KUR-World

Appendix 12

Air Quality Impact Assessment

Environmental Impact Statement

APPENDIX_ASK 2017a

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KUR-World Integrated Eco Resort

Barnwell Road, Myola, Queensland

Air Quality Impact Assessment

Report: 8852R02V02

Prepared for:

Reever and Ocean Pty Ltd

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ACOUSTICS & AIR QUALITY

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1. Introduction

ASK Consulting Engineers Pty Ltd (ASK) has been commissioned by Natural Resource Assessments (NRA) to provide air quality consultancy services for the KUR-World Integrated Eco Resort development proposed to be located at Barnwell Road, Myola, Queensland. The development is to include residential, educational, sporting, leisure, accommodation, medical and retail uses.

This report presents an assessment of the air quality impacts associated with the existing uses as well as the development. It is to form an appendix to the Environmental Impact Statement (EIS) being submitted to the Queensland Coordinator-General for consideration by stakeholders such as Mareeba Shire Council and the Department of Environment and Heritage Protection (EHP).

The purpose of this report is to address the air quality requirements of the Terms of Reference as listed in **Table 1.1**.

Table 1.1 Air Quality Requirements of the Terms of Reference

	Terms of Reference	**Relevant Sections of Report**
12.3	Fully describe the characteristics of any contaminants or materials released that may be released as a result of the construction or operations of the proposal, including point source and fugitive emissions. Emissions (point source and fugitive) during construction, commissioning, operations and upset conditions should be described.	**Sections 3.2** and **3.3**
12.4	Predict the impacts of the releases from the activity on environmental values of the receiving environment using recognised quality assured methods. The description of impacts should take into consideration the assimilative capacity of the receiving environment and the practices and procedures that would be used to avoid or minimise impacts. The impact prediction must:	**Sections 4**, **9** and **10**
12.4(a)	Address residual impacts on the environmental values (including appropriate indicators and air quality objectives) of the air receiving environment, with reference to sensitive receptors (for example, the locations of existing residences, places of work, schools, agricultural or ecologically significant areas/species). This should include all relevant values potentially impacted by the activity, under the EP Act, EP Regulation and Environmental Protection (Air) Policy 2008 (EPP (Air)).	**Section 9**
12.4(b)	Address the cumulative impact of the release with other known releases of contaminants, materials or wastes associated with existing development and possible future development (as described by approved plans and existing project approvals)	**Section 9**
12.4(c)	Quantify the human health risk and amenity impacts associated with emissions from the project for all contaminants whether or not they are covered by the National Environmental Protection (Ambient Air Quality) Measure or the EPP (Air).	**Section 10.1**
12.5	Describe the proposed mitigation measures and how the proposed activity will be consistent with best practice environmental management. Where a government plan is relevant to the activity or site where the activity is proposed, describe the activity's consistency with that plan.	**Section 10.2**
12.6	Describe how the achievement of the objectives would be monitored, audited and reported, and how corrective actions would be managed.	**Section 10.2.3**

To aid in the understanding of the terms in this report a glossary is included in **Appendix A**.

2. Study Area Description

2.1 Overview

The proposed location is on the Atherton Tablelands approximately 3 kilometres to the west of the centre of Kuranda as shown in **Figure 2.1**.

Figure 2.1 Location of KUR-World (Image from Google Earth Pro)

The site is currently occupied by a farmhouse, grazing land and forest. The immediate surrounding land uses follow:

- Residences and a small orchard off Monaro Close and High Chapparal Road are to the north.
- Residences off Barnwell Road, Scrub Street, Kingfisher Road and Myola Road are to the north-east.
- Residences off Warril Drive, Hilltop Close and Punch Close are to the east.
- The Billabong tourist facility is to the south.
- Residences and the Kuranda Pet Resort dog kennels off Boyles Road are to the west.

The zoning of the site is rural. The zoning of surrounding properties is either rural or rural-residential.

2.2 Identification of Existing Sensitive Receptors

Sensitive land uses are defined in the State Planning Policy (Department of State Development, 2014) as caretakers accommodation, child care centre, community care centre, community residence, detention facility, dual occupancy, dwelling house, dwelling unit, educational establishment, health care services, hospital, hotel, multiple dwelling, non-resident workforce accommodation, relocatable home park, residential care facility, resort complex, retirement facility, rooming accommodation, rural workers accommodation, short-term accommodation or tourist park.

The nearest sensitive receptors are summarised in **Table 2.1** including their northing and easting locations and are shown in **Figure 2.2**. The closest receptors to the proposed development are approximately 50 metres from the proposed Queenslander lots at the farm-stay accommodation. The receptors listed in **Table 2.1** are residences with the exception of 24 (pet resort) and 28 (tourist facility).

