92] is presented in Section 8.2.1.2.

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

Table 9-2 Air quality monitoring location in concurrent study

Monitoring ID in the Concurrent Study	Monitoring Location	Photo of Monitoring Location
AQ1	Villa Verde Estate	
AQ2	Jurong Pioneer Junior College	
AQ3	HDB Blk 162 Teck Whye Neighbourhood	
AQ4	West View Primary School	

Monitoring ID in the Concurrent Study	Monitoring Location	Photo of Monitoring Location
AQ5	HDB Blk 634 Senja Road	

9.2.2.2 Primary Data Collection (Survey & Sampling)

For this Project, the air quality monitoring services were provided by ALS Technichem (S) Pte Ltd. A total of five (5) air monitoring locations were proposed (at the Inception stage), based on the following considerations:

- Identification of Air Sensitive Receptors (ASRs) (schools, residences, places of worship, flora and habitats of high ecological value) nearest to the construction worksite areas / project footprint boundary of the proposed station box;
- Other ASRs away from the construction worksite areas / project footprint were eliminated as these receptors are assumed to be barricaded by the first row of buildings
- ASRs with areas having ongoing construction were avoided;
- The closest ASR to the construction worksite areas / project footprint was selected; and
- ASRs where the owner denied permission during site walkover was excluded (e.g., past experience with terrace houses/ bungalows, etc).

Air quality monitoring was conducted at the monitoring locations for one week ranging from 28 February – 24 March 2022 across the 5 monitoring locations to collect air quality samples for the following air quality parameters:

- Particulate matter smaller than 2.5 µm, $PM_{2.5}$ (for areas that is potentially impacted during both construction and operational phases);
- Particulate matter smaller than 10 µm, PM_{10} (for areas that is potentially impacted during both construction and operational phases);
- Nitrogen dioxide, NO_2 (for areas that is potentially impacted during operational phase).

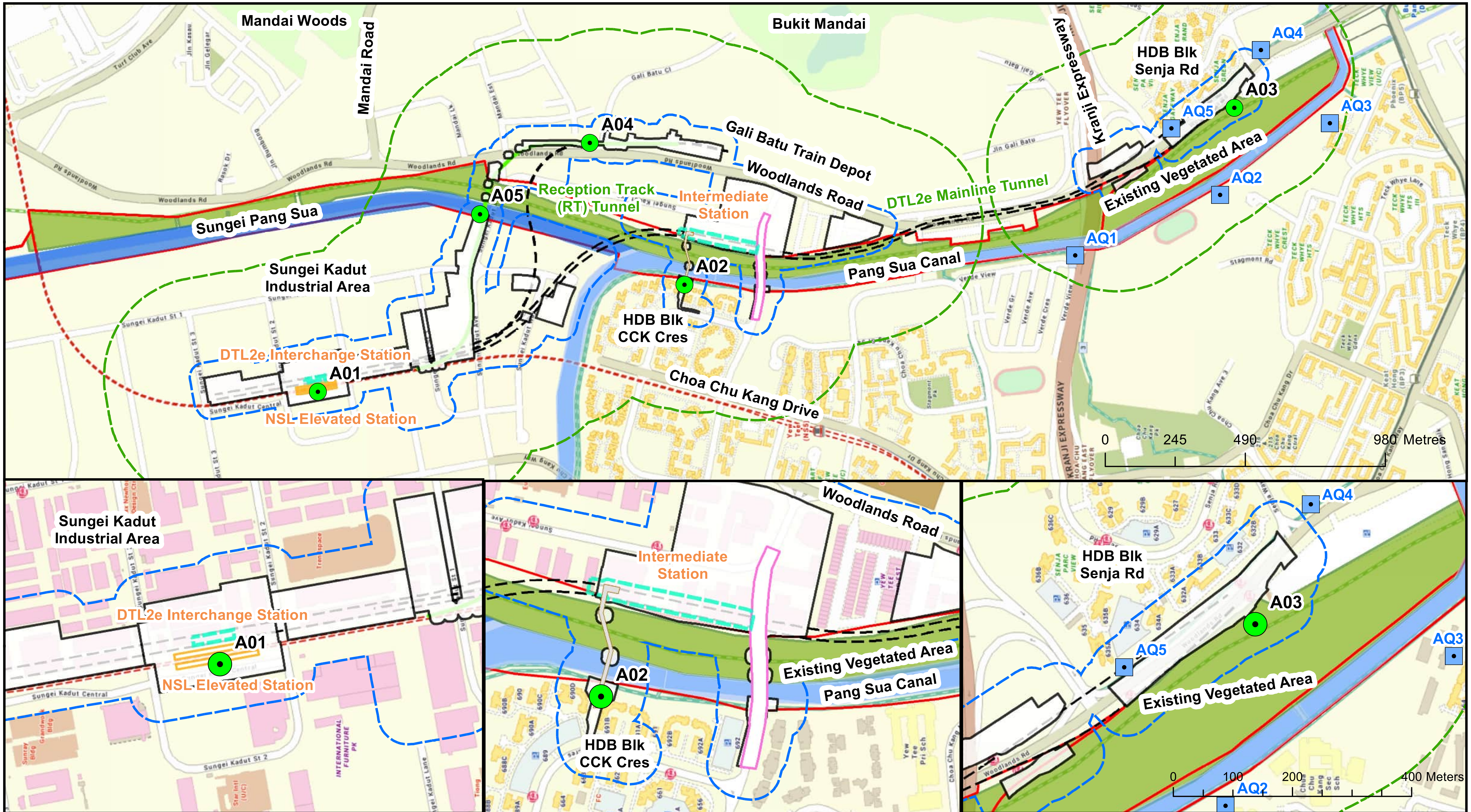
Air quality monitoring was conducted for 1 week in order to establish a baseline for existing air quality levels. Following the site survey conducted on 16 February 2021 and 24 February 2022, five (5) monitoring locations were identified to represent the site and were determined to represent the Study Area. This has been proposed and accepted in the inception report. The monitoring location was chosen so that the equipment was more than 1 metre from any buildings or structures, and not shaded by structures or trees. This is necessary to ensure adequate airflow. The indicative air quality monitor was installed at 1.8 m from ground level in the breathing zone. Baseline air monitoring locations are provided in Table 9-3, Figure 9-3 and Figure 9-4.

TSI Environmental DustTrak Monitoring System was used for the purpose of PM_{10} and $PM_{2.5}$ monitoring. Concentrations of PM_{10} and $PM_{2.5}$ are measured by the light scattering laser photometer principle using an Environmental DustTrak Monitoring System coupled with a heated inlet for 5-minute interval data logging over a 7-day continuous sampling period. The photometer uses an ellipsoidal reflector and simple optical components to collect the laser-scattered light and to focus it onto a photodiode array. The mass and particle size are determined by detecting how the particles scatter light. Gas Sensor was used for the purpose of NO_2 monitoring. Gaseous is continuously drawn and analyzed using Gas Sensitive Electrochemical (GSE) Sensors over 5-minute interval data over 7 days continuous sampling period. For further details of the Air Quality Monitoring, please refer to Appendix J.

Table 9-3 Baseline air quality monitoring locations

Monitoring Location	Nearest Construction Worksite/Project Footprint	Justification	Photo of Monitoring Location
A01: Near 18 Sungei Kadut Street 2	Sungei Kadut cut and cover tunnel and Interchange Station worksite (construction) Interchange Station (operation)	A01 was located at an open area near to 18 Sungei Kadut Street 2 within the area of Sungei Kadut industrial complex. The ambient air quality in the vicinity of A01 was affected by industrial activities and vehicular emission within the Sungei Kadut industrial area. As the potential air quality impact in this area is during both construction and operational phases, all PM_{10}, $PM_{2.5}$ and NO_2 were monitored.	
A02: HDB Blk 691B Choa Chu Kang Crescent	Intermediate Station worksite (construction) Intermediate Station (operation)	A02 was located at an open area near to HDB Blk 691B Choa Chu Kang Crescent. The ambient air quality in the vicinity of A02 was affected by traffic along Choa Chu Kang Drive and Chua Chu Kang Crescent. As the potential air quality impact in this area is during both construction and operational phases, all PM_{10}, $PM_{2.5}$ and NO_2 were monitored.	
A03: Choa Chu Kang Rail Corridor	Docking shaft worksite (construction)	A03 was located within the Rail Corridor and also within the proximity of HDB Senja Road and also Teck Whye Secondary School and Jurong Pioneer Junior College. The ambient air quality in the vicinity of A01 was affected by traffic along Woodlands Road. As the potential air quality impact in this area is only during construction phase, only PM_{10} and $PM_{2.5}$ were monitored.	

Monitoring Location	**Nearest Construction Worksite/Project Footprint**	**Justification**	**Photo of Monitoring Location**
A04: Near Gali Batu Train Depot	Retrieval shaft worksite (construction)	A04 was located at an open area along Woodlands Road near the to Gali Batu Close. The ambient air quality in the vicinity of A04 was affected by industrial activities (including Gali Batu Train Depot), and vehicular emission along Woodlands Road and Gali Batu Close. As the potential air quality impact in this area is only during construction phase, only PM_{10} and $PM_{2.5}$ were monitored.	
A05: Sungei Pang Sua	Worksite for potential future infrastructure (construction) Potential future infrastructure (operation)	A05 was located in close proximity to Sungei Pang Sua and other industrial properties. The ambient air quality in the vicinity of A05 was affected by traffic along Sungei Kadut Avenue and activities within the industrial areas. As the potential air quality impact in this area is during both construction and operational phases, all PM_{10}, $PM_{2.5}$ and NO_2 were monitored.	



Legend

- Baseline Air Monitoring Locations
- Secondary Air Monitoring Locations
- Air Study Area - Ecological (50m)
- Air Study Area - Human (350m)
- Proposed Pedestrian Overhead Bridge
- Proposed DTL2e Stations (Underground)
- Proposed NSL Elevated Station
- Proposed Vehicle Bridge
- Proposed Worksite Areas
- Potential Future Infrastructure
- Proposed DTL2e Tunnel Alignment
- 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
-	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 :
BASELINE AIR MONITORING LOCATIONS (1 OF 2)

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	9-3	A	1 of 1
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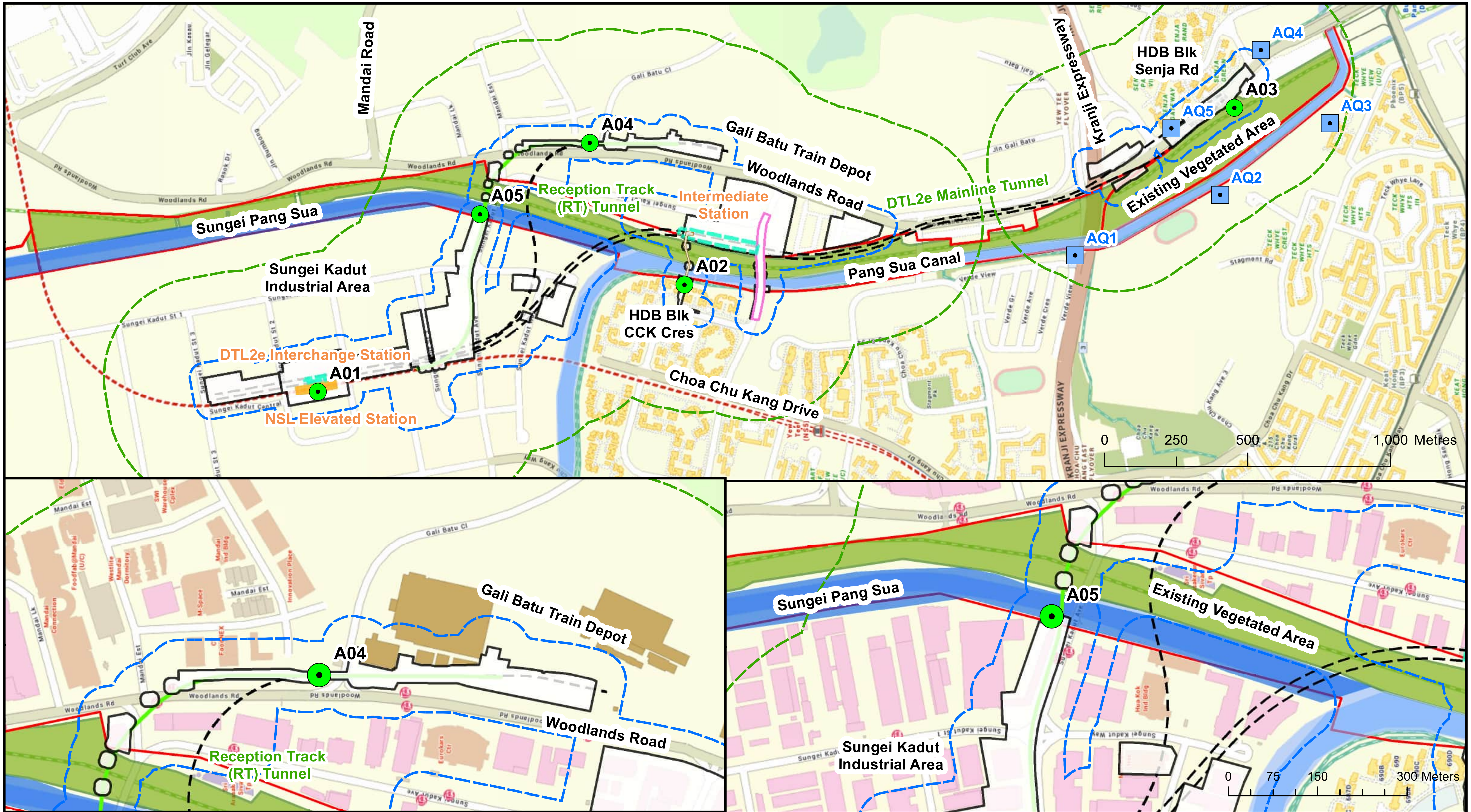
Note: Source of basemap - OneMap



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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 :

BASELINE AIR MONITORING LOCATIONS (2 OF 2)

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
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	Drawn: TTR	Date: MAY 2023	CAD File Name :N/A		A3

Note: Source of basemap - OneMap

Prediction and Evaluation of Impact Assessment

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

9.2.2.3 Construction Phase

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

9.2.2.3.1 Identification of Potential Sources of Air Quality Impacts

It is important to identify potential sources of air quality impact within the Study Area. While conducting the assessment, a typical construction machinery was assumed to be used during the construction equipment and activities. These are detailed in Section 9.3.1.

9.2.2.3.2 Identification of Sensitive Receptors

Identification of Air Sensitive Receptors (ASRs) in the Study Area was subsequently undertaken. IAQM identifies an entire area around one continuous stretch of construction footprint as a category or sensitive receptor. It does not distinguish between each unit, household or block present in the area as a separate ASR but designates the whole area as same category of sensitivity based on an overall location, number, proximity and scale to the construction activity. This approach thereby adopts a conservative principle to air quality. A further discussion on receptor sensitivity is presented in Section 9.4.1.

Sensitive areas identified as Priority 1, Priority 2, and Priority 3 for air quality during the screening process were examined in the impact assessment in this ES in order to provide a more refined classification for receptor sensitivity. Sensitivity of the area was determined based on the usage, number of receptors, distance from the construction footprint, and the current context of sensitive buildings in Singapore.

9.2.2.3.3 Understanding of Baseline Air Quality

Primary and secondary data were collected to understand the baseline air quality of the Study Area. NEA’s PSI data available from the nearest monitoring station was also reviewed for the Study Area. In addition, baseline air quality data was collected at representative locations near the construction footprint. The baseline air quality review and data measured is discussed in Section 9.5.2.

9.2.2.3.4 Impact Intensity Definition

The impact intensity was determined by reviewing the scale of construction activities and classifying them as Low, Medium or High. The IAQM Guidance document provides example definitions for determining impact intensity for earthworks (based on construction footprint, heavy duty vehicles movement, formation of bunds, and material moved), for construction (based on total building volume, on-site concrete batching), for trackout (based on heavy duty vehicle outward movement, surface material, and unpaved road lengths), and for demolition (based on total demolition volume, construction material, on-site crushing of material, and height of demolition activity), if any. The definition of parameters is defined in Table 6-6 in Section 6.4.2. It should be noted that in each case, not all criteria need to be met and that determination of magnitude is also based on the professional judgment of the air quality consultant. If the areas around the construction footprint are rated as High for one activity and Medium or Low for the other activities, the overall impact intensity result is classified as High for that site as those multiple activities may be occurring concurrently.

9.2.2.3.5 Classification of Overall Consequence

The dust impact assessment therefore evaluates the overall consequence prior to the implementation of mitigation. The work site was assessed by considering both the impact intensity and the receptor sensitivity to obtain an overall consequence rating. Since the definition of impact intensity is different for each activity, the overall consequence for each activity is explained in matrices shown in Table 9-4 to Table 9-7. Each activity for the work site was rated as being High, Medium, Low, or Imperceptible in terms of overall consequence based upon pre-mitigation measures.

Table 9-4 Overall consequence of the air impact analysis (Demolition)

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

Table 9-5 Overall consequence of the air impact analysis (Earthworks)

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

Table 9-6 Overall consequence of the air impact analysis (Construction)

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

Table 9-7 Overall consequence of the air impact analysis (Trackout)

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

9.2.2.3.6 Establishing Impact Significance

Impact Significance was evaluated by considering both the overall consequence and the likelihood of occurrence of significant adverse impacts. The likelihood of occurrence may be defined as remote, rare, occasional, regular, and continuous as per criteria listed in Table 6-8. Impact significance was evaluated in accordance with the matrix presented below in Table 9-8. The IAQM methodology does not differentiate between imperceptible and very low Consequences, due to the nature of air impacts as perceived by humans. In order to align the IAQM methodology with the methodology of this report, imperceptible and very low Consequences were consolidated.

Table 9-8 Impact significance matrix for air quality

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

9.2.2.3.7 Mitigation Measures Recommendations

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

9.2.2.3.8 Establishing Residual Impact Significance

Following implementation of mitigation measures prescribed in the ES at the proposed construction footprint, the residual Impact Significance was evaluated using the matrix outlined in Table 9-8. Ideally, the mitigation measures required should be specified within the conditions given for planning permission and should be stipulated in construction contracts.

9.2.2.4 Operational Phase

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

9.2.2.4.1 Identification of Potential Sources of Air Quality Impacts

It is important to identify potential sources of air quality impact within the Study Area. While conducting the assessment, an increase in traffic volume in the vicinity of the Project Site and along the proposed vehicular bridge during operational phase is assumed. These are detailed in Section 9.3.2.

9.2.2.4.2 Identification of Sensitive Receptors

Identification of ASRs in the Study Area within 250 m around the operational footprint was subsequently undertaken. A further discussion on Receptor Sensitivity is presented in Section 9.4.2.

Sensitive areas identified as Priority 1, Priority 2, and Priority 3 for air quality during the screening process were examined in the Impact Assessment in this ES in order to provide a more refined classification for Receptor

Sensitivity. Sensitivity of the area was determined based on the usage and the current context of sensitive buildings in Singapore.

9.2.2.4.3 Understanding of Baseline Air Quality

Primary and secondary data were collected to understand the baseline air quality of the Study Area. NEA's PSI data available from the nearest monitoring station was also reviewed for the Study Area. In addition, baseline air quality data was collected for representative location near the operational footprint. The baseline air quality review and data measured is discussed in Section 9.5.2.

9.2.2.4.4 Impact Intensity Definition

The impact intensity was determined by reviewing the scale of increase in air quality levels due to traffic volume increase in the vicinity of the operational footprint. The impact intensity was then classified as Low, Medium or High.

9.2.2.4.5 Classification of Overall Consequence

The air quality impact assessment therefore evaluates the overall consequence prior to the implementation of mitigation. The operational footprint was assessed by considering both the impact intensity and the Receptor Sensitivity to obtain an overall consequence rating. The overall consequence was rated as being High, Medium, Low, or Imperceptible in terms of overall consequence based upon pre-mitigation measures.

9.2.2.4.6 Establishing Impact Significance

Impact Significance was evaluated by considering both the overall Consequence and the Likelihood of occurrence of significant adverse impacts. The Likelihood of occurrence may be defined as unlikely, rare, occasional, regular, and continuous as per criteria listed in Table 6-8. Impact Significance was evaluated in accordance with the matrix presented in Table 9-8.