The nearest schools to the site are:

- Cairns Rudolph Steiner School 46 Boyles Rd 1 kilometre to the west of the development
- Kuranda District State College 260 Myola Rd more than 1.5 kilometres to the north of the development and off the boundary of **Figure 2.2.**

The rural residential properties around the development site already have a residence on them.

Table 2.1 List of Sensitive Receptors with UTM Coordinates (WGS84 Z55)

ID	Address	Real Property Description	Indicative Distance and Direction from Proposed Developments	Easting (m)	Northing (m)
1	7 Hilltop Close	86/RP746616	300m to the south of the villas	351965	8138646
2	10 Hilltop Close	79/RP746616	"	352033	8138670
3	2 Warril Drive	76/RP742969	100m to the south of the villas	351995	8138883
4	4 Warril Drive	75/RP742969	"	352043	8138831
5	6 Warril Drive	74/RP742969	"	352102	8138776
6	8 Warril Drive	73/RP742969	"	352147	8138829
7	10 Warril Drive	72/RP742969	"	352184	8138865
8	1 Warril Drive	77/RP742969	"	352301	8138852
9	10 Punch Close	44/RP737515	300m to the east of the villas 5 star resort	352481	8139138
10	8 Punch Close	43/RP737515	"	352512	8139179
11	6 Punch Close	42/RP737515	"	352524	8139218
12	4 Punch Close	41/RP737515	"	352549	8139245
13	Punch Close	40/RP737515	"	352578	8139273
14	77 Barnwell Road	16/N157227	200m to the east of the equestrian centre	351384	8140301
15	78 Barnwell Road	1/RP735374	100m to the north-east of the farm accommodation	351275	8140479
16	62 Barnwell Road	2/SP218094	300m to the north of the farm accommodation	351272	8140708
17	2 Leilas Way	2/RP748612	300m to the north-east of the farm accommodation	351438	8140530
18	78 Monaro Close	8/RP737018	50m to the north of farm accommodation	350979	8140493
19	68 Monaro Close	9/RP737018	"	350920	8140523
20	77 Monaro Close	7/RP737018	"	351055	8140569
21	64 High Chapparal Road	1/RP748876	500m to the north-west of the equestrian centre	350230	8140570
22	76 High Chapparal Road	3/RP748876	"	350351	8140363
23	73 High Chapparal Road	8/RP728075	"	350437	8140516

ID	Address	Real Property Description	Indicative Distance and Direction from Proposed Developments	Easting (m)	Northing (m)
24	131 Boyles Road (Pet Resort)	4/RP749637	300m to the north-west of the villas	349941	8139832
25	165 Boyles Road	3/RP749637	600m to the west of the villas	349640	8139572
26	197 Boyles Road	1/RP866988	“	349449	8139375
27	265 Boyles Road	2/RP734821	700m to the south-west of the villas	349765	8138872
28	186 Mount Haren Road (Billabong tourist facility)	44/RP851441	100m to the south-east of the small education centre	351217	8137600