9.2.2.4.7 Mitigation Measures Recommendations

Mitigation measures were proposed for implementation when the Impact Significance was predicted to be Moderate or Major.

9.2.2.4.8 Establishing Residual Impact Significance

Following implementation of mitigation measures prescribed in the ES at the proposed operational footprint, the residual Impact Significance was evaluated using the matrix outlined in Table 9-8. Ideally, the mitigation measures required should be specified within the conditions given for planning permission and should be stipulated in construction contracts.

9.3 Potential Sources of Air Quality Impact

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

9.3.1 Construction Phase

For human receptors, dust emissions could potentially result in adverse impacts on air quality and public health causing respiratory problems on human. For ecological receptors, dust generated during construction works can have adverse effects upon vegetation restricting photosynthesis, respiration and transpiration. Furthermore, it can lead to phytotoxic gaseous pollutants penetrating the plants. The overall effect can be a decline in plant productivity, which may then have indirect effects on the quality of the affected habitats and associated fauna. Table 9-9 listed potential sources of air quality impact during construction phase of the project.

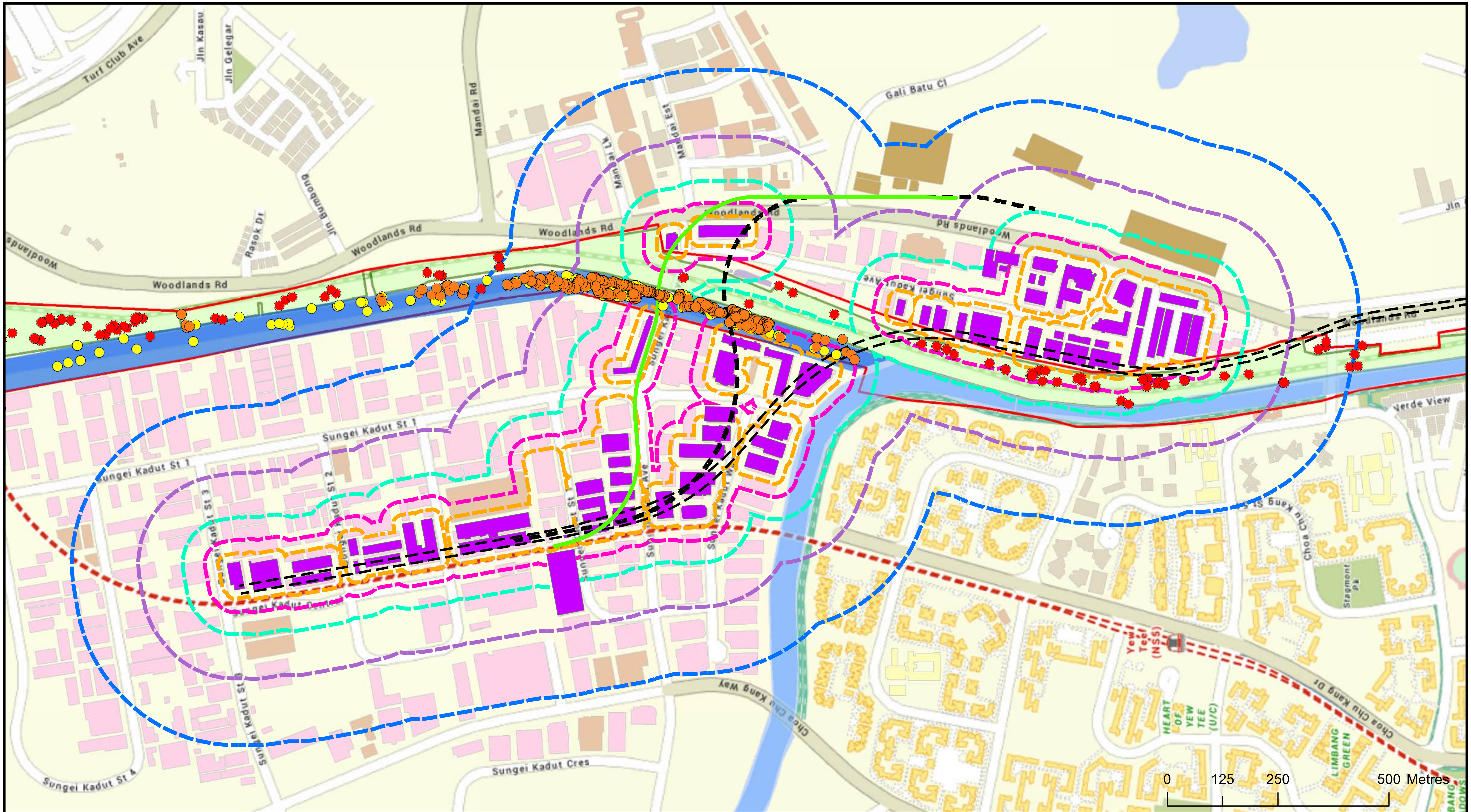
Table 9-9 Potential air quality impacts during the construction phase

Potential Source of Impacts	Potential Associated Impacts
Dust emissions generated by earthworks processes, including land clearance, soil stripping, ground levelling, excavation, stockpiling of spoil and landscaping at worksites.	Dust emissions could potentially result in adverse impacts on air quality and public health and may also generate significant nuisance at receptors, including the biodiversity, located nearby heavy construction worksite areas. A study has found out that dust could significantly reduce photosynthesis of upper and lower leaf surfaces of mangroves by 17–39% [P-66].
Dust emissions generated by the construction of new structures, such as the station box and ventilation buildings (facility buildings).	Dust emissions could potentially result in adverse impacts on air quality and public health and may also generate significant nuisance at receptors, including the biodiversity, located nearby heavy construction worksite areas. A study has found out that dust could significantly reduce photosynthesis of upper and lower leaf surfaces of mangroves by 17–39% [P-66].
Dust emissions generated from potential demolition of permanent structure, (in this project, 97 buildings).	Dust emissions could potentially result in adverse impacts on air quality and public health and may also generate significant nuisance at receptors, including the biodiversity, located nearby heavy construction worksite areas. A study has found out that dust could significantly reduce photosynthesis of upper and lower leaf surfaces of mangroves by 17–39% [P-66].
Dust emissions from transport of dust and dirt by dumper trucks for transporting spoil within the site and from the site onto public road network, where it may be deposited and resuspended by vehicles using the network.	Dust emissions could potentially result in adverse impacts on air quality and public health and may also generate significant nuisance at receptors nearby haulage routes. A study has found out that dust could significantly reduce photosynthesis of upper and lower leaf surfaces of mangroves by 17–39% [P-66].
Gaseous emissions from vehicle exhaust due to movement of construction vehicles and equipment, including spoil disposal	Exhaust emissions (NO_2, SO_2, CO, PM_{10} and $PM_{2.5}$) could potentially impact the air quality in the vicinity of construction worksites.
Gaseous emissions from off-road diesel engines on-site such as generators, if any	Exhaust emissions (NO_2, SO_2, CO, PM_{10} and $PM_{2.5}$) could potentially impact the air quality in the vicinity of construction worksites.

In the general context of air quality impact assessment, earthworks include some extent of soil-cutting, excavation, piling and excavation works, while the construction activity includes the construction of the proposed buildings. The worst-case emission sources for earthworks and construction activities may comprise most of the existing industrial and residential buildings within the Project Site, including part of Pang Sua Canal, Sungei Pang Sua and the Rail Corridor. According to the preliminary planning, the Project is expected to be generating 20,000 – 100,000 tonnes of spoil amount for docking shaft, retrieval shaft and potential future infrastructure worksites, and >100,000 tonnes of spoil amount for intermediate and interchange station worksites. In view of the scale of this Project, about 5 to 10 heavy vehicles/ machineries are expected to be operating on site at any of the time throughout the construction phase.

The Project is estimated to require approximately >100,000 m^3 of concrete for the construction of each intermediate and interchange stations and 25,000 – 100,000 m^3 of concrete for the construction of potential future infrastructure. At current stage, it is assumed that 1 concrete batching plant for station will be located within the intermediate and interchange stations worksites. Demolition of certain permanent structures/ buildings will be required and is estimated to be generating >50,000 m^3 of concrete.

The trucks carrying construction materials and/or spoil to and from the construction footprint on access roads are also considered as a potential source of emission (referred to as trackout activity) as shown in Figure 9-14 to Figure 9-18. The number of outward trucks movement is expected to be around 10 - 50 HDVs per day for docking shaft, retrieval shaft and potential future infrastructure worksites, and >50 HDVs per day for intermediate and interchange station worksites. The HDVs are expected to travel along the existing paved roads for access to the Project Site, it is assumed that <100 m unpaved roads are involved. Impact prediction and evaluation were detailed in Section 9.7.1.



Legend

- Sonneratia caseolaris
- Species of Conservation Significance
- Large Plant Specimens
- Potential Future Infrastructure
- Proposed DTL2e Tunnel Alignment
- Buildings to be Demolished
- 20m from Sources
- 50m from Sources
- 100m from Sources
- 200m from Sources
- 350m from Sources
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Sensitive Receptors

- Public Housing Commercial Building
- Place of Worship
- Educational Institution
- Transport Infrastructure Industrial Facility
- Unclassified Building (incl. Condominium and Landed Properties)

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

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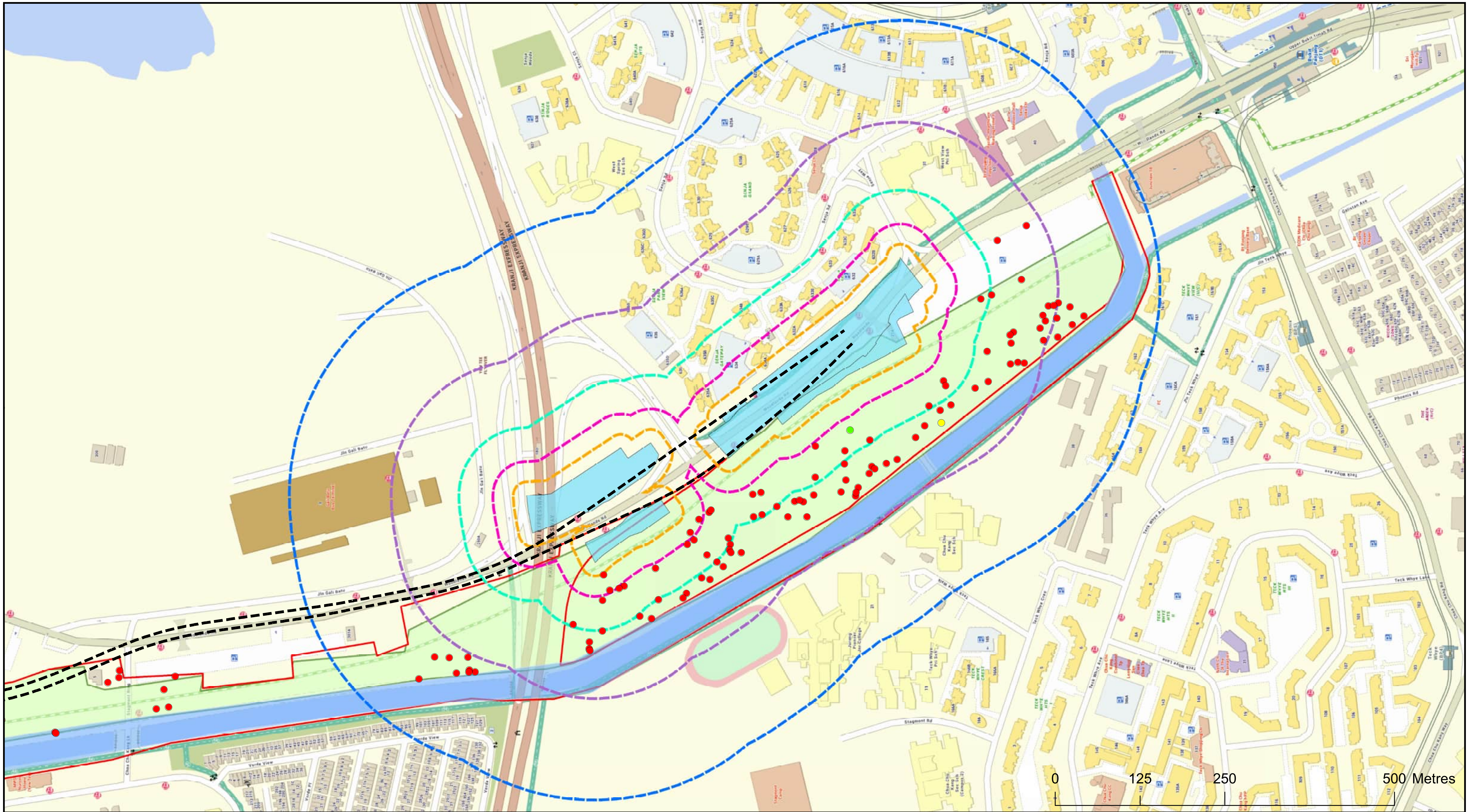
Project Title :
CONTRACT 9175 ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE

Figure Title :
EMISSION SOURCES AND SENSITIVE RECEPTORS - DEMOLITION

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	9-5	A	1 of 1

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

Note: Source of basemap - OneMap



Legend

- Species of Conservation Significance
- Other Specimens of Value
- Large Plant Specimens
- Proposed DTL2e Tunnel Alignment
- Earthworks Footprint
- 20m from Sources
- 50m from Sources
- 100m from Sources
- 200m from Sources
- 350m from Sources
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Sensitive Receptors

- Public Housing
- Commercial Building
- Place of Worship
- Educational Institution
- Transport Infrastructure
- Park/ Playground
- Utility
- Unclassified Building (incl. Condominium and Landed Properties)

N

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

Qualified Person Endorsement : N/A

LTA Endorsement : N/A

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 :
DOCKING SHAFT WORKSITE EMISSION SOURCES AND SENSITIVE RECEPTORS - EARTHWORKS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	9-6	A	1 of 1
	Drawn TTR	Date MAY 2023	CAD File Name :N/A		A3

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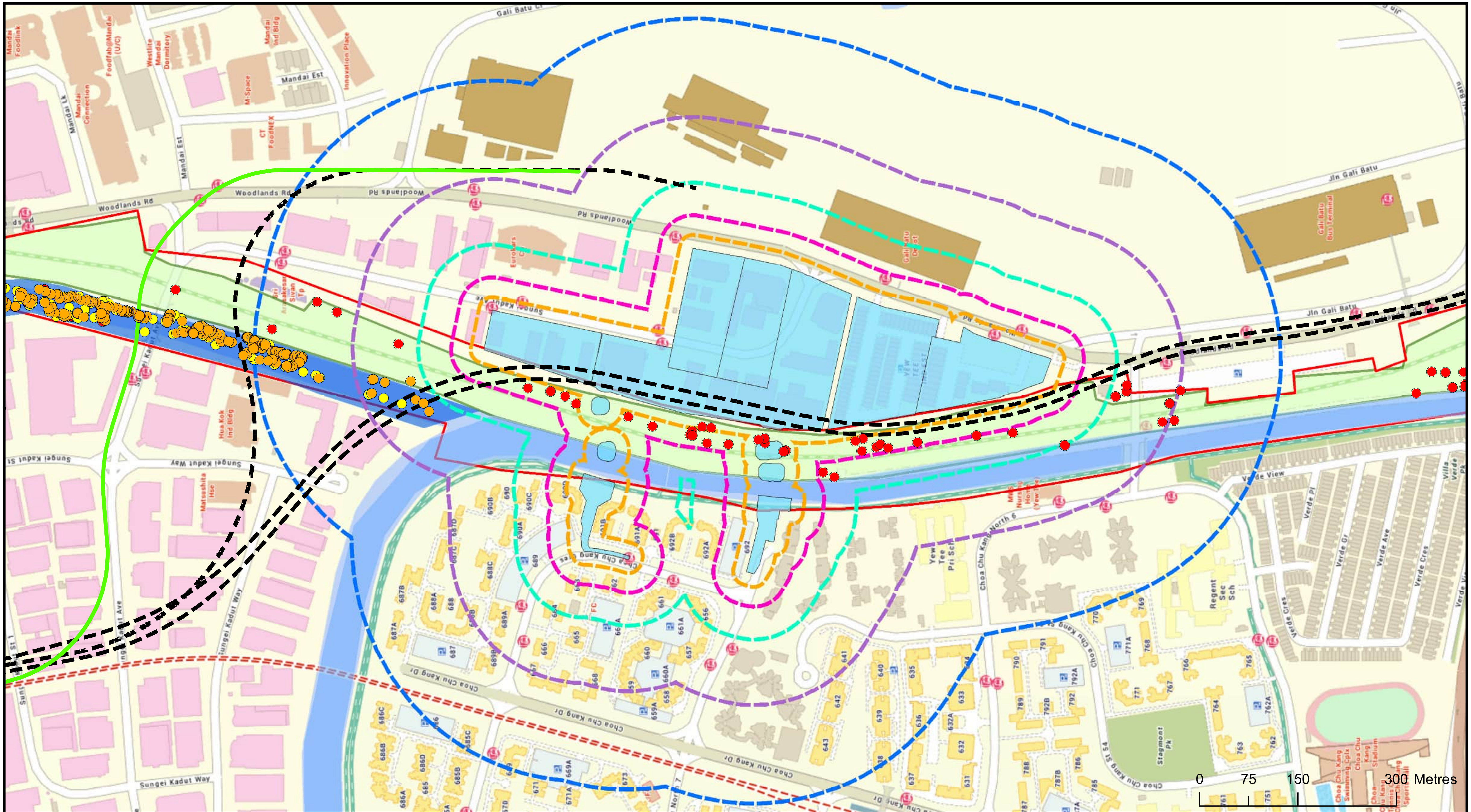

Legend

- Sonneratia caseolaris
- Species of Conservation Significance
- Large Plant Specimens
- Earthworks Footprint
- 20m from Sources
- 50m from Sources
- 100m from Sources
- 200m from Sources
- 350m from Sources
- Potential Future Infrastructure
- Proposed DTL2e Tunnel Alignment
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Sensitive Receptors

- Public Housing
- Commercial Building
- Place of Worship
- Educational Institution
- Transport Infrastructure
- Park/ Playground
- Utility
- Industrial Facility
- Unclassified Building (incl. Condominium and Landed Properties)

N

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

Qualified Person Endorsement : N/A

LTA Endorsement : N/A

Consultant : AECOM

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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 :
INTERMEDIATE STATION WORKSITE EMISSION SOURCES AND SENSITIVE RECEPTORS – EARTHWORKS

Designed	Checked	Approved	Drawn	Date	Figure No.	Rev.	Sheet
TTR	HHL	JAG	TTR	MAY 2023	9-7	A	1 of 1

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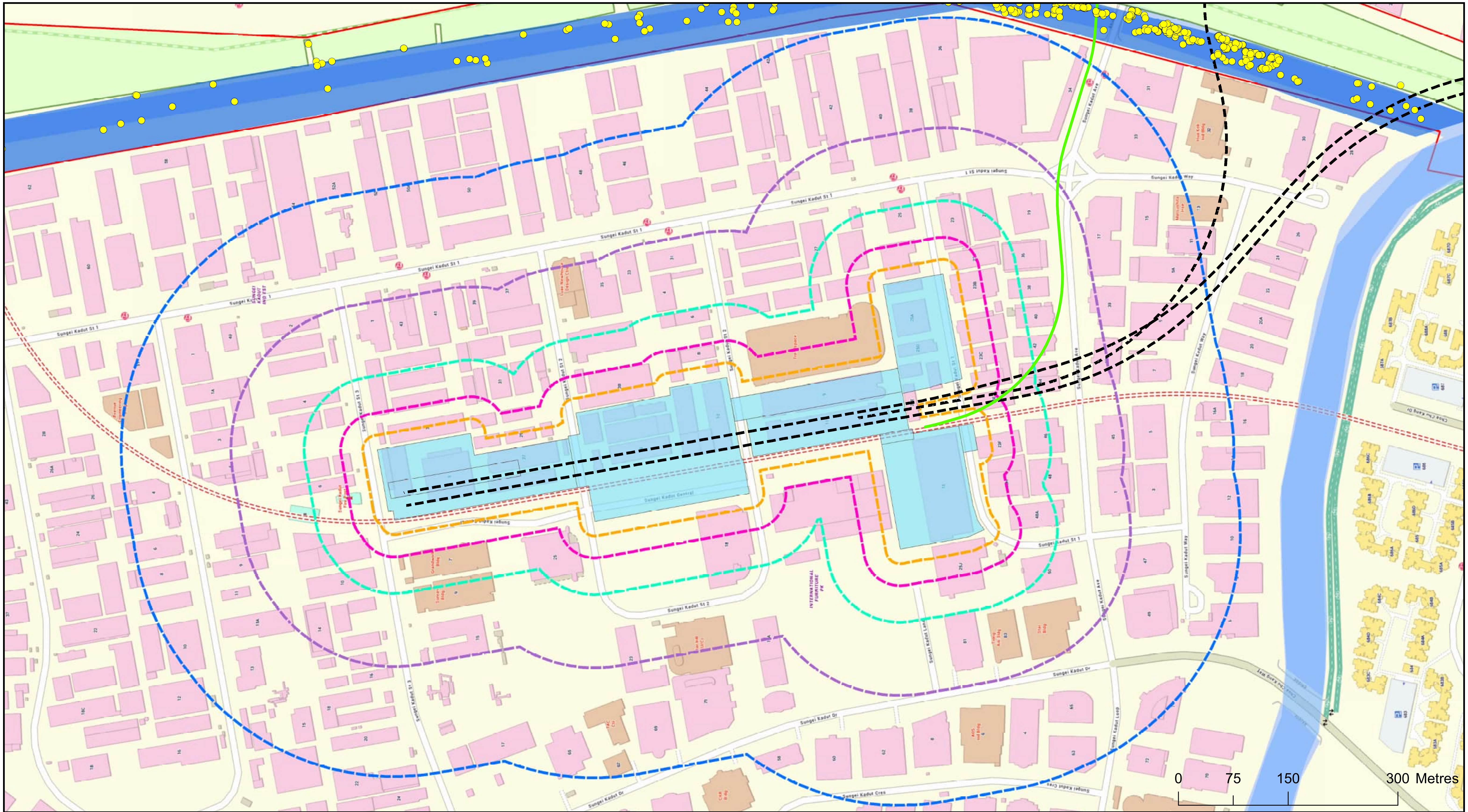
Note: Source of basemap - OneMap



Legend

- Species of Conservation Significance
- Potential Future Infrastructure
- Proposed DTL2e Tunnel Alignment
- Earthworks Footprint
- 20m from Sources
- 50m from Sources
- 100m from Sources
- 200m from Sources
- 350m from Sources
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Sensitive Receptors

- Commercial Building
- Industrial Facility

N

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

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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 :
INTERCHANGE STATION WORKSITE EMISSION SOURCES AND SENSITIVE RECEPTORS – EARTHWORKS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	9-8	A	1 of 1
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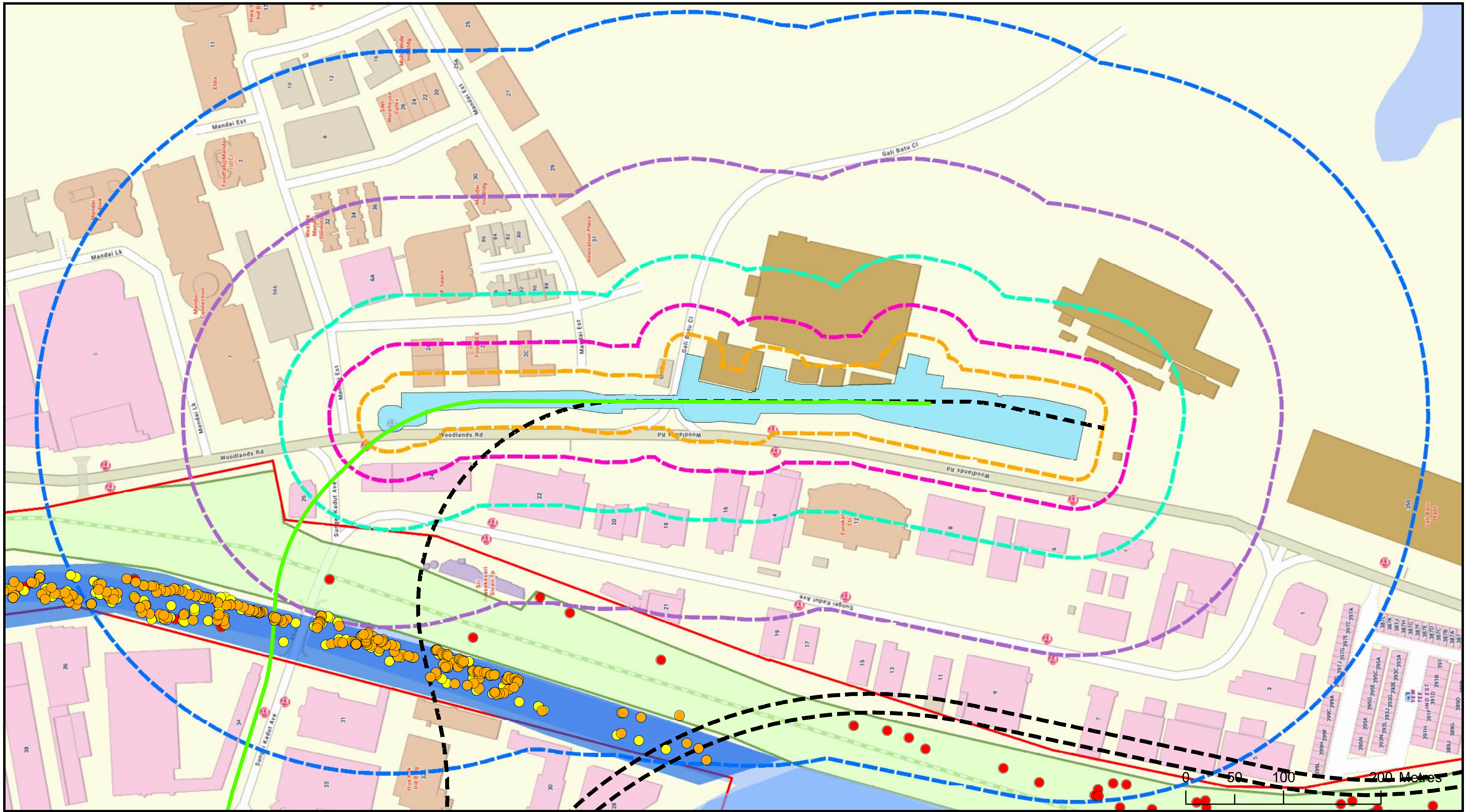

Legend

- Sonneratia caseolaris
- Species of Conservation Significance
- Large Plant Specimens
- Potential Future Infrastructure
- Proposed DTL2e Tunnel Alignment
- Earthworks Footprint
- 20m from Sources
- 50m from Sources
- 100m from Sources
- 200m from Sources
- 350m from Sources
- Pang Sua Canal Sungei
- Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Sensitive Receptors

- Commercial Building
- Transport Infrastructure
- Industrial Facility
- Unclassified Building (incl. Condominium and Landed Properties)

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

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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

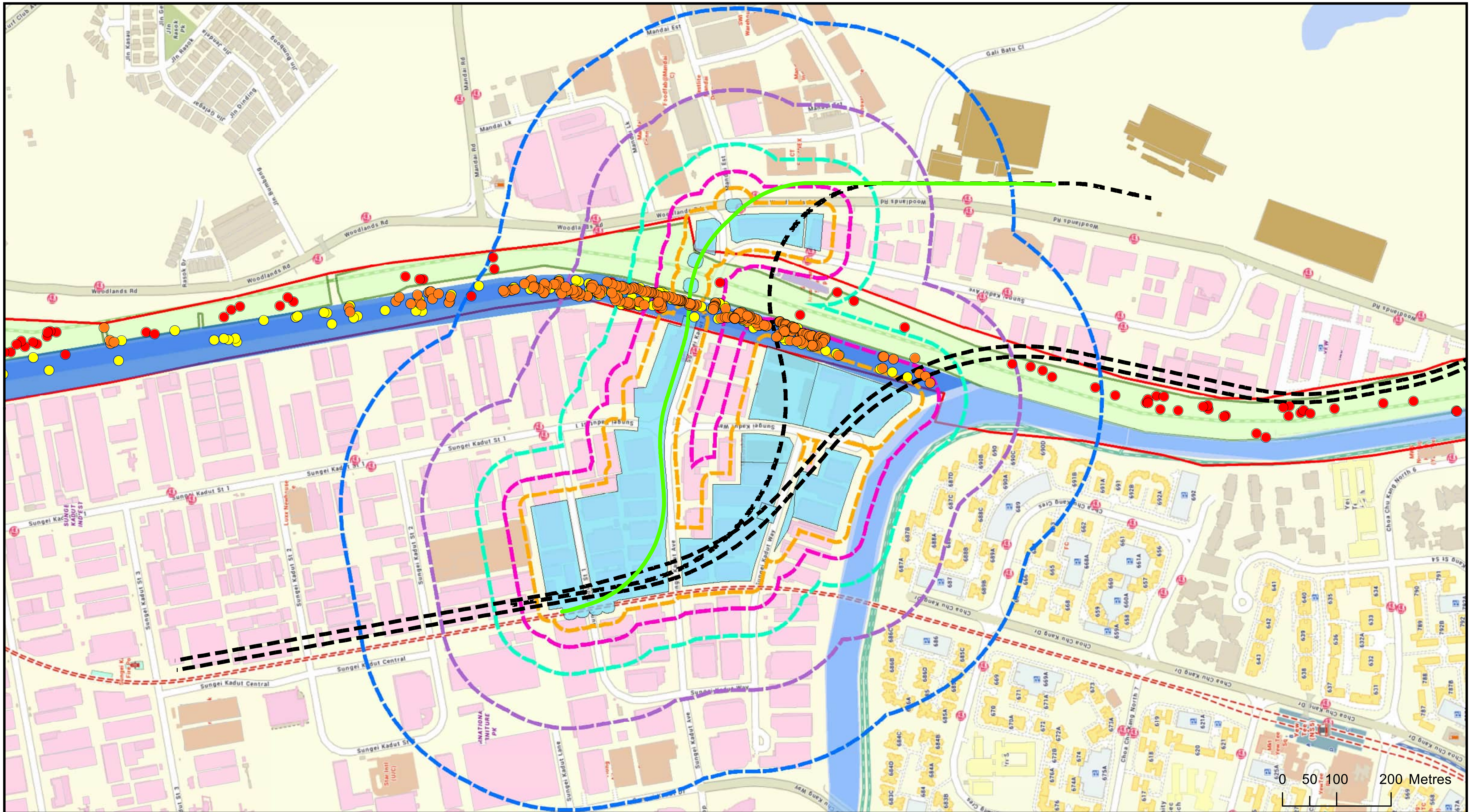
Figure Title :
RETRIEVAL SHAFT WORKSITE EMISSION SOURCES AND SENSITIVE RECEPTORS – EARTHWORKS

Designed	Checked	Approved	Drawn	Date
TTR	HHL	JAG	TTR	MAY 2023

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

CAD File Name :N/A | A3

Note: Source of basemap - OneMap



Legend

- Sonneratia caseolaris
- Species of Conservation Significance
- Large Plant Specimens
- Potential Future Infrastructure
- Proposed DTL2e Tunnel Alignment
- Earthworks Footprint
- 20m from Sources
- 50m from Sources
- 100m from Sources
- 200m from Sources
- 350m from Sources
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Sensitive Receptors

- Public Housing
- Commercial Building
- Place of Worship
- Educational Institution
- Transport Infrastructure
- Industrial Facility
- Unclassified Building (incl. Condominium and Landed Properties)

N

Rev.	Date	By	Description	Chk'd	App'd
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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 :
POTENTIAL FUTURE INFRASTRUCTURE WORKSITE EMISSION SOURCES AND SENSITIVE RECEPTORS – EARTHWORKS

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	9-10	A	1 of 1
	Drawn TTR	Date MAY 2023	CAD File Name :N/A		A3

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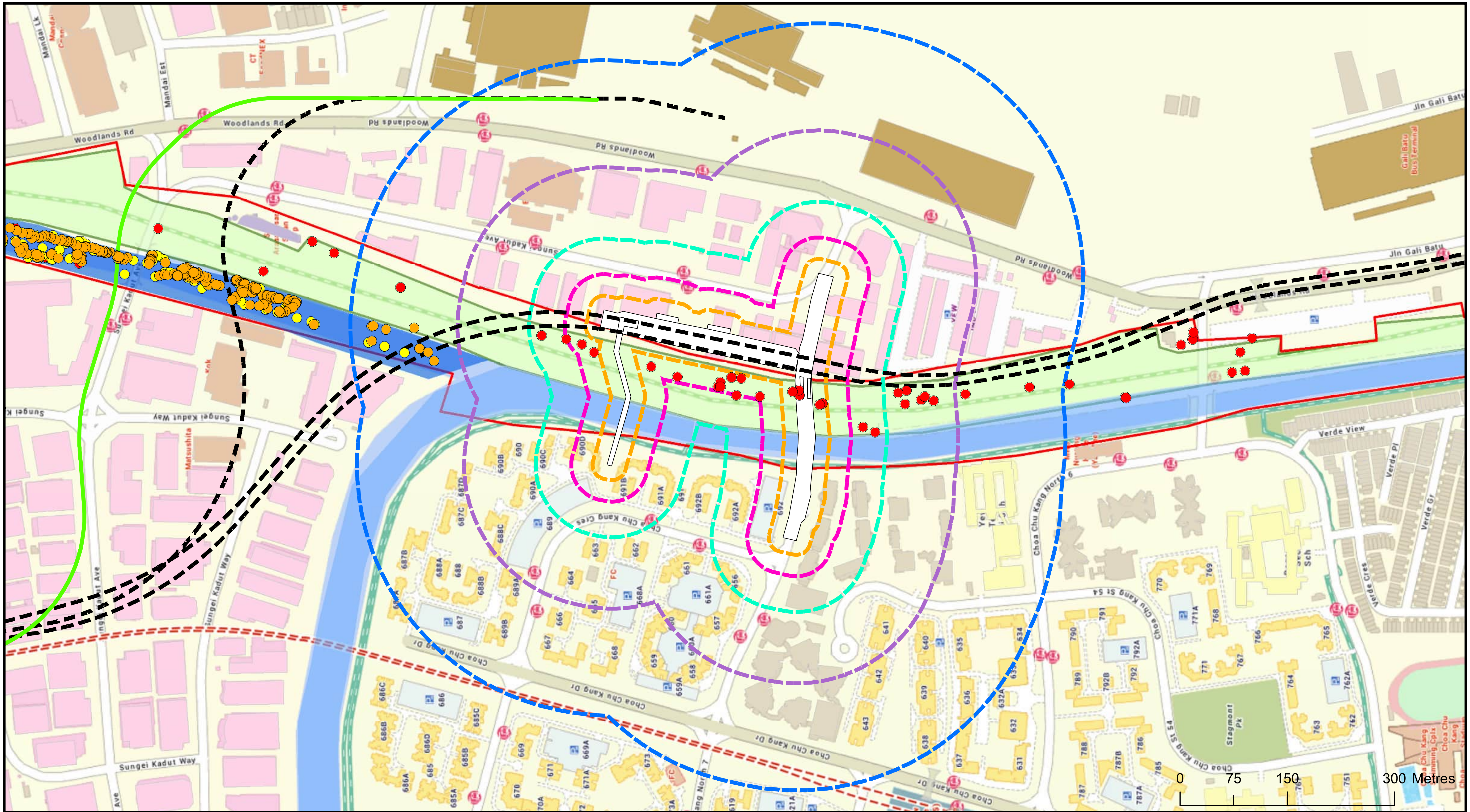

Legend

- Sonneratia caseolaris
- Species of Conservation Significance
- Large Plant Specimens
- Construction Footprint
- 20m from Sources
- 50m from Sources
- 100m from Sources
- 200m from Sources
- 350m from Sources
- Potential Future Infrastructure
- Proposed DTL2e Tunnel Alignment
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Sensitive Receptors

- Public Housing
- Commercial Building
- Place of Worship
- Educational Institution
- Transport Infrastructure
- Park/ Playground
- Utility
- Industrial Facility
- Unclassified Building (incl. Condominium and Landed Properties)

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

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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 :
INTERMEDIATE STATION WORKSITE EMISSION SOURCES AND SENSITIVE RECEPTORS – CONSTRUCTION

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	9-11	A	1 of 1
	Drawn: TTR	Date: MAY 2023	CAD File Name :N/A		A3

Note: Source of basemap - OneMap

Legend

- Species of Conservation Significance
- Potential Future Infrastructure
- Proposed DTL2e Tunnel Alignment
- Construction Footprint
- 20m from Sources
- 50m from Sources
- 100m from Sources
- 200m from Sources
- 350m from Sources
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area

Sensitive Receptors

- Commercial Building
- Industrial Facility

N

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LTA 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 :

INTERCHANGE STATION WORKSITE EMISSION SOURCES AND SENSITIVE RECEPTORS – CONSTRUCTION

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	9-12	A	1 of 1

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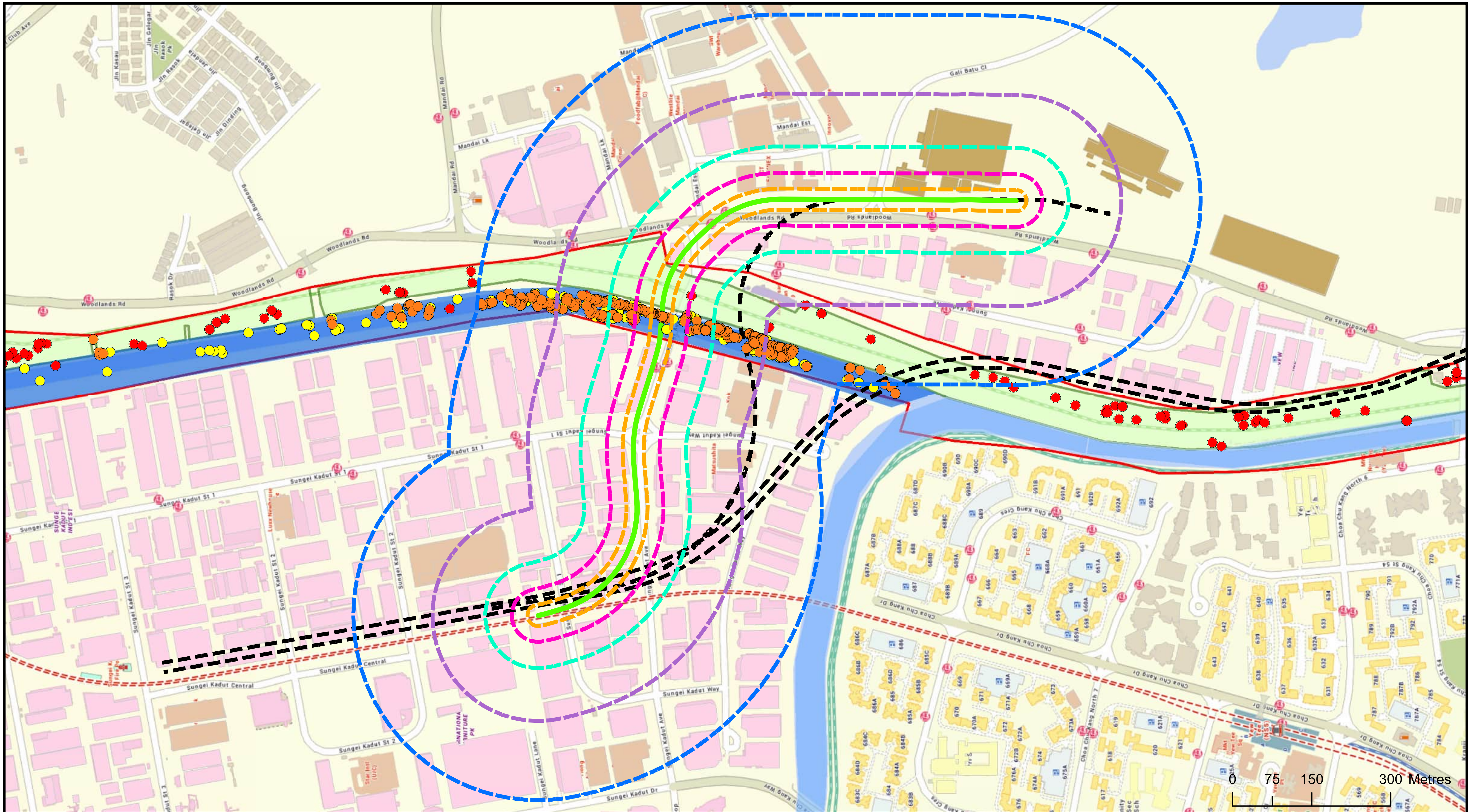