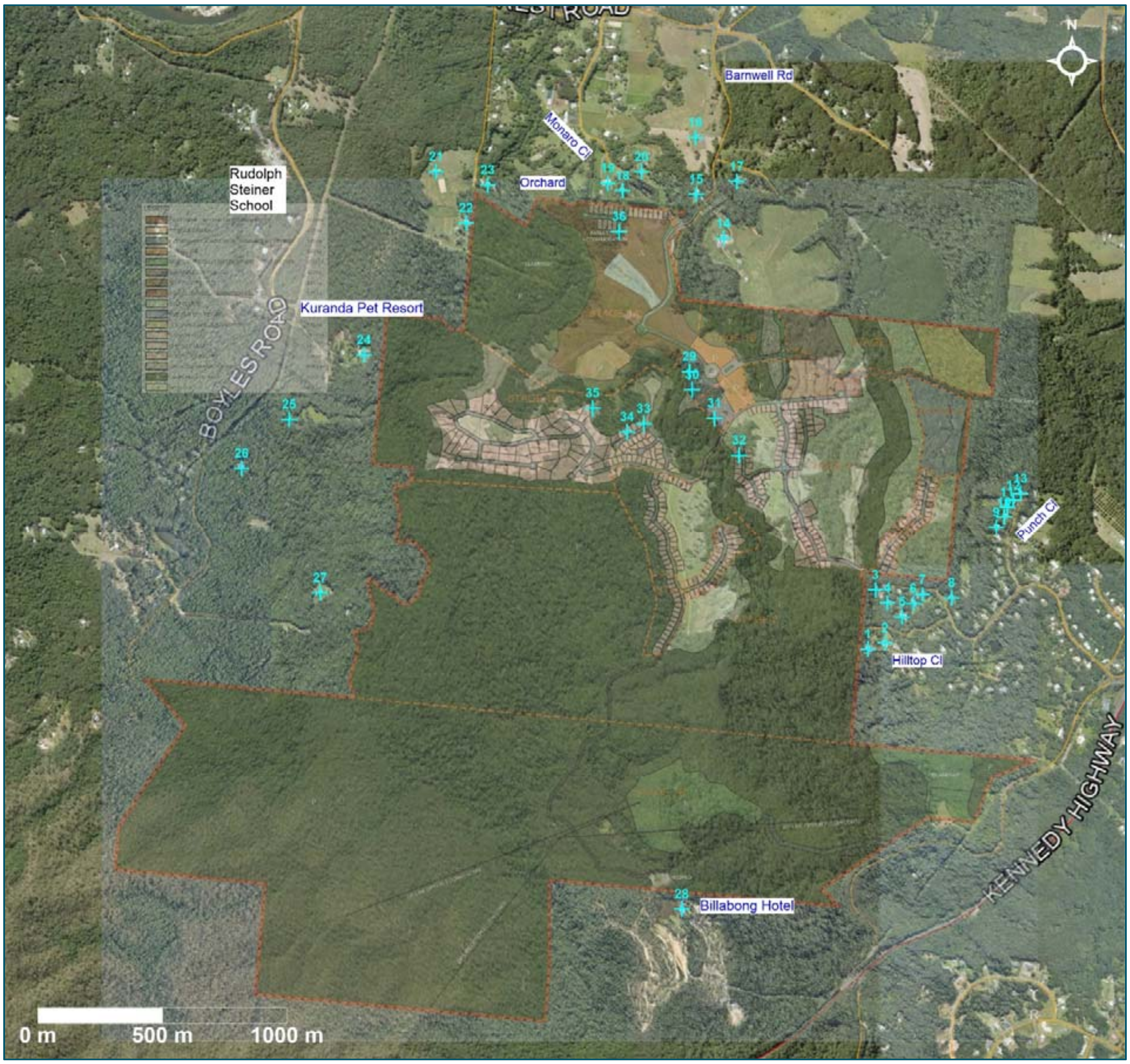

Figure 2.2 Location of Site and Sensitive Receptors (Image from Google Earth Pro)

The receptor locations listed in **Table 2.1** and identified in **Figure 2.2** are existing receptors that have the potential to be impacted by the proposed Project. They were selected based on the presence of a sensitive land use and the distance and direction of the receptor from parts of the proposed development site that may include air emission sources.

2.3 Description of Air Emission Sources in the Vicinity

A survey of potential air emission sources in the surrounding area was conducted on 22nd and 23rd February 2017 and the results are summarised in **Table 2.2**.

Table 2.2 List of Nearby Industrial Activities

Address	Name	Location relative to development	Potential air emissions
56 Monaro Close	A small orchard	Approximately 100m to the north on **Figure 2.2**	Spray drift
45 Myola Rd	Kuranda Landscape Supplies	Further to the east than the boundary of **Figure 2.2** approximately 800m from the development	Dust and odour
47 Myola Rd	Kuranda Raw Materials	Further to the east than the boundary of **Figure 2.2** approximately 800m from the development	Dust and odour
186 Mount Haren Road	Billabong tourist facility	Approximately 100m to the south-east on **Figure 2.2**	Dust associated with recreational activities
131 Boyles Road	Kuranda Pet Resort	Approximately 300m to the west on **Figure 2.2**	Odour
46/RP851443	Quarry on Kennedy Highway opposite Windy Hollow Road	Further to the south than the boundary of **Figure 2.2** approximately 1.5km from the development	Dust and suspended particulates

The landscape supplies, material supplies and quarry are all well over 500 metres from the development site. In addition, this quarry is not shown on key resource area mapping under the State Planning Policy. Thus due to the distance of these sources from the development site and for the quarry to be apparently not considered as a significant source under the State Planning Policy, dust and suspended particulates from these activities are considered very unlikely to impact on the development site.

The closest development area to the orchard is the proposed farm theme park and equestrian centre which are not considered sensitive to the potential spray drift. The proposed farm-stay accommodation is approximately 150 metres south-west of the orchard and is separated from the orchard by forest. Similarly, the Billabong tourist facility located approximately 100 metres from proposed locations for development activities is surrounded with forest. Thus it is considered very unlikely that impacts from spray drift and dust respectively would occur at the sensitive locations proposed for development activities.