Legend

- Sonneratia caseolaris
- Species of Conservation Significance
- Large Plant Specimens
- Construction Footprint
- 20m from Sources
- 50m from Sources
- 100m from Sources
- 200m from Sources
- 350m from Sources
- Proposed DTL2e Tunnel Alignment
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Sensitive Receptors

- Public Housing
- Commercial Building
- Place of Worship
- Educational Institution
- Transport Infrastructure
- Industrial Facility
- Unclassified Building (incl. Condominium and Landed Properties)

N

Rev.	Date	By	Description	Chk'd	App'd
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LTA Endorsement : N/A

Consultant : AECOM

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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 :
POTENTIALFUTURE INFRASTRUCTURE WORKSITE EMISSION SOURCES AND SENSITIVE RECEPTORS – CONSTRUCTION

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	9-13	A	1 of 1

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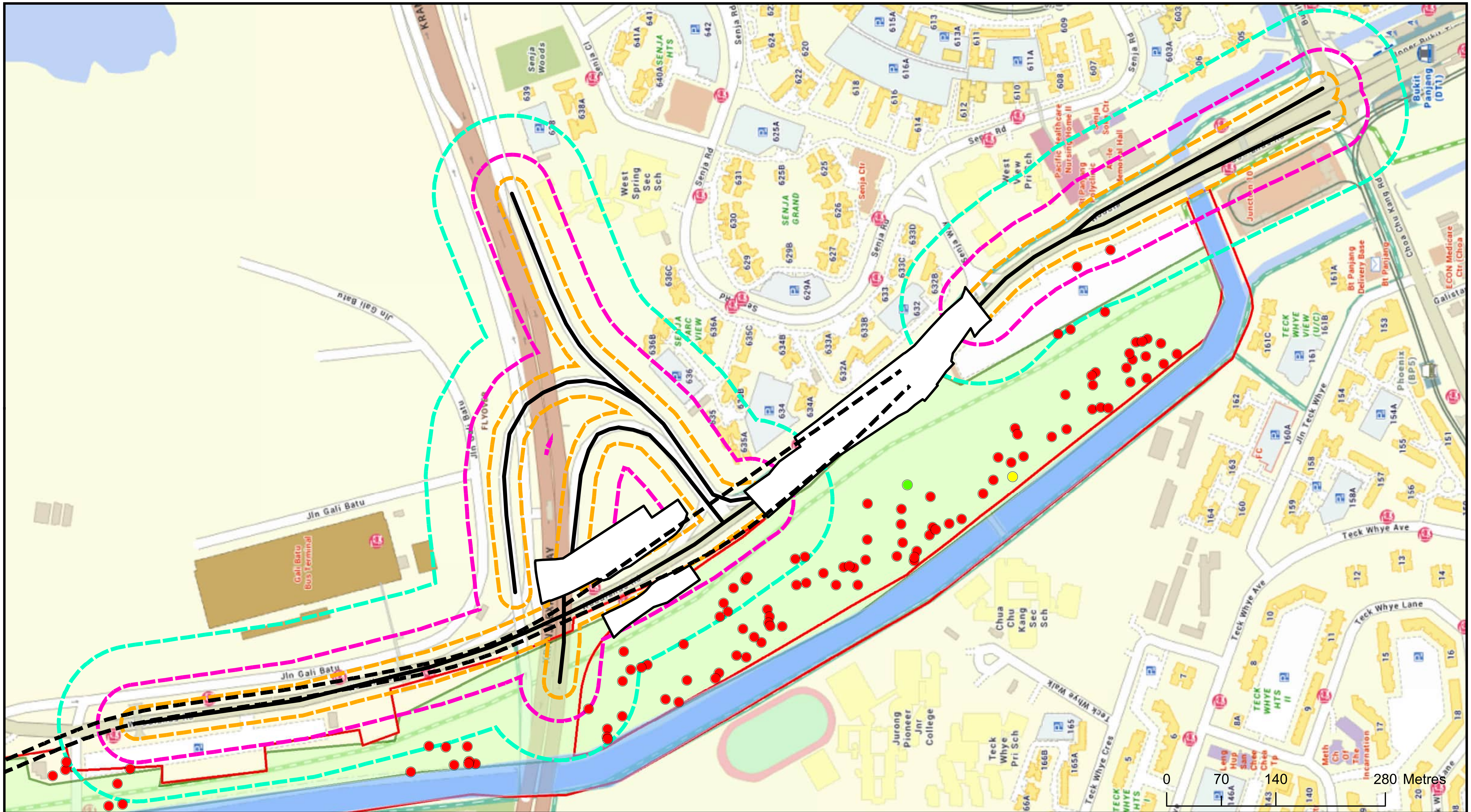

Legend

- Species of Conservation Significance
- Other Specimens of Value
- Large Plant Specimens
- Proposed DTL2e Tunnel Alignment
- Proposed Worksite Areas
- Potential Access Road
- 20m from Sources
- 20m from Sources
- 20m from Sources
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Sensitive Receptors

- Public Housing
- Commercial Building
- Place of Worship
- Educational Institution
- Transport Infrastructure
- Park/ Playground
- Utility
- Unclassified Building (incl. Condominium and Landed Properties)

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 :
DOCKING SHAFT WORKSITE EMISSION SOURCES AND SENSITIVE RECEPTORS – TRACKOUT

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	9-14	A	1 of 1
	Drawn: TTR	Date: MAY 2023	CAD File Name :N/A		A3

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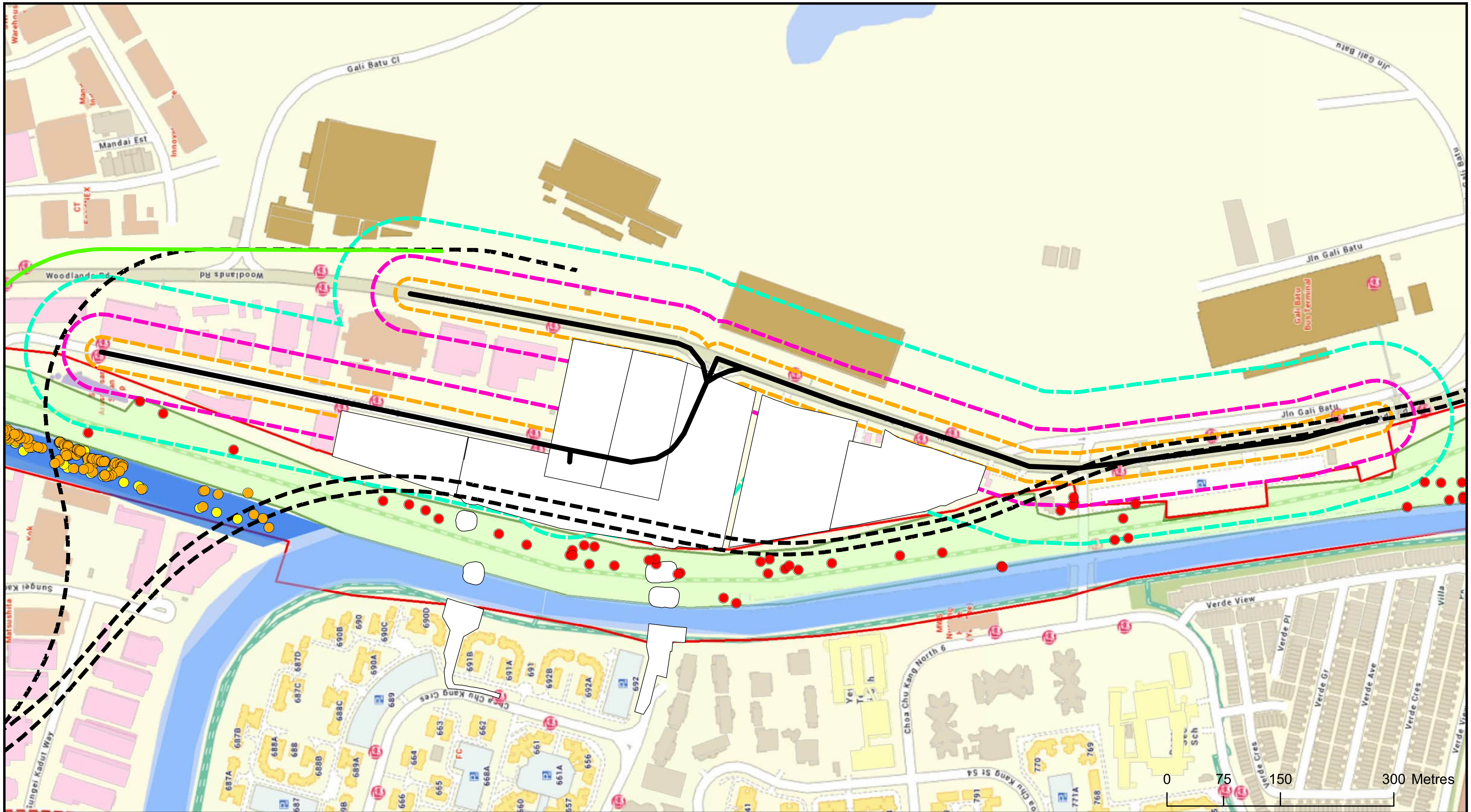

Legend

- Sonneratia caseolaris
- Species of Conservation Significance
- Large Plant Specimens
- Potential Future Infrastructure
- Proposed DTL2e Tunnel Alignment
- Potential Access Road
- Proposed Worksite Areas
- 20m from Sources
- 50m from Sources
- 100m from Sources
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Sensitive Receptors

- Public Housing
- Commercial Building
- Place of Worship
- Educational Institution
- Transport Infrastructure
- Utility
- Industrial Facility
- Unclassified Building (incl. Condominium and Landed Properties)

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Qualified Person Endorsement : N/A

LTA Endorsement : N/A

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 :
INTERMEDIATE STATION WORKSITE EMISSION SOURCES AND SENSITIVE RECEPTORS – TRACKOUT

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	9-15	A	1 of 1
	Drawn TTR	Date MAY 2023	CAD File Name :N/A		A3

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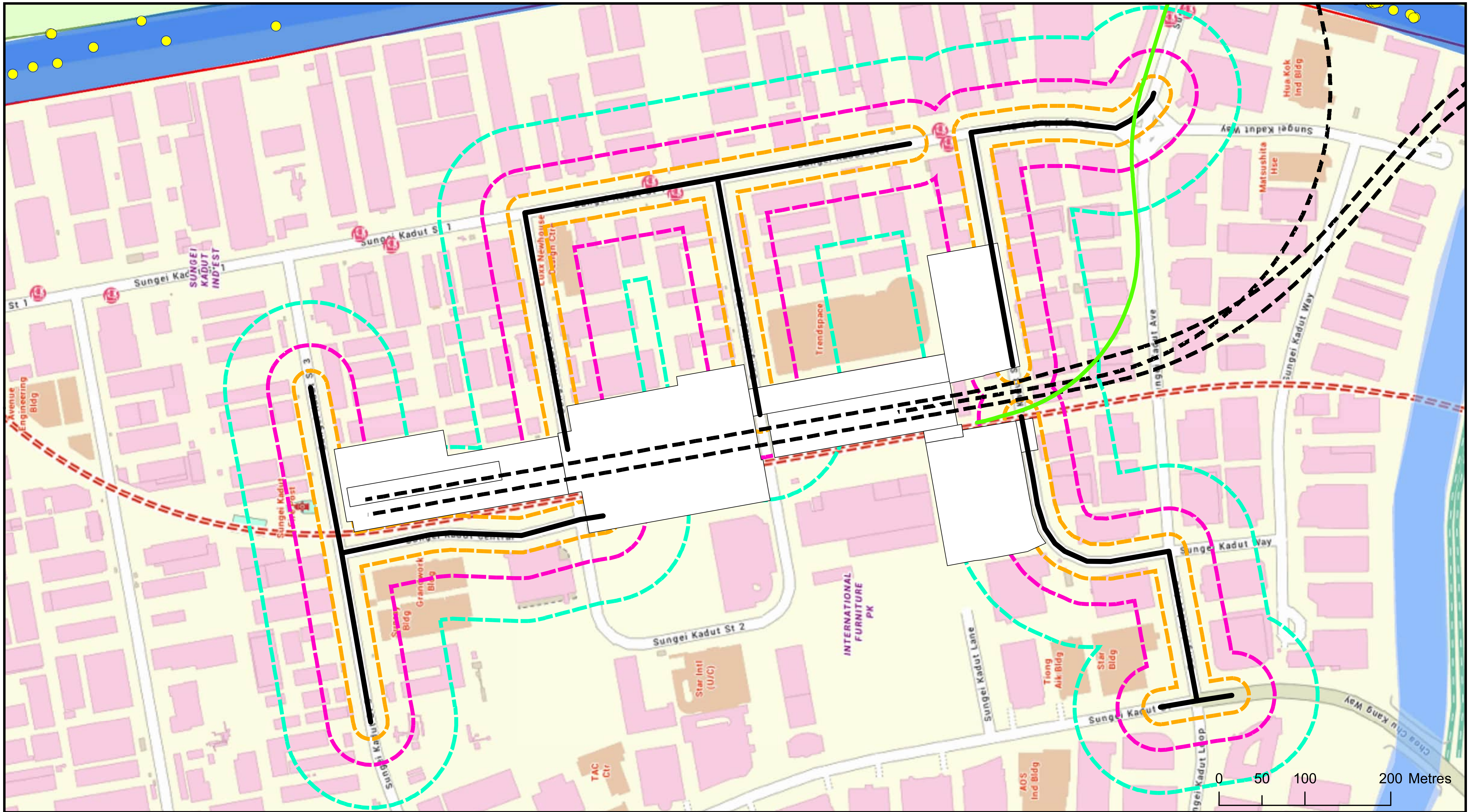

Legend

- Species of Conservation Significance
- Potential Future Infrastructure
- Proposed DTL2e Tunnel Alignment
- Potential Access Road
- Proposed Worksite Areas
- 20m from Sources
- 50m from Sources
- 100m from Sources
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Sensitive Receptors

- Commercial Building
- Industrial Facility

N

Rev.	Date	By	Description	Chk'd	App'd
A	MAY 2023	TTR	Draft Final Report	HHL	JAG
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LTA 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 :
INTERCHANGE STATION WORKSITE EMISSION SOURCES AND SENSITIVE RECEPTORS – TRACKOUT

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	9-16	A	1 of 1

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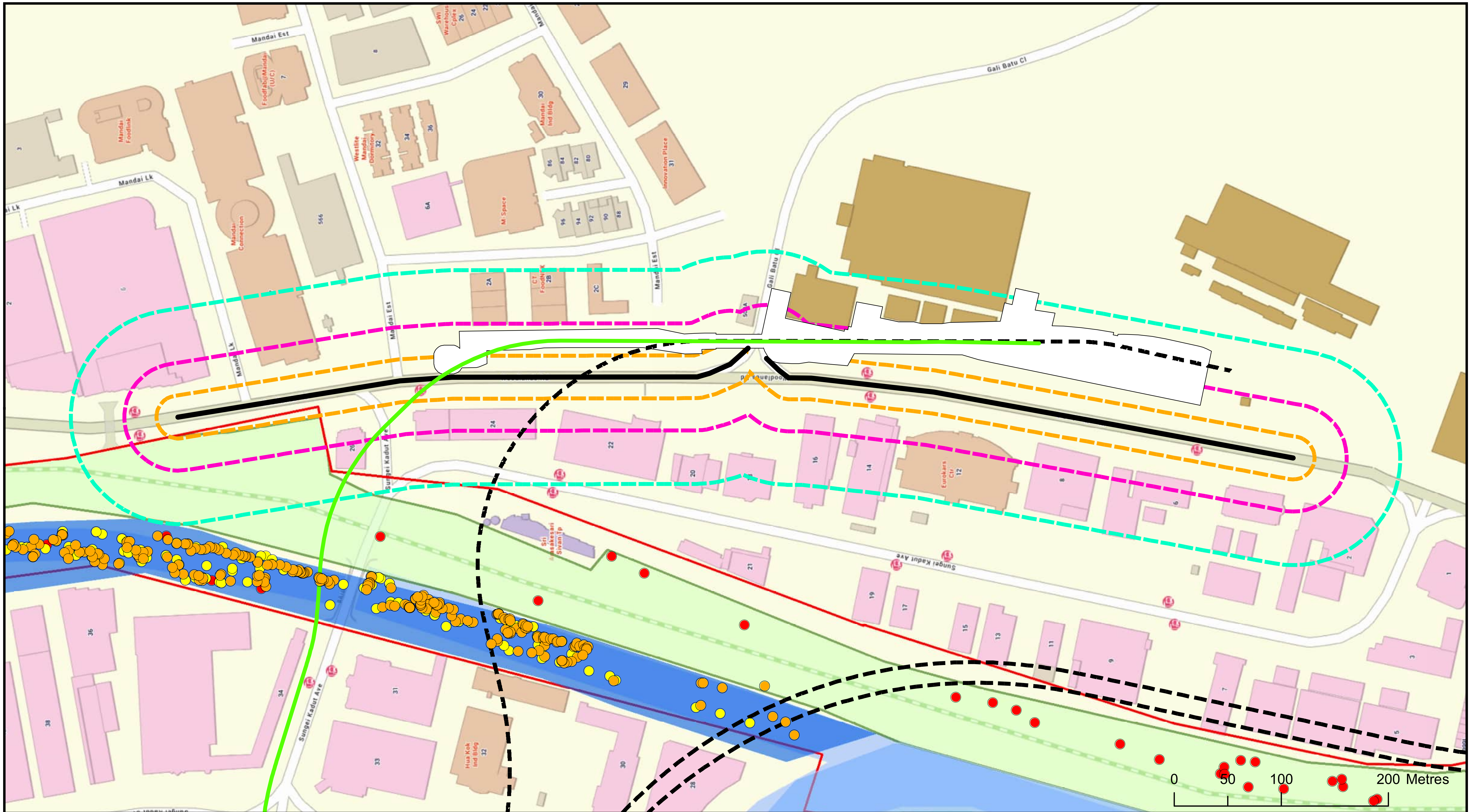


Legend

- Sonneratia caseolaris
- Species of Conservation Significance
- Large Plant Specimens
- Potential Future Infrastructure
- Proposed DTL2e Tunnel Alignment
- Potential Access Road
- Proposed Worksite Areas
- 20m from Sources
- 50m from Sources
- 100m from Sources
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Sensitive Receptors

- Commercial Building
- Transport Infrastructure
- Industrial Facility
- Unclassified Building (incl. Condominium and Landed Properties)