The Kuranda Pet Resort is located approximately 300 metres west from the proposed development. The distance of the Kuranda Pet Resort from the proposed development is likely to be adequate to prevent its impacts from reaching the development.

3. Proposed Development

3.1 Master Plan

The proposed development site consists of twelve allotments as described in **Table 3.1** below covering approximately 680 hectares[1] in Barnwell Road, Myola, approximately 22 kilometres directly north-west of Cairns. The site is currently used for cattle grazing. Surrounding properties include large rural residential allotments.

Table 3.1 Lot and Plan Details

Lot and Plan Details	Area (hectares)	Lot and Plan Details	Area (hectares)
Lot 22 on N157227	37.26	Lot 20 on N157423	70.62
Lot 17 on N157227	57.71	Lot 95 on N157452	34.05
Lot 18 on N157227	63.01	Lot 43 on N157359	64.51
Lot 2 on RP703984	48.31	Lot 129 on NR456	65.89
Lot 1 on RP703984	16.19	Lot 131 on N157491	64.75
Lot 19 on N157452	39.60	Lot 290 on N157480	64.75

The proposed development is to include the following:

- The KUR-World educational campus and sporting facility is to include dining facilities, three storey accommodations, sports fields, swimming pool and training hall.
- An equestrian centre and farm theme park will include an arena, stables, accommodation and animal yards. There will be cattle paddocks and yards and horse stables.
- 342 accommodation villas are planned over approximately 34 hectares.
- A village will include plaza, restaurant, bar, amphitheatre, convention centre, market area and boutique retail precinct. A 3-star resort in the village will comprise 270 rooms, restaurant, bar, pool and children's adventure park.
- A medical retreat will include accommodation and facilities for 60 guests and a herbal laboratory.
- A 5-star eco-resort will include 200 two-storey villas, restaurant, pools, and function centre.
- A small education centre in the southern zone will include 14 boarding cabins, kitchens, function spaces and laboratories.
- An adventure park in the southern zone will include a high ropes course, suspended bridges, zip lines and rope ladders.
- Other facilities include a golf course, horse riding and walking trails.

Electricity is to be provided via high voltage extensions along the Kennedy Highway. All refuse and waste will be disposed of at Mareeba and/or Cairns waste transfer facility. An Environmental Management Plan, Operational Plan, and Waste Management Plan will form part of the EIS.

The concept master plan shows the two main zones: the north zone and the south zone as shown in **Figure 3.1**. Most of the facilities will be in the northern zone.

[1] This is the total property area, including proposed access road area.

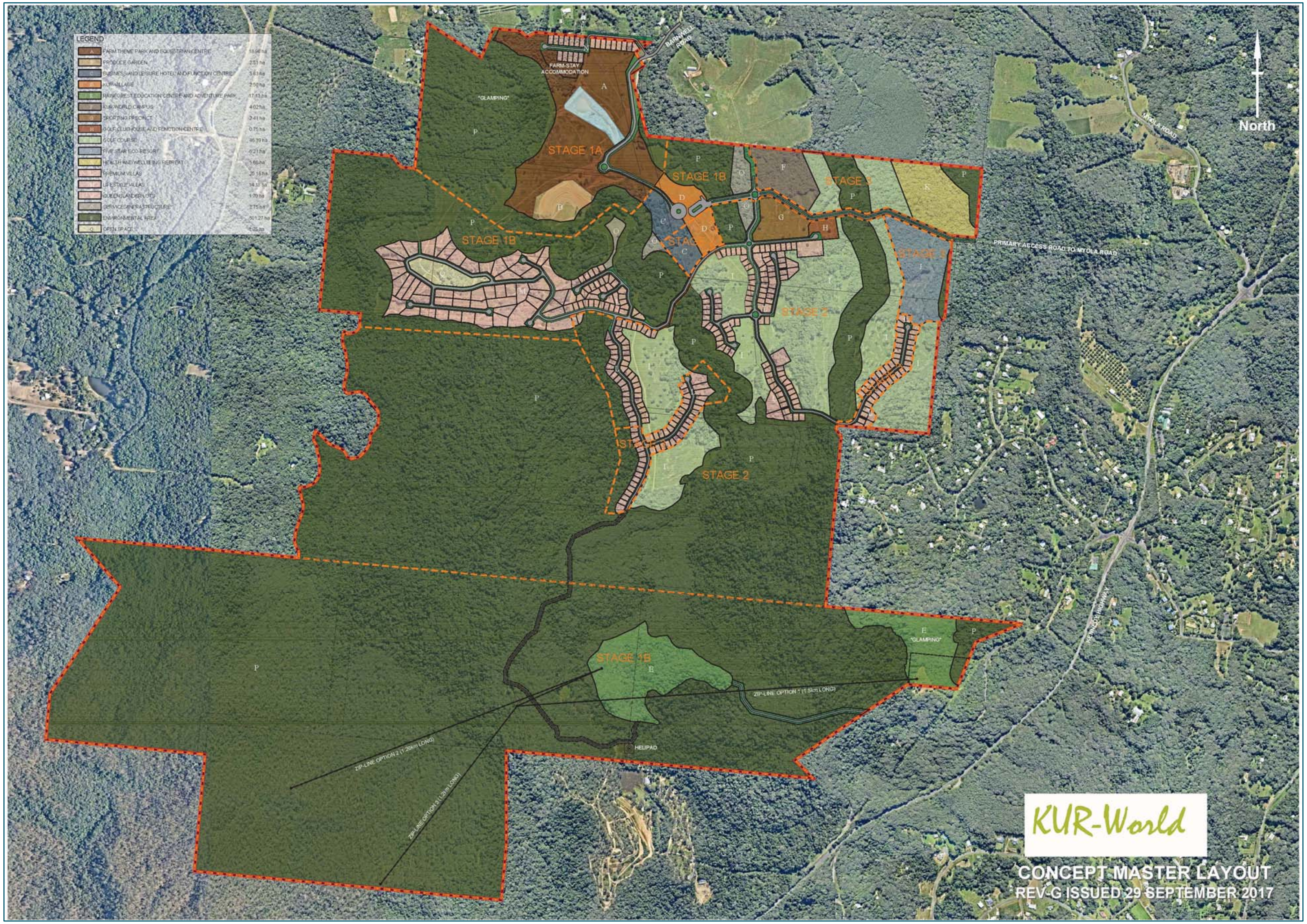

Figure 3.1 KUR World Master Plan

3.2 Construction Activities

3.2.1 On-site Construction Emission Sources

Construction activities onsite will have the potential to generate particulates from construction dust and, to a lesser degree of impact, combustion products from plant exhausts.

Typical plant equipment used for construction include the following:

- Excavators
- Dozers
- Haul trucks
- Loaders
- Cranes
- Graders
- Scrapers

The main emissions from construction activities would be fugitive dust emissions originating from the following sources:

- Excavation
- Filling
- Material handling including loading and unloading of gravel and sand
- Wheel-generated dust from hauling on unsealed road surfaces
- Wind erosion of stockpiles and unsealed roads

Other emissions include combustion by-products from engine exhausts including suspended particulates, NO_X, SO_2, CO and volatile organic compounds (VOCs).

Construction activities in the southern zone will be minimal in comparison to those in the northern zone.

A qualitative assessment of impacts due to construction activities on-site is presented in **Section 4**.

3.2.2 On-site Construction Staging

The current Master Plan (Version G, 29 September 2017) features four sequential development stages over 7.5 years commencing in 2018.

Stage 1A (2018):

- Farm Theme Park and Equestrian Centre (Phase 1)
- Residential Precinct: Queenslander Lots (21 lots)
- Organic Produce Garden
- Services and Infrastructure (Phase 1)
- Environmental Area (Phase 1).

Stage 1B (2019-2020):

- Farm Theme Park and Equestrian Centre (Phase 2)
- Residential Precinct: Lifestyle Villas (56 lots)
- Open Space
- KUR-Village (Phase 1)
- Four Star Business and Leisure Hotel and Function Centre (Phase 1, 60 rooms)
- Residential Precinct: Premium Villas (39 lots)

- Rainforest Education Centre and Adventure Park
- Sevices and Infrastructure (including a sewerage treatment plant, access road from Mount Haren Road to rainforest education centre) (Phase 2)
- Environmental Area (Phase 2).

Stage 2 is planned to start immediately after the completion of Stage 1 and be constructed over a further two year period from 2021-2022. Stage 2 will include:

- KUR-Village (Phase 2)
- Four Star Business and Leisure Hotel and Function Centre (Phase 2, 210 rooms)
- Sporting Precinct
- Golf Club House and Function Centre
- Golf Course
- Residential Precinct: Premium Villas (154 lots and 60 units)
- Services and Infrastructure (Phase 3)
- Environmental Area (Phase 3).