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

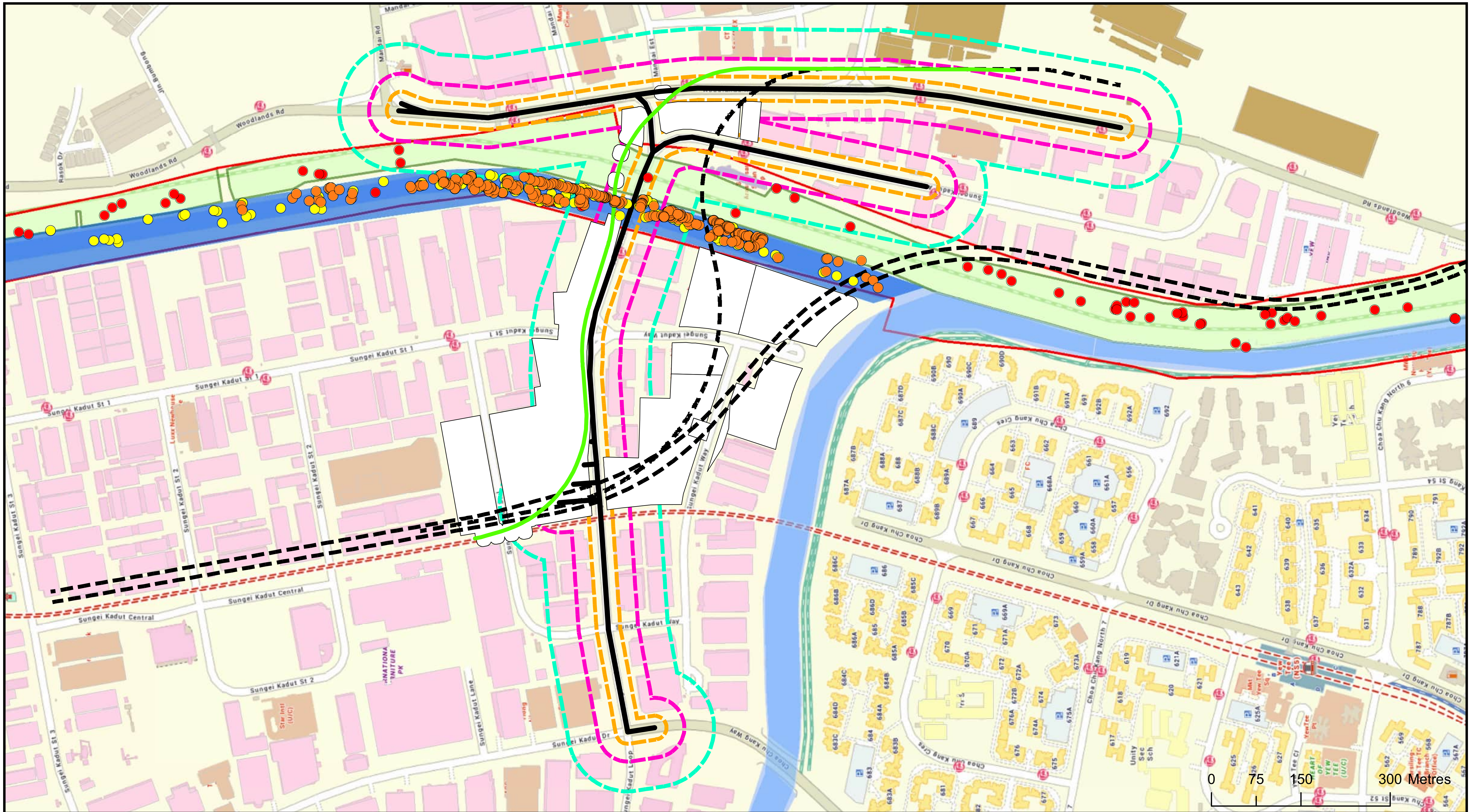
Project Title :
**CONTRACT 9175
ADVANCE ENGINEERING STUDY FOR THE PROPOSED DOWNTOWN LINE 2 EXTENSION AND A NEW STATION ON EXISTING NORTH-SOUTH LINE**

Figure Title :
RETRIEVAL SHAFT WORKSITE EMISSION SOURCES AND SENSITIVE RECEPTORS – TRACKOUT

Designed	Checked	Approved	Figure No. :	Rev.	Sheet
TTR	HHL	JAG	9-17	A	1 of 1

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

Note: Source of basemap - OneMap



Legend

- Sonneratia caseolaris
- Species of Conservation Significance
- Large Plant Specimens
- Potential Access Road
- Proposed Worksite Areas
- 20m from Sources
- 50m from Sources
- 100m from Sources
- Potential Future Infrastructure
- Proposed DTL2e Tunnel Alignment
- Pang Sua Canal
- Sungei Pang Sua
- Biodiversity Study Area
- Existing Vegetated Area

Sensitive Receptors

- Public Housing
- Commercial Building
- Place of Worship
- Educational Institution
- Transport Infrastructure
- Industrial Facility
- Unclassified Building (incl. Condominium and Landed Properties)

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 :

POTENTIAL FUTURE INFRASTRUCTURE WORKSITE EMISSION SOURCES AND SENSITIVE RECEPTORS – TRACKOUT

Designed	Checked	Approved	Figure No.	Rev.	Sheet
TTR	HHL	JAG	9-18	A	1 of 1

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

Note: Source of basemap - OneMap

9.3.2 Operational Phase

As presented in Table 9-10, potential air quality impact during operational phase of the Project would be vehicular emissions due to increased traffic in the vicinity of the Project, which in this context, the potential emission sources would be the stretch of existing roads connected to the nearest junctions from the Project Site and from the vehicle exhaust along the proposed vehicular bridge. Note that the potential future infrastructure is not a potential source of air quality impact as electric trains will be used.

For human receptors, gaseous and particulate emissions from the increased traffic could potentially result in adverse impacts on air quality and public health causing respiratory problems on humans. For ecological receptors, the main air pollutants affecting vegetation and ecosystems are nitrogen oxides (NOx), sulphur dioxide (SO_2) and ammonia (NH_3) [R-85]. In the context of this Project, the air pollutant of concern will be NOx which are produced from road traffic emission. SO_2 is not relevant for this Project as low sulphur content fuel will be used by vehicles in Singapore. NH_3 is mainly produced from agricultural activities and therefore, not relevant for the purpose of this Project. There is no published evidence for any direct toxic effect of NOx on animals and therefore effects on animals are not included in ecological impact assessment [R-85].

As per the NEA website, since 1 September 2017, all new petrol vehicles have had to meet the Euro 4 emission standard, and since 1 January 2018, all new diesel vehicles have had to meet the Euro 6 emission standard. The new standards will tighten fine particulate emissions from direct-injection petrol engines in addition to the other pollutants. Since 1 January 2018, the emission standard for all three-wheeled (Cat L5e) and large motorcycles with an engine capacity more than 200cc have been tightened to Euro 4 standard, while smaller motorcycles with an engine capacity of 200cc and below will see the Euro 4 emission standard implemented from 1 January 2020. Compared to the Euro 3 emission standard, the tighter Euro 4 emission standard will help reduce emissions of hydrocarbons and nitrogen oxides (NOx), which are precursors to ozone. The emission standards for various vehicle classes have been summarized in Table 9-11.
.

Table 9-10 Potential air quality impacts during the operational phase

Potential Source of Impacts	Potential Associated Impacts
Gaseous and particulate emissions from vehicle exhaust due to the increased traffic in vicinity of the project due to project operation.	Exhaust emissions (NO_2, SO_2, CO, PM_{10} and $PM_{2.5}$) could potentially impact the air quality in the vicinity of the project.
Gaseous and particulate emissions from the vehicle exhaust along the proposed vehicular bridge.	

Table 9-11 Emission standard of various vehicle classes

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

9.4 Identification of Air Quality Sensitive Receptors

9.4.1 Construction Phase

Ecological Receptors

The construction activities at the construction worksite pose a potential risk of dust emissions that may impact upon target habitat areas lying within the zone of influence of the construction site. Demolition footprint, earthworks footprint, construction footprint and access roads are located within or in close proximity to ecologically sensitive receptors. In line with the IAQM Guidance, a Study Area of 50 m was considered for ecological impacts during construction phase.

As classified in Table 6-2, Priority 1 refers to the nearest ecologically sensitive receptors of high ecological value located <20 m from the construction worksites with potential air emission sources, while Priority 2 refers to the nearest ecologically sensitive receptors of high ecological value located within 20 m – 50 m from the construction worksites. For this Project, based on the distances of emission sources to the identified receptors presented in Figure 9-5 to Figure 9-18, the Sensitivity of the Area was determined to range from Priority 1 to Priority 2. There are no other internationally-recognised or locally-gazetted ecological sites within 50 m of the Study Area, hence no Priority 3 receptors are identified.

As discussed in Table 6-2, according to UK IAQM [R-35], ecological receptor refers to any sensitive habitat affected by dust soiling, hence the air quality impact assessment of this ES will only focus on the flora of conservation significance or sensitive plant communities of large specimens which may receive the direct impacts species due to dust deposition from the construction worksites. The focal list with flora species of high ecological value identified within the air quality Study Area are presented in Table 9-12. A more comprehensive list of flora and fauna species as well as the associated biodiversity baseline and impact assessment findings are provided in Section 7. Table 9-13 summarizes the sensitivity of each construction phase for demolition, earthworks and construction, as well as trackout.

Table 9-12 Focal List of Flora Species of High Ecological Value Identified within the Air Quality Study Area

Distance from Worksites	Identified Species	Status	Number of Species Identified
DOCKING SHAFT WORKSITE			
Species of Conservation Significance			
Within 20 m	-	-	-
Between 20 m to 50 m	-	-	-
Large Specimens			
Within 20 m	-	-	-
Between 20 m to 50 m	*Khaya senegalensis*	Cultivated only	4
INTERMEDIATE STATION WORKSITE			
Species of Conservation Significance			
Within 20 m	-	-	-
Between 20 m to 50 m	-	-	-
Large Specimens			
Within 20 m	*Spathodea campanulate*	Vulnerable	7
Between 20 m to 50 m	*Spathodea campanulate* *Ficus macrocarpa* *Terminalia catappa* *Falcataria moluccana* *Dimocarpus longan ssp. Malesianus*	Vulnerable Common Native Naturalised Casual	9 2 4 2 1

Distance from Worksites	Identified Species	Status	Number of Species Identified
INTERCHANGE STATION WORKSITE			
Species of Conservation Significance			
Within 20 m	-	-	-
Between 20 m to 50 m	-	-	-
Large Specimens			
Within 20 m	-	-	-
Between 20 m to 50 m	-	-	-
RETRIEVAL SHAFT WORKSITE			
Species of Conservation Significance			
Within 20 m	-	-	-
Between 20 m to 50 m	-	-	-
Large Specimens			
Within 20 m	-	-	-
Between 20 m to 50 m	-	-	-
POTENTIAL FUTURE INFRASTRUCTURE WORKSITE			
Species of Conservation Significance			
Within 20 m	*Sonneratia caseolaris* *Amphineuron opulentum* *Cerbera odollam*	Critically endangered Endangered Vulnerable	5 1 1
Between 20 m to 50 m	*Sonneratia caseolaris* *Acanthus sp.* *Acanthus ebracteatus* *Caesalpinia crista* *Calophyllum inophyllum* *Cerbera odollam* *Finlaysonia obovata* *Lumnitzera racemosa* *Nypa fruticans*	Critically endangered Vulnerable Vulnerable Vulnerable Critically endangered Vulnerable Critically endangered Endangered Vulnerable	110 8 1 2 2 2 1 1 25
Large Specimens			
Within 20 m	-	-	-
Between 20 m to 50 m	*Nypa fruticans* *Talipariti tiliaceum* *Khaya senegalensis*	Vulnerable Common Cultivated only	7 1 1

Table 9-13 Receptor sensitivity for air quality impact assessment – construction phase (ecological receptors)

Distance	Identified Receptors	Sensitivity of the Area
ALL WORKSITES		
For Demolition		
Within 20 m	Rail Corridor	-

Distance	Identified Receptors	Sensitivity of the Area
Between 20 to 50 m	Rail Corridor	Priority 2
DOCKING SHAFT WORKSITE		
For Earthworks		
Within 20 m	Rail Corridor	-
Between 20 m to 50 m	Rail Corridor	Priority 2
For Trackout		
Within 20 m	Rail Corridor	-
Between 20 m to 50 m	Rail Corridor	Priority 2
INTERMEDIATE STATION WORKSITE		
For Earthworks		
Within 20 m	Rail Corridor	Priority 1
Between 20 m to 50 m	Rail Corridor	
For Construction		
Within 20 m	Rail Corridor	Priority 1
Between 20 m to 50 m	Rail Corridor	
For Trackout		
Within 20 m	Rail Corridor	-
Between 20 m to 50 m	Rail Corridor	Priority 2
INTERCHANGE STATION WORKSITE		
For Earthworks		
Within 20 m	Rail Corridor	-
Between 20 m to 50 m	Rail Corridor	
For Construction		
Within 20 m	Rail Corridor	-
Between 20 m to 50 m	Rail Corridor	
For Trackout		
Within 20 m	Rail Corridor	-
Between 20 m to 50 m	Rail Corridor	
RETRIEVAL SHAFT WORKSITE		
For Earthworks		
Within 20 m	Rail Corridor	-
Between 20 m to 50 m	Rail Corridor	
For Trackout		
Within 20 m	Rail Corridor	-
Between 20 m to 50 m	Rail Corridor	
POTENTIAL FUTURE INFRASTRUCTURE WORKSITE		
For Earthworks		
Within 20 m	Rail Corridor	Priority 1

Distance	Identified Receptors	Sensitivity of the Area
Between 20 m to 50 m	Rail Corridor	
For Construction		
Within 20 m	Rail Corridor	Priority 1
Between 20 m to 50 m	Rail Corridor	
For Trackout		
Within 20 m	Rail Corridor	Priority 1
Between 20 m to 50 m	Rail Corridor	

Human Receptors

Study Area of 350 m was considered for human health impacts during construction phase. Based on Table 6-2, in line with the IAQM Guidance, Priority 1 is defined as having sensitive receptors (i.e., residentials, hospitals, schools) within 20 m of construction worksite or >100 sensitive receptors within 50 m of construction worksite. While Priority 2 is defined as having commercial receptors within 20 m of construction worksite, having 1-100 sensitive receptors between 20 - 50 m of construction worksite or having >100 sensitive receptors between 50 - 100 m of construction worksite. All other buildings within the 350 m Study Area will be considered as Priority 3. Therefore, based on the distances of emission sources to the identified receptors presented in Figure 9-5 to Figure 9-18, the Sensitivity of the Area for each construction worksite was determined to be ranging from Priority 1 to Priority 3 as summarized in Table 9-14 for demolition, earthworks, construction, and trackout. Due to the extensive list of the identified sensitive receptors for construction phase, this is elaborated and presented in Appendix Q.

Table 9-14 Receptor sensitivity for air quality impact assessment – construction phase (human receptors)

Worksite	Activities	Sensitivity of the Area
All	Demolition	Priority 1
Docking Shaft Worksite	Earthworks	Priority 1
	Trackout	Priority 1
Intermediate Station Worksite	Earthworks	Priority 1
	Construction	Priority 1
	Trackout	Priority 2
Interchange Station Worksite	Earthworks	Priority 1
	Construction	Priority 2
	Trackout	Priority 1
Retrieval Shaft Worksite	Earthworks	Priority 1
	Trackout	Priority 1
Potential Future Infrastructure Worksite	Earthworks	Priority 1
	Construction	Priority 1
	Trackout	Priority 1

9.4.2 Operational Phase

Potential air quality impact during operational phase of the Project would be vehicular emissions due to increased traffic to the proposed development (e.g., existing roads within Project Site) as discussed in Section 9.3.2. Potential human and ecological sensitive receptors which might be impacted by the increased traffic within 250 m air quality Study Area are presented in Table 9-15 below. It should be noted that there is no detailed plan of project or operational footprint (e.g., stations, vehicular bridge, overhead bridge, potential future infrastructure, etc.) at this early stage, hence the air quality sensitive receptors were identified based on the existing land uses and the future proposed land use plan in Figure 4-1.

Table 9-15 Receptor sensitivity for air quality impact assessment – operational phase

No.	Receptor Name	Land Use	Receptor Type	Sensitivity Classification
Existing Receptors				
1	Yew Tee Primary School	Educational	Human	Priority 1
2	Teck Whye Secondary School	Educational	Human	Priority 1
3	West View Primary School	Educational	Human	Priority 1
4	HDB Block 635 at Choa Chu Kang North 6	Residential	Human	Priority 1
5	HDB Block 639-643 at Choa Chu Kang Street 64	Residential	Human	Priority 1
6	The Windermere	Residential	Human	Priority 1
7	The Quintet	Residential	Human	Priority 1
8	Regent Grove	Residential	Human	Priority 1
9	HDB Block 656-666, 668, 690, 690A, 690B, 690C, 690D, 691, 691A, 691B, 692A, 692B at Choa Chu Kang Crescent	Residential	Human	Priority 1
10	HDB Block 687C, 687D, 688B, 688C, 689A, 689B, 690A, 690B, 690C, 690D at Choa Chu Kang Drive	Residential	Human	Priority 1
11	HDB Block 625, 626, 627, 629, 629B, 630, 632A, 632B, 633, 633A, 633B, 633C, 633D, 634A, 634B 635, 635A, 635B, 635C at Senja Road	Residential	Human	Priority 1
12	Sri Arasakesari Sivan Temple	Place of Worship	Human	Priority 1
13	HDB Multi Storey Carpark Block 629A, 632, 634, 636 at Senja Road	Commercial	Human	Priority 3
14	Senja Centre	Commercial	Human	Priority 3
15	HDB Multi Storey Carpark Block 660A, 661A, 668A, 692 at Choa Chu Kang Crescent	Commercial	Human	Priority 3
16	HDB Multi Storey Carpark 689 Choa Chu Kang Drive	Commercial	Human	Priority 3
17	Matsushita House Singapore	Commercial	Human	Priority 3
18	Trendspace	Commercial	Human	Priority 3
19	LUXX Newhouse Design Centre	Commercial	Human	Priority 3
20	Sungei Kadut Fire Post	Commercial	Human	Priority 3
21	Sunray Building	Commercial	Human	Priority 3
22	Grandwork Building	Commercial	Human	Priority 3
23	Mandai Connection	Commercial	Human	Priority 3
24	566 Woodlands Road	Commercial	Human	Priority 3
25	BHL Factories	Commercial	Human	Priority 3
26	M-Space	Commercial	Human	Priority 3
27	80, 82, 84, 86, 88, 90, 92, 94, 96 Mandai Estate	Commercial	Human	Priority 3
28	Innovation Place	Commercial	Human	Priority 3
29	West Life Mandai Dormitory	Commercial	Human	Priority 3

No.	Receptor Name	Land Use	Receptor Type	Sensitivity Classification
30	Gali Batu Depot	Commercial	Human	Priority 3
31	Eurokars Centre	Commercial	Human	Priority 3
32	6, 8, 14, 16, 18, 19, 20, 21, 22, 31, 33, 39, 45, 46, 47, 48, 48A, 50, Sungei Kadut Avenue	Industrial	Human	Priority 3
33	1, 3, 5, 14, 15, 16, 16A, 17, 18, 20, 20A Sungei Kadut Way	Industrial	Human	Priority 3
34	21, 23, 23A, 23F, 23H, 25J, 25, 27, 35, 36, 38, 40, 41, 43 Sungei Kadut Street 1	Industrial	Human	Priority 3
35	4, 6, 8, 15, 18, 19A, 23, 29, 31, 37, 38, 39 Sungei Kadut Street 2	Industrial	Human	Priority 3
36	1, 2, 3, 4, 6, 10, 14, 15, 16, 18 Sungei Kadut Street 3	Industrial	Human	Priority 3
37	1A, 3, 5, 7, 9, 11, 11A Sungei Kadut Street 4	Industrial	Human	Priority 3
38	71 Sungei Kadut Drive	Industrial	Human	Priority 3
39	6 Mandai Link	Industrial	Human	Priority 3
40	Yew Tee Industrial Estate G7	Industrial	Human	Priority 3
41	Yew Tee Industrial Estate A1	Industrial	Human	Priority 3
42	Rail Corridor	Natural Area	Ecological	Priority 1
43	Sungei Pang Sua	Natural Area	Ecological	Priority 1

9.5 Baseline Air Quality

9.5.1 Baseline Monitoring Personnel

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

- Ms. Jagriti Dawra, AECOM (ES Specialist);
- Mr. Hanzel Lalitan, AECOM (Air Quality Consultant);
- Mr. Edmundo II Casapao, ALS Technichem (S) Pte Ltd; and
- Mr. Yong Li Sheng, ALS Technichem (S) Pte Ltd.

Site reconnaissance surveys were carried out on 28 October 2021, 5 November 2021 and 22 February 2022. Subsequently, the primary baseline air quality data collection was conducted on 14 – 21 February 2022 at AQ2 monitoring location and on 24 – 31 March 2022 at AQ1 monitoring location. The baseline monitoring locations are presented in Table 9-3, Figure 9-3 and Figure 9-4.