Stage 3 is planned to start immediately after the completion of Stage 2 and be constructed over a one year period in 2023-2024. Stage 3 will include:

- Health and Wellbeing Retreat (60 rooms)
- Residential Precinct: Premium Villas (93 lots)
- Five-Star Eco-Resort (200 rooms)
- KUR-World Campus
- Services and Infrastructure (Phase 4)
- Environmental Area (Phase 4).

3.2.3 Off-site Road Construction

Off-site road construction activities also have the potential to impact sensitive receptors.

KUR-World intends to have three access points to the northern zone and an access to the southern zone (east-west access from the Rainforest Education Centre and Adventure Park) is under consideration. The primary access will be from the east of the site, being constructed from Myola Road along an existing gazetted road reserve (refer **Figure 3.2**). Secondary access will be provided from Barnwell Road in the north of the site (refer **Figure 3.3**). A third emergency access will be provided at Warril Drive in the east/south-east of the site and will be controlled by a gate (refer **Figure 3.4**).

There are two residences adjacent to the primary access road reserve:

- Residence 1 at 11 Myola Road
- Residence 2 at 27 Myola Road.

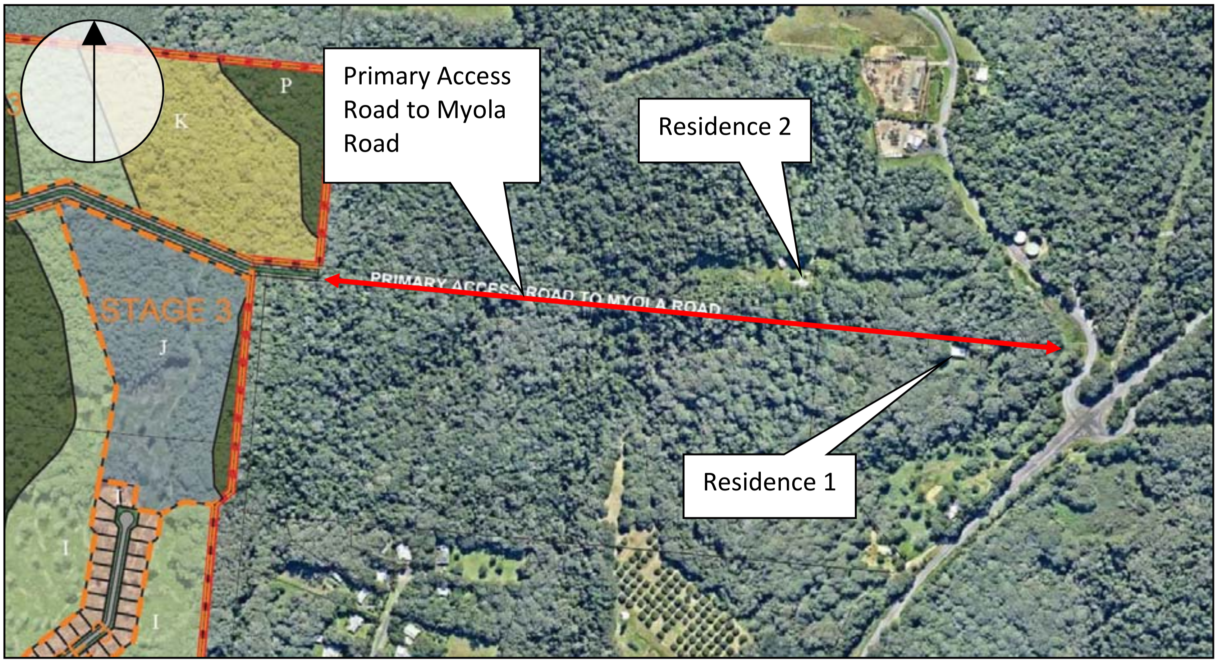

Figure 3.2 Primary Access from Myola Road to North-East

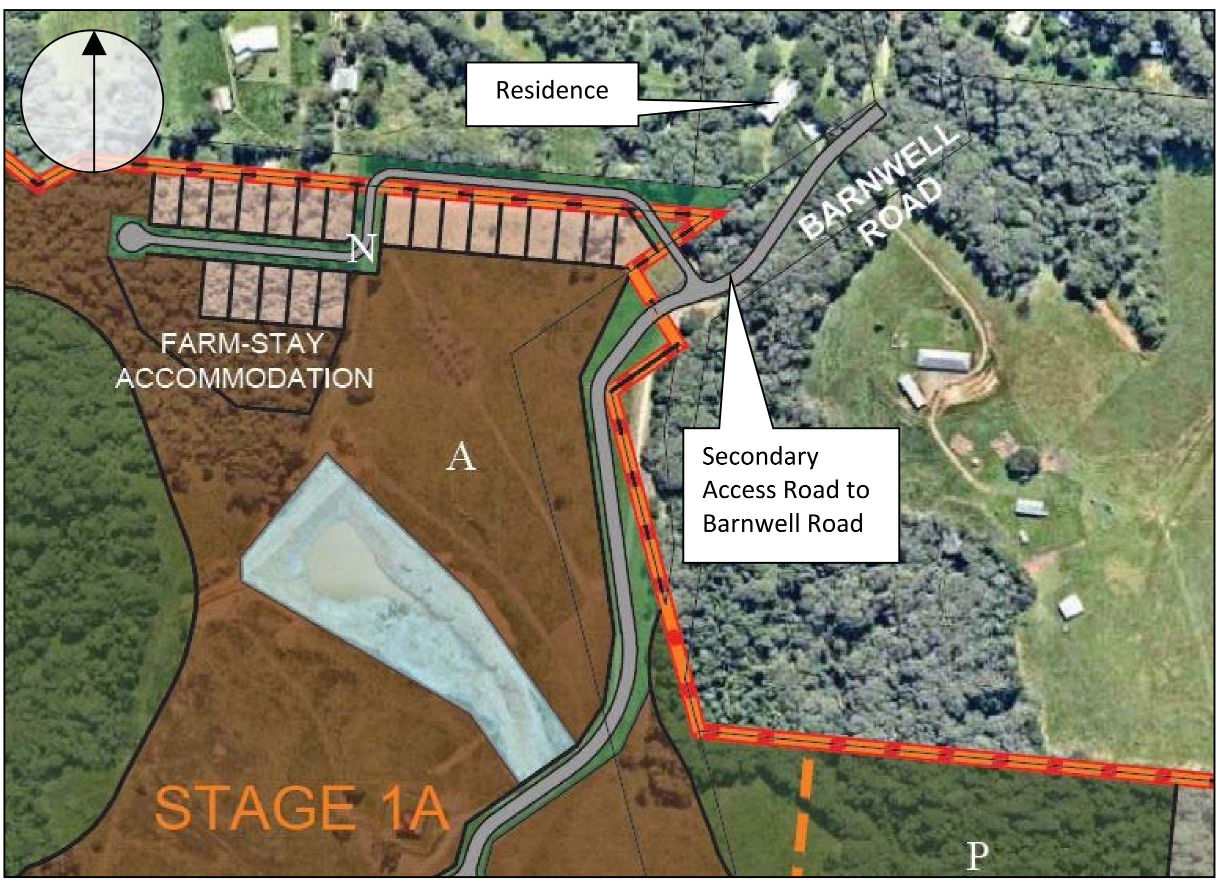

Figure 3.3 Secondary Access from Barnwell Road to North

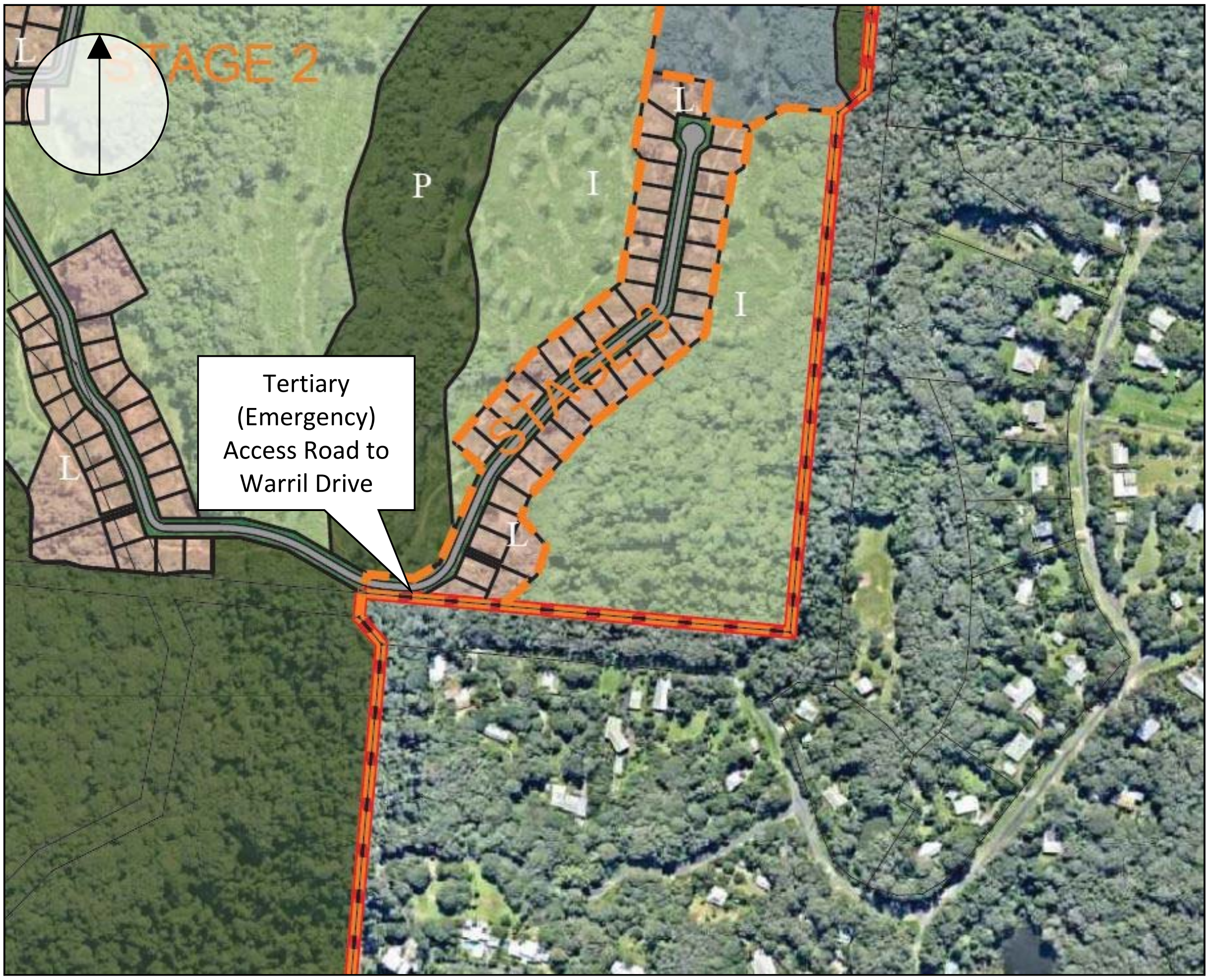