9.5.2 Baseline Findings

9.5.2.1 Secondary Data Collection (Review of Background Data)

9.5.2.1.1 NEA Singapore Ambient Air Quality Targets and Monitoring

Table 9-16 provides the general NEA ambient air monitoring results for Singapore over the period 2016 – 2020 and compares them with the Year 2020 and Long Term Singapore Ambient Air Quality Targets (SAAQT) (the latter is meant to be slightly more stringent in consideration of progressive improvements towards the desired ambient air quality in long term). The SAAQT have been adopted in this report and are generally more stringent than the USEPA National Ambient Air Quality Standards (NAAQS).

It can be observed from Table 9-16 that the NEA monitoring results for background carbon monoxide (CO) and nitrogen dioxide (NO_2) were below the SAAQT between 2016 and 2020. Whereas the background particulate matter less than 10 µm (PM_{10}) annual mean, particulate matter less than 2.5 µm ($PM_{2.5}$) annual mean, sulphur dioxide (SO_2) 24-hour average and ozone (O_3) 8-hour average, have consistently exceeded either the Long Term SAAQT or both the Year 2020 and Long Term SAAQT over the period 2016 - 2020. The elevated PM_{10}, $PM_{2.5}$, SO_2 and O_3 concentrations in Singapore are partly attributable to the intermittent haze periods resulting from forest fires in neighbouring countries, although other significant contributors to the background levels may also be domestic emissions from industries, shipping and motor vehicles.

Nonetheless, the NEA monitored results have also demonstrated a considerably great reduction in most of the air pollutant levels (except for O_3) in Year 2020. This may be due to the COVID-19 restrictions at regional and global levels where human activities such as commercial events and transportation activities have drastically decreased.

Table 9-16 NEA ambient air quality monitoring [R-88, R-89]

Pollu-tants	Averaging Period	2016 results (µg/m³)	2017 results (µg/m³)	2018 results (µg/m³)	2019 results (µg/m³)	2020 results (µg/m³)	Average results 2016 – 2020 (µg/m³)	Singapore Ambient Air Quality Long Term Targets (µg/m³)
PM_{10}	99th %ile of 24-Hour Averages	**61**	**57**	**59**	**90**	43	**62**	*50*
	Annual Mean	**26**	**25**	**29**	**30**	**25**	**27**	*20*
$PM_{2.5}$	99th %ile of 24-Hour Averages	**40**	**34**	**32**	**62**	24	**38**	*25*
	Annual Mean	**15**	**14**	**15**	**16**	**11**	**14**	*10*
CO	Maximum 1-Hour Average	2,700	2,300	2,500	2,300	1,600	2280	*30,000*
	Maximum 8-Hour Average	2,200	1,700	2,000	1,700	1,200	1760	*10,000*
NO_2	Maximum 1-Hour Average	123	158	147	156	118	140	*200*
	Annual Mean	26	25	26	23	20	24	*40*
SO_2	24-Hour Average	**61**	**59**	**65**	**57**	**30**	**54**	*20*
O_3	8-Hour Average	**115**	**191**	**150**	**125**	**145**	**145**	*100*

Notes:

Values in **Bold** exceed the Long Term Singapore Ambient Air Quality Target.

9.5.2.1.2 Hourly 24-hour PM_{10} and $PM_{2.5}$ Concentration Readings

Hourly 24-hr PM_{10} and $PM_{2.5}$ readings available on data.gov.sg for Western and Northern Regions of Singapore were collected during the same period as primary data collection period for comparison against primary baseline monitoring results.

A review was conducted for 24-hr PM_{10} and $PM_{2.5}$ readings available on data.gov.sg for Western and Northern Singapore during the monitoring period (28 February – 24 March 2022). Figure 9-19 and Figure 9-20 show the variation of PM_{10} and $PM_{2.5}$ concentrations recorded by the NEA during the primary baseline data collection period respectively.

As observed from Figure 9-19 and Figure 9-20, the PM_{10} and $PM_{2.5}$ levels obtained from data.gov.sg were observed to meet the Singapore Ambient Air Quality Targets in Western and Northern Singapore throughout the primary data collection period.

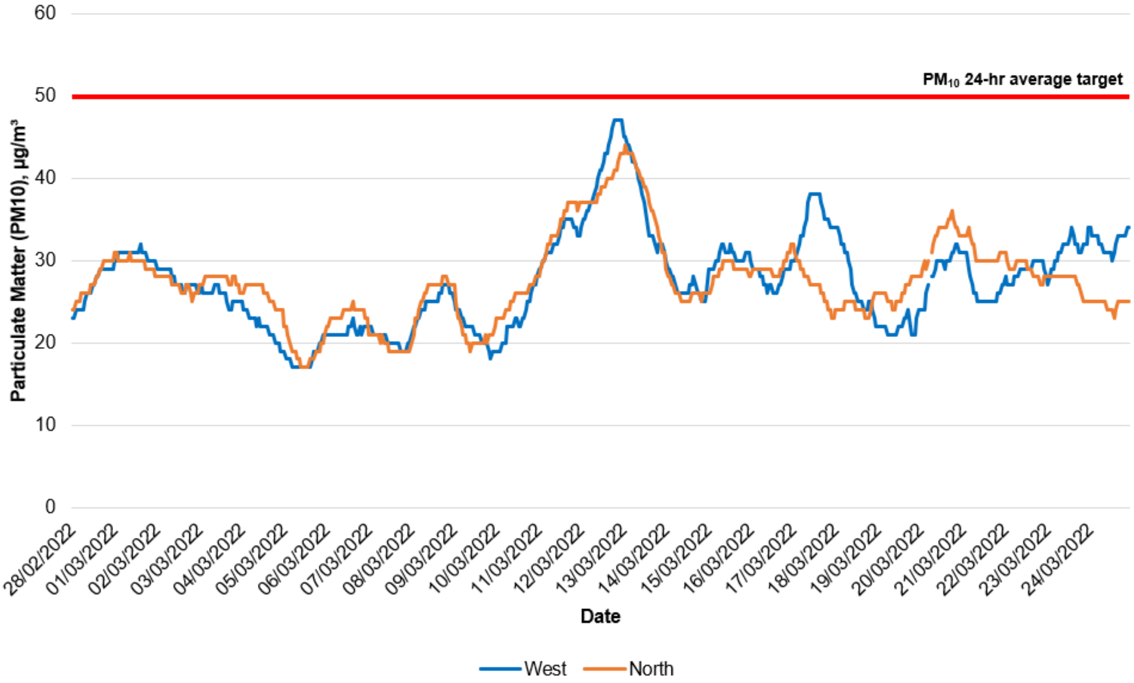


Figure 9-19 24-hr PM_{10} concentrations reading of Western and Northern Singapore (28 February – 24 March 2022) [W-67]

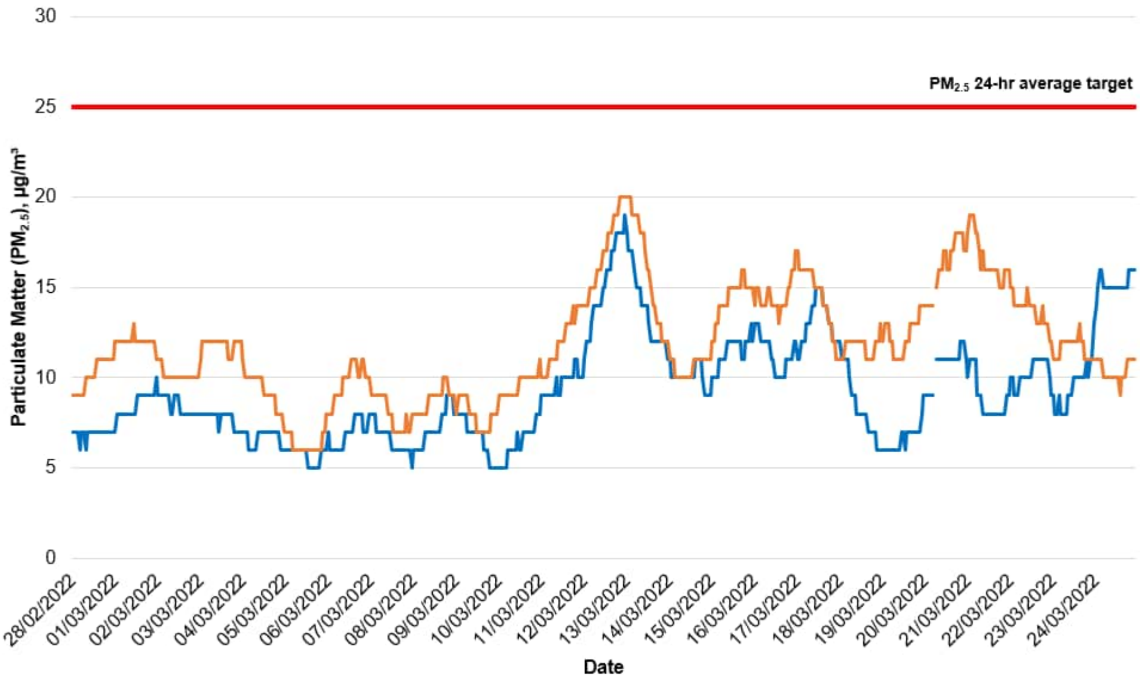


Figure 9-20 24-hr $PM_{2.5}$ concentrations reading of Western and Northern Singapore (28 February – 24 March 2022) [W-67]

9.5.2.1.3 Other Parameters (Rainfall, Temperature, Wind Speed)

Figure 9-21, Figure 9-22, and Figure 9-23 below present the trend of daily total rainfall, mean temperature and mean wind speed observed at Bukit Panjang, Admiralty and Tengah weather monitoring stations, from March 2017 to March 2022.

From Figure 9-21, an average of approximately 7.6 mm, 6.3 mm and 7.4 mm of daily rain was observed from Bukit Panjang, Admiralty and Tengah monitoring stations, respectively. This calculates to approximately 2770 mm, 2290 mm and 2683 mm of rain annually for Bukit Panjang, Admiralty and Tengah monitoring stations respectively. With regards to mean temperature and mean wind speed, the temperature and wind speed within Study Area is expected to be relatively constant with average 27.7°C and 27.7°C mean temperature as observed in Figure 9-22 from Admiralty and Tengah monitoring stations respectively, and 11.2 km/h and 10.2 km/h mean wind speed as observed in Figure 9-23 from Admiralty and Tengah monitoring stations respectively.

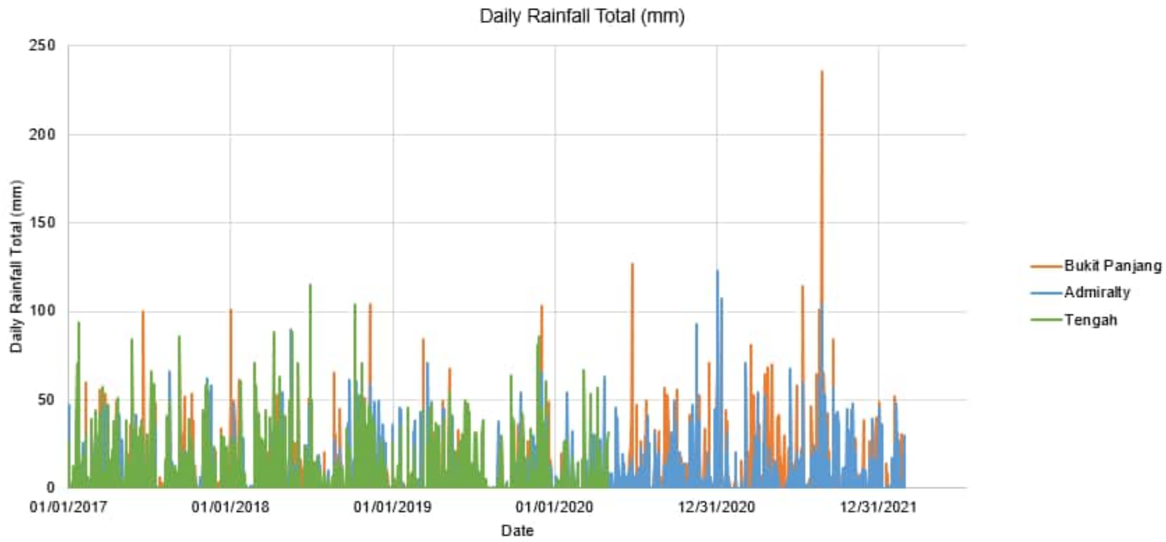


Figure 9-21 Daily rainfall monitored at Bukit Panjang, Admiralty and Tengah monitoring stations [W-66]

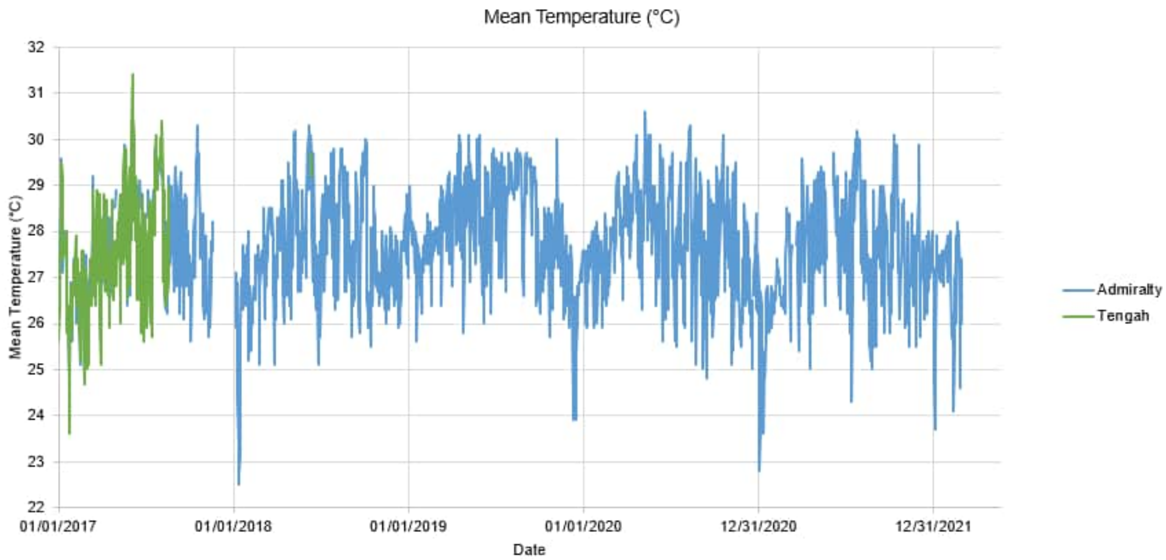


Figure 9-22 Mean temperature monitored at Admiralty and Tengah monitoring stations [W-66]

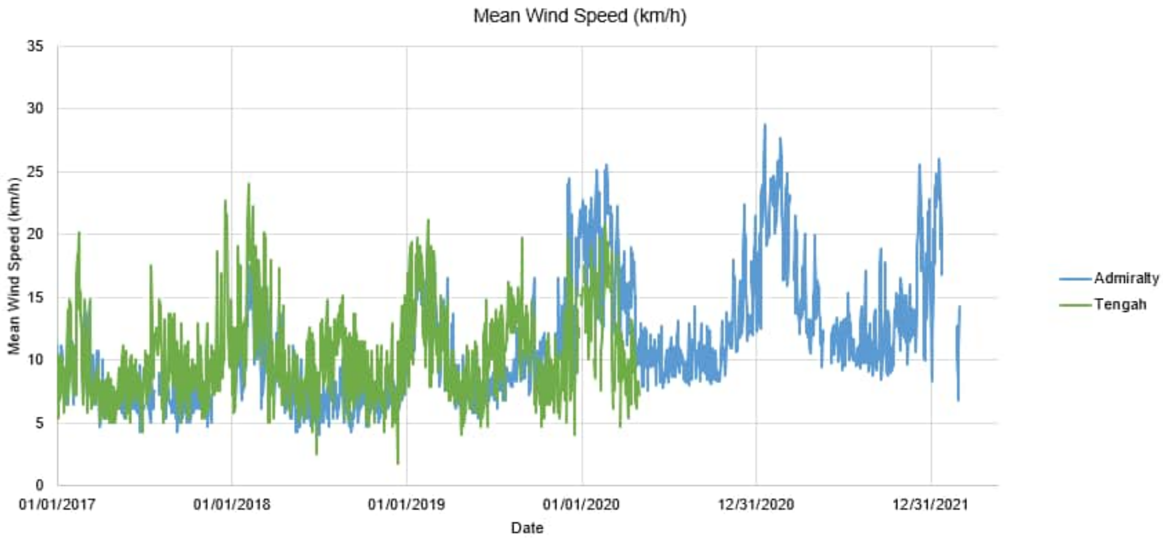


Figure 9-23 Mean wind speed monitored at Tengah and Admiralty monitoring stations [W-66]

9.5.2.2 Primary Data Collection (Survey & Sampling)

Seven (7) days of continuous ambient air quality monitoring was conducted at the locations mentioned in Table 9-3 to determine the pollutant concentrations from existing background pollutant sources. The monitoring results for each pollutant at all monitoring locations are summarized in Table 9-17 below and compared with the Singapore Ambient Air Quality Long Term Targets.

It can be observed from Table 9-17 that the results at A01 meet the target for all pollutants throughout the monitoring period with PM_{10}, $PM_{2.5}$, and NO_2 monitored concentrations ranging from 11.8 – 27.8 µg/m^3, 8.6 – 24.1 µg/m^3 and <10.0 – 102 µg/m^3 respectively. Monitoring location A01 was located within Sungei Kadut industrial area and along Sungei Kadut Central. Thus, the pollutants recorded in this location is generally affected by industrial activities within Sungei Kadut industrial area and traffic along Sungei Kadut Central.

For A02, the results also meet all pollutants targets for all days as presented in Table 9-17 with PM_{10}, $PM_{2.5}$, and NO_2 monitored concentrations ranging from 8.8 – 30.5 µg/m^3, 6.8 – 24.8 µg/m^3 and <10.0 – 136 µg/m^3 respectively. Monitoring location A02 was located within HDB Choa Chu Kang Crescent estate and approximately 170 m from industrial area along Sungei Kadut Avenue across Pang Sua Canal. Thus, the pollutants recorded in this location is generally affected by localized activities within the HDB estate and some influence from industrial activities along Sungei Kadut Avenue.

Monitoring location A03 was located within Choa Chu Kang Rail Corridor along Woodlands Road near HDB Senja Road estate. The results at A03 meet all pollutants targets for all days as presented in Table 9-17 with PM_{10} and $PM_{2.5}$ monitored concentrations ranging from 8.5 – 25.1 µg/m^3 and 5.8 – 20.6 µg/m^3 respectively. The pollutants recorded in this location is generally affected by localized activities within the Rail Corridor and traffic along Woodlands Road.

The results at A04 monitoring location also meet all pollutants targets for all days as presented in Table 9-17 with PM_{10} and $PM_{2.5}$ monitored concentrations ranging from 8.8 – 30.5 µg/m^3 and 6.8 – 24.8 µg/m^3 respectively. A04 was located along Woodlands Road, approximately 100 m from nearby industries within Mandai Estate and less than 70 m from existing Gali Batu train depot. Thus, the pollutants recorded in this location is generally affected by traffic along Woodlands Road, industrial activities within Mandai Estate and activities within Gali Batu train depot.

With regards to A05 monitoring location, it was located along Sungei Kadut Avenue, approximately 12 m to Sungei Pang Sua and 18 m to nearest industry within Sungei Kadut industrial area. The results at A05 meet the target for all pollutants throughout the monitoring period with PM_{10}, $PM_{2.5}$, and NO_2 monitored concentrations ranging from 9.9 – 33.8 µg/m^3, 6.6 – 24.1 µg/m^3 and <10.0 – 118 µg/m^3 respectively. The pollutants recorded in this location is generally affected by traffic along Sungei Kadut Avenue and industrial activities within Sungei Kadut industrial area.

Table 9-17 Baseline air quality monitoring results

Monitoring Location	Monitoring Date	24-hr PM_{10} Concentration, µg/m^3			24-hr $PM_{2.5}$ Concentration, µg/m^3			1-hr NO_2 Concentration, µg/m^3		
		Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
A01: Near 18 Sungei Kadut Street 2	16 – 23 March 2022	11.8	27.8	17.8	8.6	24.1	13.9	<10.0	102	44.2
A02: HDB Blk 691B Choa Chu Kang Crescent	8 – 16 March 2022	8.8	30.5	19.5	6.8	24.8	15.1	<10.0	136	34.7
A03: Choa Chu Kang Rail Corridor	7 – 14 March 2022	8.5	25.1	16.1	5.8	20.6	12.5	–*	–*	–*
A04: Near Gali Batu Train Depot	28 Feb – 7 March 2022	8.0	22.4	15.0	4.6	15.1	10.2	–*	–*	–*
A05: Sungei Pang Sua	28 Feb – 7 March 2022	9.9	33.8	22.3	6.6	24.1	14.9	<10.0	118	31.0
Singapore Ambient Air Quality Long Term Targets		*50*			*25*			*200*		

Notes: Air quality monitoring was conducted during COVID-19 pandemic. Ambient air quality in this area might be higher during pre-COVID condition.

* The potential air quality impact in this area is only during construction phase. Hence, only PM_{10} and $PM_{2.5}$ were monitored.

9.6 Minimum Control Measures

This section proposes minimum controls or standard practices commonly implemented that have been assumed to be implemented for the purposes of impact assessment. Generally, the minimum control has also considered design optimization detailed in Section 3.2.1.

9.6.1 Construction Phase

The following control measures should be observed during the construction phase:

- The construction footprint should be hoarded on all sides;
- Access road construction or expansion is recommended to be completed first and paved before the construction of other development commences.

9.6.2 Operational Phase

No minimum control was assumed for the purpose of air quality impact assessment during operational phase.

9.7 Prediction and Evaluation of Air Quality Impacts

9.7.1 Construction Phase

Throughout the study a conservative but credible approach was adopted to assess the air quality impacts of this Project where the potential sources are mainly dust emissions (PM_{10} and $PM_{2.5}$) from construction activities (e.g., earthworks, dust/ dirt from on-site transport), and other gaseous emissions (e.g., NO_2, SO_2, CO) from construction equipment (e.g., off-road diesel engines like generator) and site vehicle exhausts as discussed in Section 9.3.1. This may lead to an over-estimation of the levels of pollutants that will arise in practice, but this is considered to be appropriate for planning purposes at this stage of the project and is consistent with precautionary principles.

9.7.1.1 Impact Assessment on Dust Emissions from Demolition, Earthworks, Construction and Trackout

The assessment was conducted using the site area, hours of operation, timescale of construction, construction material, excavation quantities, surface material and number of vehicles on site based on the approach described in Section 9.2.2.3.

Ecological Receptors

Dust from construction worksites deposited on vegetation may create ecological stress within the local plant community. During dry periods dust can coat plant foliage adversely affecting photosynthesis and other biological functions. Rainfall removes the deposited dust from foliage and can rapidly leach chemicals into the soil. Large scale construction worksites may give rise to dust deposition over an extended period of time and adversely affect vascular plants. Deposition of concrete dust has the potential to increase the surface alkalinity, which in turn can hydrolyse lipid and wax components, penetrate the cuticle, and denature proteins, finally causing the leaf to wilt [P-62]. Dust may affect photosynthesis, respiration, transpiration and allow the penetration of phytotoxic gaseous pollutants [P-63].

In line with the IAQM Guidance, the Impact Intensity was determined by reviewing the scale of construction activities and classifying them as low, medium or high for each activity type (demolition, earthworks, construction, and trackout). The amount of dust deposited, and its effects are also dependent upon weather conditions. During wet weather, less dust will be generated and that which has been deposited upon foliage is more likely to be washed off. As discussed in Section 9.5.2.1.3, the Project is expected to receive relatively higher rainfall in the long term compared to the other parts of Singapore. Hence, this is expected to help to lessen the intensity of dust generated and deposited upon plant foliage. However, the IAQM methodology does not take into account the rainfall intensity in the Study Area. Therefore, the air quality assessment is expected to be conservative for the purpose of the Project.

The overall Consequence for each activity was classified by considering Impact Intensity with the Receptor Sensitivity. Without any mitigation measures in place, the Likelihood of occurrence of impacts from construction of the project is classified as Regular as the activity would occur on a regular basis during construction. The Impact Intensity, overall Consequence and Impact Significance are outlined in Table 9-18.

Based on the assessment, the Impact Significance was predicted to be ranging from Moderate to Major for ecological impact. Hence, based on the assessment methodology in Section 9.2.2.3.7, Impact Significance evaluated as Major and Moderate requires the adoption of management or mitigation measures.

Human Receptors

In line with the IAQM Guidance, the Impact Intensity was determined by reviewing the scale of construction activities and classifying them as low, medium or high for each activity type (demolition, earthworks, construction, and trackout). The project was expected to receive relatively higher rainfall in the long term compared to the other parts of Singapore. Hence, this was expected to help to lessen the intensity of dust generated and deposited. However, the IAQM methodology does not take into account the rainfall intensity in the Study Area. Therefore, the air quality assessment was expected to be conservative for the purpose of the project.

The overall Consequence for each activity was classified by considering Impact Intensity with the Receptor Sensitivity. Without any mitigation measures in place, the Likelihood of occurrence of impacts from construction of the project was classified as Regular as the activity would occur on a regular basis during construction. The Impact Intensity, overall Consequence and Impact Significance are outlined in Table 9-18 to Table 9-21.

Based on the assessment, the Impact Significance was predicted to be ranging from Moderate to Major for human health impact. Hence, based on the assessment methodology in Section 9.2.2.3.7, Impact Significance evaluated as Major and Moderate requires the adoption of management or mitigation measures.

Table 9-18 Impacts of dust risk assessment (demolition)

Construction Worksite	Key Parameter - Demolition			Impact Assessment							
	Total Building Volume (m^3)	Construction Material	Height of Demolition Activities (m)	Impact Intensity	Sensitivity of the Area		Overall Consequence / Dust Risk		Likelihood Ecological Receptor	Impact Significance	
					Ecological Receptor	Human Receptor	Ecological Receptor	Human Receptor		Ecological Receptor	Human Receptor
Overall	>50,000	Potentially dusty (e.g., concrete)	10-20	High	Priority 2	Priority 1	Medium	High	Regular	Moderate	Major

Table 9-19 Impacts of dust risk assessment (earthworks)

Construction Worksite	Key Parameter - Earthworks			Impact Assessment							
	Total Site Area (m^2)	No. of Vehicles Moving Within the Site	Total Material Moved (tonnes)	Impact Intensity	Sensitivity of the Area		Overall Consequence / Dust Risk		Likelihood	Impact Significance	
					Ecological Receptor	Human Receptor	Ecological Receptor	Human Receptor		Ecological Receptor	Human Receptor
Docking Shaft	>10,000	5-10	20,000-100,000	High	Priority 2	Priority 1	Medium	High	Regular	Moderate	Major
Intermediate Station	>10,000	5-10	>100,000	High	Priority 1	Priority 1	High	High	Regular	Major	Major
Interchange Station	>10,000	5-10	>100,000	High	-	Priority 1	-	High	Regular	-	Major
Retrieval Shaft	>10,000	5-10	20,000-100,000	High	-	Priority 1	-	High	Regular	-	Major
Potential Future Infrastructure	>10,000	5-10	20,000-100,000	High	Priority 1	Priority 1	High	High	Regular	Major	Major

Table 9-20 Impacts of dust risk assessment (construction)

Key Parameter - Construction					Impact Assessment						
Construction Worksite	**Total Building Volume (m^3)**	**Construction Material**	**No. of On-Site Concrete Batching Plant**	**Impact Intensity**	**Sensitivity of the Area**		**Overall Consequence / Dust Risk**		**Likelihood**	**Impact Significance**	
					Ecological Receptor	**Human Receptor**	**Ecological Receptor**	**Human Receptor**		**Ecological Receptor**	**Human Receptor**
Intermediate Station	>100,000	Potentially dusty (e.g., concrete)	1	High	Priority 1	Priority 1	High	High	Regular	Major	Major
Interchange Station	>100,000	Potentially dusty (e.g., concrete)	1	High	Priority 1	Priority 2	High	Medium	Regular	Major	Moderate
Potential Future Infrastructure	25,000-100,000	Potentially dusty (e.g., concrete)	0	Medium	Priority 1	Priority 1	Medium	Medium	Regular	Moderate	Moderate

Table 9-21 Impacts of dust risk assessment (trackout)

Key Parameter - Trackout					Impact Assessment						
Construction Worksite	**No. of Outward Trucks Movement Per Day**	**Road surface material**	**Unpaved Road Length (m)**	**Impact Intensity**	**Sensitivity of the Area**		**Overall Consequence / Dust Risk**		**Likelihood**	**Impact Significance**	
					Ecological Receptor	**Human Receptor**	**Ecological Receptor**	**Human Receptor**		**Ecological Receptor**	**Human Receptor**
Docking Shaft	10-50	Moderately Dusty	<100	Medium	Priority 2	Priority 1	Low	Medium	Regular	Moderate	Moderate
Intermediate Station	>50	Moderately Dusty	<100	High	Priority 2	Priority 2	Medium	Medium	Regular	Moderate	Moderate
Interchange Station	>50	Moderately Dusty	<100	High	-	Priority 1	-	High	Regular	-	Major

Construction Worksite	Key Parameter - Trackout				Impact Assessment						
	No. of Outward Trucks Movement Per Day	Road surface material	Unpaved Road Length (m)	Impact Intensity	Sensitivity of the Area		Overall Consequence / Dust Risk		Likelihood	Impact Significance	
					Ecological Receptor	Human Receptor	Ecological Receptor	Human Receptor		Ecological Receptor	Human Receptor
Retrieval Shaft	10-50	Moderately Dusty	<100	Medium	-	Priority 1	-	Medium	Regular	-	Moderate
Potential Future Infrastructure	10-50	Moderately Dusty	<100	Medium	Priority 1	Priority 1	Medium	Medium	Regular	Moderate	Moderate

9.7.1.2 Impact Assessment on Gaseous Emissions from Construction Equipment, Vehicle and Off-Road Diesel Exhaust

Exhaust emissions from construction equipment, machineries and vehicles have the potential to cause air quality impact. Petrol and diesel construction equipment utilized during the construction period will generate pollutants such as PM_{10}, $PM_{2.5}$, CO, SO_2, and NO_x. It should be noted that all construction machines will not operate at the same time and at the same location. The emission will be spread out across the construction duration within the day and also across the Project Site, hence the human and ecological receptors in terms of equipment exhaust activities will be classified as Priority 1 receptors. All construction equipment fall under the definition of off-road diesel engine will also comply to Singapore's Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations 2012. The impact is usually localised within the construction worksite and only short-term during the operation of the equipment/vehicle only. Therefore, only small-scale increase in air quality levels is expected and the Impact Intensity is considered as Low, hence resulting in a Low Impact Consequence based on Table 6-6. With likelihood of Regular, the overall Impact Significance from equipment exhaust is expected to be Moderate, which requires the adoption of management or mitigation measures based on the assessment methodology in Section 9.2.2.3.7.

9.7.2 Operational Phase

As discussed in Section 9.3.2, emissions from vehicle exhaust due to increased traffic to the proposed project is expected. It is assumed that all new petrol and diesel vehicles will meet Euro 6 emission standard, while all motorcycles will meet Euro 4 standard going forward and slowly completely convert to these or better standards as they get phased out in 10 years from their onset. It can be observed from Table 9-22, NO_x reduction from the last three Euro emission standard tier is 55.6% and 25% for diesel and gasoline passenger cars respectively. Similarly, as observed in Table 9-23, NOx reduction from the last three Euro emission standard tier is approximately 55% and 25% for diesel and gasoline commercial good vehicles respectively across all vehicle categories.

Table 9-22 Euro emission standard for passenger cars [W-99]

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

Table 9-23 Euro emission standard for commercial good vehicles [W-99]

Category	Tier	Approval Date	Emission standard for commercial good vehicles, g/km				
			CO	HC	NO_X	HC+NO_X	PM
Compression Ignition (Diesel)							
N1, Class I ≤ 1305 kg	Euro 5a	September 2009	0.50	-	0.18	0.23	0.005
	Euro 5b	September 2011	0.50	-	0.18	0.23	0.005
	Euro 6	September 2014	0.50	-	0.08	0.17	0.005
N1, Class II 1305 – 1760 kg	Euro 5a	September 2009	0.63	-	0.235	0.295	0.005
	Euro 5b	September 2011	0.63	-	0.235	0.295	0.005
	Euro 6	September 2014	0.63	-	0.105	0.195	0.005
N1, Class III 1760-3500 kg	Euro 5a	September 2009	0.74	-	0.28	0.35	0.005
	Euro 5b	September 2011	0.74	-	0.28	0.35	0.005
	Euro 6	September 2014	0.74	-	0.125	0.215	0.005
N2, 3500 – 12000 kg	Euro 5a	September 2009	0.74	-	0.28	0.35	0.005
	Euro 5b	September 2011	0.74	-	0.28	0.35	0.005
	Euro 6	September 2014	0.74	-	0.125	0.215	0.005
Positive Ignition (Gasoline)							
N1, Class I ≤ 1305 kg	Euro 4	January 2005	1.00	0.10	0.08	-	-
	Euro 5	September 2009	1.00	0.10	0.06	-	0.005
	Euro 6	September 2014	1.00	0.10	0.06	-	0.005
N1, Class II 1305 – 1760 kg	Euro 4	January 2005	1.81	0.13	0.10	-	-
	Euro 5	September 2009	1.81	0.13	0.075	-	0.005
	Euro 6	September 2014	1.81	0.13	0.075	-	0.005
N1, Class III 1760-3500 kg	Euro 4	January 2005	2.27	0.16	0.11	-	-
	Euro 5	September 2009	2.27	0.16	0.082	-	0.005
	Euro 6	September 2014	2.27	0.16	0.082	-	0.005
N2, 3500 – 12000 kg	Euro 5	September 2009	2.27	0.16	0.082	-	0.005
	Euro 6	September 2014	2.27	0.16	0.082	-	0.005

Within the 250 m Study Area, the existing residential properties are mostly located at the southwest of the intermediate station worksite, and at the east of the docking shaft worksite, including the HDB blocks along Choa Chu Kang Crescent and Senja Road, and the private residences (the nearest being The Quintet). There are also educational institutes located at the southwest of the intermediate station worksite, and at the east and west of the docking shaft worksite, (e.g., Yew Tee Primary School, Teck Whye Secondary School, and West View Primary School). Typically, the pollutants of concern in a traffic-related pollution tend to be CO, NO_x (NO/NO_2), PM_{10} and $PM_{2.5}$. As the vehicles use low sulphur fuel, SO_2 is less of concern these days from vehicular exhaust.

Ecological Receptors

The particulates, viz. PM_{10} and $PM_{2.5}$ (dust) can have direct and indirect impacts on ecological receptors. Dust emissions can have direct adverse effects upon vegetation restricting photosynthesis, respiration and transpiration. It can also lead to phytotoxic gaseous pollutants penetrating the plants. The overall effect can be a decline in plant productivity, which may then have indirect effects on the quality of the affected habitats and associated fauna.

NO_x can affect plants directly or indirectly. It may directly enter a plant via the stomata, where it has phytotoxic effects. Lower plants such as lichens and bryophytes (including mosses, landworts and hornwarts) are particularly vulnerable to direct exposure to the gases in this way [W-100]. Since the biodiversity survey was focused on only vascular plants, there is limited information on the locations of these non-vascular species. However, based on empirical observation, rain trees are known to other biomes such as mosses. Numerous specimens of large trees were recorded within the Study Area (refer to Section 9.4.1).

Indirectly, NO_x can also deposit onto soil and, following transformation to nitrate, enrich the soil, leading to eutrophication. The effects of elevated NO_x concentrations on vegetation can be broadly categorised as [R-86]:

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

Indirectly in the long run, accumulation of nitrogen oxides (NO_x) via acidic rain causes soil and water to become more acidic and hence, reducing the nutritional value of food sources for fauna [P-61]. There is no published evidence for any direct toxic effect of NO_x on animals and therefore effects on animals are not included in ecological impact assessment [R-35].

Lichens/ mosses are indicator of good air quality and high level of SO_2 emission might impact these plants tremendously. Although this is not seemingly a potential concern in the operation of a residential area. Other development within the residential estates, such as community centre, might employ generators which might emit high level of SO_2. In order to avoid this, low sulphur diesel fuel should be used as minimum control in line with NEA's latest regulations.

From CO however, there is no known specific impact on ecological receptors. It should also be noted that some of the ecological receptors along Sungei Pang Sua are immediately adjacent to the Sungei Kadut Avenue with the existing disturbance from the vehicular road emissions.

Human Receptors

As for impacts of pollutants on human, NO_2 increases the risk of respiratory infection and impairs lung functions in asthmatics. CO deprives body tissues of oxygen and causes nausea and impairs vigilance. Particulate matters can affect the heart and lungs, especially in people who already have chronic heart or lung disease (e.g., asthma). $PM_{2.5}$ can cause decreased lung function, increased respiratory symptoms and heart attacks. PM_{10} can cause respiratory impairment and aggravate existing respiratory and cardiovascular disease. Short term exposure to particulate matters may also cause irritation of the eyes, nose and throat in healthy individuals [W-101].

In 2010, the Health Effects Institute published their authoritative report titled "Traffic-related air pollution: a critical review of the literature on emissions, exposure, and health effects". This report has been used as the basis of WHO Technical Report on Review of evidence on health aspects of air pollution 2013 [R-87]. In this WHO Technical Report, Roorda-Knape et al. (1998), Hitchins et al. (2000), Zhu et al. (2002), and Gilbert et al. (2003) reported a significant decrease of particulates and gases within 150-200 m of a road. However, on the downwind side of a highway, concentrations do not generally reach background levels until at least 300 m –500 m, though Zhu et al. (2002) found a 60% to 80% decrease of CO from roadside concentrations within 100 m. In some studies, this was extended to up to 1500 m for NO_2 (Gilbert et al., 2003; Jerrett et al., 2007). At the moment, the vehicles are using low sulphur content fuel, hence the decrease of SO_2 with distance is not discussed.

The potential source of operational air quality impacts would be due to the vehicular emissions from the high traffic volume along the existing roads. Hence, locally the traffic within and in the vicinity of the Project Site is likely to increase. It should also be noted that currently there is a significant traffic volume along the Woodlands Road. Traffic near worksites is not likely to increase as only intermittent traffic for maintenance staff will be observed. The exact numbers in terms of increase /change in volume of traffic to and from the worksites were not available. Without any mitigation measures in place, the Likelihood of occurrence of impacts during the operational phase is classified as Regular.

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

As discussed in Section 9.4.2, the Sensitivity of the receptors was classified to be Priority 1. Thus, as per Table 6-7, the Impact Consequence was calculated to be Very Low. Based on the impact significance matrix in Table 9-8, the Impact Significance was predicted to be Minor (refer to Table 9-24). No mitigation measures are required during operational phase.

Table 9-24 Impacts of air quality from vehicular traffic – operational phase

Impact Intensity	Sensitivity of the Area	Overall Consequence	Likelihood	Impact Significance
Negligible	Priority 1	Very Low	Regular	**Minor**
Negligible	Priority 3	Imperceptible	Regular	**Minor**

9.8 Recommended Mitigation Measures

9.8.1 Construction Phase

Based on the assessment in Section 9.7.1, the Impact Significance was determined to be ranging from Moderate to Major. The range of dust mitigation measures to be implemented at the construction sites are outlined in Table 9-25. Upon the implementation of mitigation measures, the residual Impact Significance was determined to be **Minor**. This will be detailed in Section 9.9.1.

Table 9-25 Air quality mitigation measures (construction phase)

Mitigation Measures	Docking Shaft Worksite	Intermediate Station Worksite	Interchange Station Worksite	Retrieval Shaft Worksite	Potential Future Infrastructure Worksite
GENERAL MITIGATION MEASURES TO BE IMPLEMENTED THROUGH OUT CONSTRUCTION PERIOD					
Communications					
Develop and implement a stakeholder communications plan that includes community engagement before work commences on site.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Display the name and contact details of person(s) accountable for air quality and dust issues on the site boundary. This may be the environment manager/engineer or the site manager.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Develop and implement an Air Pollution Control Plan (APCP) (see paragraph below for APCP details).	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Site Management					
Record all dust and air quality complaints, identify cause(s), take appropriate measures to reduce emissions in a timely manner, and record the measures taken.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Make the complaints log available to the local authority when asked.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Record any exceptional incidents that cause dust and/or air emissions, either on-site or off- site, and the action taken to resolve the situation in the log book.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Hold liaison meetings with other high-risk construction sites within 500 m of the site boundary, if any, to ensure plans are co-ordinated and dust and particulate matter emissions are minimised.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Monitoring					
Undertake regular (daily frequency recommended) on-site and off-site inspections and record results. The log should be made available to the NEA or other Government Agencies if required. Inspections should include regular dust soiling checks of surfaces such as street furniture,	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory

Mitigation Measures	Docking Shaft Worksite	Intermediate Station Worksite	Interchange Station Worksite	Retrieval Shaft Worksite	Potential Future Infrastructure Worksite
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.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Increase the frequency of site inspections during prolonged dry or windy conditions.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Conduct monitoring for PM_{10} and $PM_{2.5}$ at suitable locations (refer to Section 14.8.1)	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Preparing and maintaining the site					
Plan site layout so that machinery and dust causing activities are located away from receptors, where possible.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Erect hoarding around dusty activities and at the site boundary wherever possible. Boundary screens should be at least as high as any stockpiles or dust emission sources on site.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Fully enclose specific activities where there is a known high potential for dust production and the site will be active for an extensive period of time.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Keep site fencing, barriers, and scaffolding clean by cleaning regularly using wet methods (dry methods may give rise to fugitive dust).	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Remove materials that have the potential to produce dust from site as soon as possible, unless being re-used on site. If they are being re-used on-site, stockpiled material should be covered, seeded, fenced or enclosed to prevent fugitive dust formation.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Operating vehicle/machinery and sustainable travel					
Ensure all vehicles and engine powered equipment comply with the legislative requirements of Singapore.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory

Mitigation Measures	**Docking Shaft Worksite**	**Intermediate Station Worksite**	**Interchange Station Worksite**	**Retrieval Shaft Worksite**	**Potential Future Infrastructure Worksite**
Ensure all vehicles and equipment switch off their engines when stationary – i.e., no idling vehicles or engines. Clear signs should be erected at site entrance to inform all visitors.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Where practicable, avoid the use of diesel- or petrol-powered generators and use mains electricity or battery powered equipment.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Impose and signpost a maximum-speed-limit of 25 km/hr on paved or surfaced haul roads and 15 km/hr on unpaved haul roads and work areas.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Produce a Construction Logistics Plan to manage the sustainable delivery of goods and materials.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
<u>Construction Operations</u>					
Only use cutting, grinding or sawing equipment fitted with, or in conjunction with, suitable dust suppression techniques such as water sprays or local extraction e.g., local exhaust ventilation system.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Ensure an adequate water supply on the site for effective dust/particulate matter suppression/mitigation, using non-potable water where possible and appropriate.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Use enclosed chutes and conveyors and covered skips wherever possible.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Minimise drop heights from conveyors, loading shovels, hoppers, and other loading or handling equipment and use fine water sprays on such equipment wherever appropriate.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
A stringent “Clean as you go” Policy should be implemented on site to ensure no loose dry material is left exposed when not in use. Equipment should be readily available on site to clean any dry spillages, and cleaning should be conducted as soon as reasonably practicable after the event using wet cleaning methods.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
<u>Waste Management</u>					

Mitigation Measures	**Docking Shaft Worksite**	**Intermediate Station Worksite**	**Interchange Station Worksite**	**Retrieval Shaft Worksite**	**Potential Future Infrastructure Worksite**
Avoid burning of waste or other materials.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Where possible, horticultural waste should be upcycled as wood material for products. As much as possible, horticultural waste should be transported offsite by licensed waste management contractors to horticultural waste recycling facilities where the wood waste can be grinded into wood chips for horticultural reuse (i.e., compost or mulch).	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
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).	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
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.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Avoid explosive blasting, using appropriate manual or mechanical alternatives.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Bag and remove any biological debris or damp down such material before demolition.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
MITIGATION MEASURES FOR EARTHWORKS					
Closed turfing to the exposed areas where possible and maintain proper storage of soil stockpiles to stabilise surfaces as soon as practicable. When a particular work is finished in an area, the soil will need to be reinstated upon completion, before moving on to different areas. This will reduce dust emission. In the air assessment it refers to reinstatement as a regrown area, it does not mean replanting same	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory

Mitigation Measures	**Docking Shaft Worksite**	**Intermediate Station Worksite**	**Interchange Station Worksite**	**Retrieval Shaft Worksite**	**Potential Future Infrastructure Worksite**
trees. It only refers to vegetation plantation which prevents erosion of soil to form dust.					
Use Hessian, mulches or soil tackifiers where it is not possible to re-vegetate or cover with topsoil, as soon as practicable. Soil erosion blankets may also be used as an alternative.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Only remove the cover in intended working areas and not all at once.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
MITIGATION MEASURES FOR CONSTRUCTION					
Avoid scabbling (roughening of concrete surfaces) if possible.	-	Recommended	Recommended	-	Recommended
Sand and aggregates will be delivered in a dampened stage and will be re-wetted before being dumped into storage bunker.	-	Recommended	Recommended	-	-
Drop heights at transfer points will be minimised to lessen dust generation	-	Recommended	Recommended	-	-
Special covered area will be provided for loading and unloading process	-	Recommended	Recommended	-	-
Water sprays or sprinklers will be employed at conveyor transfer points	-	Recommended	Recommended	-	-
Ensure sand and other aggregates are stored in bunded areas and are not allowed to dry out, unless this is required for a particular process, in which case ensure that appropriate additional control measures are in place.	-	Mandatory	Mandatory	-	Mandatory
Ensure bulk cement and other fine powder materials are delivered in enclosed tankers and stored in silos with suitable emission control systems to prevent escape of material and overfilling during delivery.	-	Recommended	Recommended	-	Recommended
For smaller supplies of fine power materials ensure bags are sealed after use and stored appropriately to prevent dust.	-	Recommended	Recommended	-	Recommended
Vent will be provided with efficient fixed filter bags to comply with the dust emissions criteria.	-	Mandatory	Mandatory	-	-
Silos will not be filled up with cement more than 90% of its loading capacity, to avoid overfilling,	-	Recommended	Recommended	-	-

Mitigation Measures	**Docking Shaft Worksite**	**Intermediate Station Worksite**	**Interchange Station Worksite**	**Retrieval Shaft Worksite**	**Potential Future Infrastructure Worksite**
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.	-	Mandatory	Mandatory	-	-
MITIGATION MEASURES FOR TRACKOUT					
Use water-assisted dust sweeper(s) on the access and affected local roads, to remove, as necessary, any material tracked out of the site. This may require the sweeper being continuously in use.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Avoid dry sweeping of large areas.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Ensure vehicles entering and leaving sites are covered to prevent escape of materials during transport.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Inspect on-site haul routes for integrity and instigate necessary repairs to the surface as soon as reasonably practicable.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Record all inspections of haul routes and any subsequent action in a site log book.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Install hard surfaced haul routes, which are regularly damped down with fixed or mobile sprinkler systems, or mobile water bowsers and regularly cleaned.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Implement a wheel washing system (with rumble grids to dislodge accumulated dust and mud prior to leaving the site where reasonably practicable).	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Ensure there is an adequate area of hard surfaced road between the wheel wash facility and the site exit, wherever site size and layout permits.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Site access gates to be located at least 10 m from receptors where possible.	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory

The APCP should include the following information as a minimum:

- Summary of all work to be carried out including breakdown of phases and individual activities that may give rise to fugitive dust formation;
- Project title, project location and area, description of the site layout and locations of areas where dust is most likely to be generated such as haulage routes, excavation areas, etc. This description should also include the location of the water supply or chemical suppressants for applying to the dust generating areas on site;
- List of each dust generating activity, the likely schedule for each activity and the dust control measures to be implemented and frequency for their implementation. The level of detail will depend on the overall Consequence classification identified in this report and should include as a minimum the mitigation measures listed as mandatory in this document;
- Summary of the air monitoring to be undertaken including monitoring location and schedule. The air monitoring results should be recorded, and trends observed to determine the efficacy of dust control measures over the different construction stages;
- Details and procedures on using the site logbook which is used to record information on incidents such as dust episodes, the sources identified, and the action taken and its efficacy. Any complaints should also be recorded within the logbook along with the subsequent mitigation implemented and time to close out the complaint. The logbook should also be used to keep track of the daily dust control measures implemented such as wheel washing, site watering, site inspections etc.;
- Details of the Superintending Officer (SO) should be included in this plan for managing dust management at the site. The responsibilities of the SO are listed in Section 14.4; and
- The air pollution control plan should be reviewed at regular intervals during the construction phase to ensure the effectiveness of the procedures in place and to maintain the goal of minimisation of dust and emissions through the use of best practice and procedures.

9.8.2 Operational Phase

As discussed in Section 9.7.2, the potential impact significance due to increased traffic is considered to be **Minor**. No mitigation measures are required during operational phase.

9.9 Residual Impacts

9.9.1 Construction Phase

Residual Impact Assessment assumes that the mitigation measures within Section 9.8.1 are implemented within the construction footprint.

9.9.1.1 Impact Assessment on Dust Emissions from Demolition, Earthworks, Construction and Trackout

The Likelihood of occurrence of a significant adverse impact would be classified as Rare, subject to relevant mitigation measures identified being implemented. This Likelihood is combined with Impact Consequence, resulting in **Minor** Impact Significance for the construction footprint as listed in Table 9-26 to Table 9-29 below.

Table 9-26 Impacts of dust risk assessment (demolition)

Key Parameter - Demolition					Impact Assessment						
Construction Worksite	Total Building Volume (m^3)	Construction Material	Height of Demolition Activities (m)	Impact Intensity	Sensitivity of the Area		Overall Consequence / Dust Risk		Likelihood Ecological Receptor	Impact Significance	
					Ecological Receptor	Human Receptor	Ecological Receptor	Human Receptor		Human Receptor	Ecological Receptor
Overall	>50,000	Potentially dusty (e.g., concrete)	10-20	High	Priority 2	Priority 1	Medium	High	Rare	**Minor**	**Minor**

Table 9-27 Impacts of dust risk assessment (earthworks)

Construction Worksite	Key Parameter - Earthworks				Impact Assessment						
	Total Site Area (m^2)	No. of Vehicles Moving Within the Site	Total Material Moved (tonnes)	Impact Intensity	Sensitivity of the Area		Overall Consequence / Dust Risk		Likelihood	Impact Significance	
					Ecological Receptor	Human Receptor	Ecological Receptor	Human Receptor		Ecological Receptor	Human Receptor
Docking Shaft	>10,000	5-10	20,000-100,000	High	Priority 2	Priority 1	Medium	High	Rare	**Minor**	**Minor**
Intermediate Station	>10,000	5-10	>100,000	High	Priority 1	Priority 1	High	High	Rare	**Minor**	**Minor**
Interchange Station	>10,000	5-10	>100,000	High	-	Priority 1	-	High	Rare	**-**	**Minor**
Retrieval Shaft	>10,000	5-10	20,000-100,000	High	-	Priority 1	-	High	Rare	**-**	**Minor**
Potential Future Infrastructure	>10,000	5-10	20,000-100,000	High	Priority 1	Priority 1	High	High	Rare	**Minor**	**Minor**

Table 9-28 Impacts of dust risk assessment (construction)

Construction Worksite	Key Parameter - Construction			Impact Assessment							
	Total Building Volume (m^3)	Construction Material	No. of On-Site Concrete Batching Plant	Impact Intensity	Sensitivity of the Area		Overall Consequence / Dust Risk		Likelihood	Impact Significance	
					Ecological Receptor	Human Receptor	Ecological Receptor	Human Receptor		Ecological Receptor	Human Receptor
Intermediate Station	>100,000	Potentially dusty (e.g., concrete)	1	High	Priority 1	Priority 1	High	High	Rare	**Minor**	**Minor**
Interchange Station	>100,000	Potentially dusty (e.g., concrete)	1	High	Priority 1	Priority 2	High	Medium	Rare	**Minor**	**Minor**
Potential Future Infrastructure	25,000-100,000	Potentially dusty (e.g., concrete)	0	Medium	Priority 1	Priority 1	Medium	Medium	Rare	**Minor**	**Minor**

Table 9-29 Impacts of dust risk assessment (trackout)

Construction Worksite	Key Parameter - Trackout			Impact Assessment							
	No. of Outward Trucks Movement Per Day	Road surface material	Unpaved Road Length (m)	Impact Intensity	Sensitivity of the Area		Overall Consequence / Dust Risk		Likelihood	Impact Significance	
					Ecological Receptor	Human Receptor	Ecological Receptor	Human Receptor		Ecological Receptor	Human Receptor
Docking Shaft	10-50	Moderately Dusty	<100	Medium	Priority 2	Priority 1	Low	Medium	Rare	**Minor**	**Minor**
Intermediate Station	>50	Moderately Dusty	<100	High	Priority 2	Priority 2	Medium	Medium	Rare	**Minor**	**Minor**
Interchange Station	>50	Moderately Dusty	<100	High	-	Priority 1	-	High	Rare	**-**	**Minor**
Retrieval Shaft	10-50	Moderately Dusty	<100	Medium	-	Priority 1	-	Medium	Rare	**-**	**Minor**

Construction Worksite	Key Parameter - Trackout				Impact Assessment						
	No. of Outward Trucks Movement Per Day	Road surface material	Unpaved Road Length (m)	Impact Intensity	Sensitivity of the Area		Overall Consequence / Dust Risk		Likelihood	Impact Significance	
					Ecological Receptor	Human Receptor	Ecological Receptor	Human Receptor		Ecological Receptor	Human Receptor
Potential Future Infrastructure	10-50	Moderately Dusty	<100	Medium	Priority 1	Priority 1	Medium	Medium	Rare	**Minor**	**Minor**

9.9.1.2 Impact Assessment on Gaseous Emissions from Construction Equipment, Vehicle and Off-Road Diesel Exhaust

With the implementation of mitigation measures outlined in Table 9-25, such as ensure all vehicles and engine powered equipment comply with the legislative requirements, switch off vehicles and equipment engines when stationary, avoid the use of diesel- or petrol-powered generators among many others, the Likelihood of the impact is expected to reduce from **Regular** to **Rare**, resulting in **Minor** Impact Significance after consideration of the **Low** Impact Consequence as evaluated in Section 9.7.1.2.

9.9.2 Operational Phase

As discussed in Section 9.7.2, the potential impact significance due to increased traffic is considered to be **Minor**, hence not requiring further mitigation measures. No residual impact assessment is required for operational phase.

9.10 Cumulative Impacts from Other Major Concurrent Development

It is known that construction activities are planned to occur in the vicinity of the Project as highlighted in Section 3.5.2. Hence, cumulative impacts from other relevant major concurrent development in the vicinity of the Project have been assessed and considered.

9.10.1 Construction Phase

There are two (2) nearby concurrent Projects such as HDB CCK N1 construction and JTC Woodlands Road realignment.

9.10.1.1 HDB CCK N1 Construction

The timeline overlap is considered minimal as by the time the Project commences work, HDB CCK N1 would already be at tail end of its construction period while the Project's docking shaft would have only started its commencement. Hence, increase in cumulative air quality impact in the vicinity of Docking Shaft Worksite is expected to be insignificant.

9.10.1.2 JTC Woodlands Road realignment

Due to the presence of concurrent construction site, the construction footprint in this area is expected to be larger. More vehicles moving within the area, increasing potential dust emission within the site and on public roads leading and leaving the site. The construction may increase cumulative air quality impact in the vicinity of the Project.

9.10.2 Operational Phase

No cumulative impacts were considered during operational phase.

9.11 Summary of Key Findings

Air quality impacts from the construction and operation of the proposed Project were assessed on air sensitive receptors (ASRs) in the vicinity of the Project site. Primary baseline air quality monitoring was collected at five (5) representative monitoring locations for one (1) week each ranging from 28 February – 24 March 2022 across the Study Area. PM_{10} and $PM_{2.5}$ were monitored at all monitoring locations and additionally NO_2 was also monitored for areas that is potentially impacted during operational phase (i.e., A01, A02 and A05). Based on the monitored results, all pollutants' ambient air quality targets were met throughout the monitoring duration at all 5 monitoring locations. The pollutants recorded is generally affected by different sources depending on the monitoring location as detailed in Section 9.2.2.2.

Secondary weather data of the past 5 years shows an average of approximately 7.6 mm, 6.3 mm and 7.4 mm of daily rain was observed from Bukit Panjang, Admiralty and Tengah monitoring stations, respectively. With regards to mean temperature and mean wind speed, the temperature and wind speed within Study Area is expected to be relatively constant with average 27.7°C and 27.7°C mean temperature as observed from Admiralty and Tengah monitoring stations respectively, and 11.2 km/h and 10.2 km/h mean wind speed as observed from Admiralty and Tengah monitoring stations respectively.

Potential impacts to the neighbouring sensitive receptors during construction phase mainly include emissions from the heavy vehicular exhaust and dust emitted from the demolition, earthworks, construction and trackout activities. During the operational phase, emissions from vehicle exhaust due to increased traffic in the vicinity of the proposed development is identified as the predominant air emission source.

Air quality impact assessment for construction phase were undertaken in accordance with the UK IAQM Guidance on the Assessment of Dust from Demolition and Construction. Pursuant to which, 50 m and 350 m Study Area for ecological and human receptors respectively were considered for demolition, earthworks, construction and trackout activities. Dust generated during construction works can have adverse effects upon vegetation restricting photosynthesis, respiration and transpiration. Furthermore, it can lead to phytotoxic gaseous pollutants penetrating the plants. The overall effect can be a decline in plant productivity. For human receptors, the dust and gaseous emissions might cause respiratory problems and diseases in human health.

The results of the assessment show that unmitigated impacts are classified as Moderate to Major and have the potential to affect the receptors near the construction footprint unless mitigation measures are put in place (see Section 9.7.1 for assessment details). This is largely because of the large extent of the construction worksite located very close to the neighbouring sensitive receptors. This report pulls together mitigation measures that can be implemented by the contractor as administrative or management measures, sourcing from best practice measures internationally, which are detailed Section 9.8.1, which when applied successfully, the significance of impacts is anticipated to be reduced to **Minor** (see Section 9.9.1 for details). The key control and mitigation measures include but not limited to development and stringent implementation of air pollution control plan, dust control measures on site, site hoarding, planning of dust causing activities-location and timing, reinstating land upon completion of works amongst several others.

For air quality impact assessment during operational phase, it is assumed that all new vehicles to meet their Euro emission standard. The buffer from some green areas which will not be disturbed as part of the Project, will also help in terms of providing cleaner air from the impact from the vehicles. At a much higher level, trains are meant to replace substantial vehicles from roads, therefore in that scheme, the Project may have a positive effect on road traffic. However, immediate localised road traffic to and from the stations may see minor increase. In this aspect with the information assessed at this stage, the air quality impact contributed from the proposed development is anticipated to be **Minor** during the operational phase. No mitigation measures are required during operational phase as no significant air quality impact is expected from Project operation.

Cumulative impacts from other major concurrent development in the vicinity of each construction worksite are presented and detailed in Section 9.10. With regards to HDB CCK N1, the timeline overlap is considered minimal as by the time the Project commences work, HDB CCK N1 would already be at tail end of its construction period while the Project's docking shaft would have only started its commencement. Hence, increase in cumulative air quality impact in the vicinity of Docking Shaft Worksite is expected to be insignificant. While for JTC Woodlands Road realignment, due to the presence of concurrent construction site, the construction footprint in this area is expected to be larger. More vehicles moving within the area, increasing potential dust emission within the site and on public roads leading and leaving the site. The construction may increase cumulative air quality impact in the vicinity of the Project.

Table 9-30 Summary of Air Quality Impact Assessment

Sensitive Receptors and Phases	Impact Significance with minimum controls	Residual Impact Significance with mitigation measures (if required)
Construction Phase		
Ecologically Sensitive Receptors	Moderate to Major	**Minor**
Human Sensitive Receptors	Moderate to Major	**Minor**
Operational Phase		
Ecologically Sensitive Receptors	Minor	**Minor[1]**
Human Sensitive Receptors	Minor	**Minor[1]**
Note: [1] The initial impact assessment with minimum controls was considered insignificant (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.		