Figure 3.4 Tertiary (Emergency) Access from Warril Drive to East/South-East

There is no current existing road for the primary access and hence this will be constructed as part of the development. The secondary access road is an existing unsealed road. This will be sealed as part of the development. The tertiary access is an existing sealed road. However, the road ends outside the site boundary and hence it will have to be extended by approximately 90 metres to the west to reach the site boundary.

The air quality impacts at nearby sensitive receptors due to the sealing of the secondary access road and the extension of the tertiary access road are likely to be low. The fourth access road to the southern zone will be relatively far away from sensitive receptors and hence air quality impacts due to the construction of this road are not likely. Because of these reasons, the construction activities of these three roads are not assessed further in this report.

The construction activities for the primary access have the most potential to impact on sensitive receptors due to the nature of the activities and the proximity of the residences to the proposed road. Hence, detailed dispersion modelling was undertaken for these activities.

3.3 Operational Emissions

Potential emissions due to the operation of the Project are presented in **Table 3.2**. The emission sources will be located in the northern zone only except for sewage pump stations and a power generator which will also exist in the southern zone.

Table 3.2 Operational Emissions

Emission source	Potential emissions
Sewage treatment plant and sewage pump stations	Odour
Biosolid re-use	Odour
Irrigation of recycled water	Odour
Power generators	Combustion by-products (particulates, NO_X, SO_2, CO etc)
Boilers	Combustion by-products (particulates, NO_X, SO_2, CO etc)
Solid wastes	Odour
Composting	Dust and odour
Cooking exhausts	Odour, Combustion by-products (particulates, NO_X, SO_2, CO etc)
Animal farm and stables	Dust and odour

3.3.1 Sewage Treatment Plant

The estimated wastewater volume that will be generated in the operation of the project will likely exceed the capacity of the Kuranda Wastewater Treatment Plant and reticulation network servicing the Mareeba Shire Council (Arup, 2017). Thus an onsite wastewater treatment plant is proposed to treat the wastewater generated onsite and produce high quality recycled water for non-potable re-use (Arup, 2017).

The operation of an STP in the northern zone is less likely to impact the existing sensitive receptors identified in **Section 2.2** than the proposed sensitive receptors onsite due its relative location. Therefore the proposed sensitive receptors assessed in this study for the operation of an STP are all located on-site as presented in **Table 3.3** and **Figure 3.5**.

Table 3.3 List of Proposed Sensitive Receptors with UTM Coordinates (WGS84 Z55)

ID	Property Description	Approximate Distance and Direction from Proposed Sewage Treatment Plant	Easting (m)	Northing (m)
29	Business and Leisure Hotel	130 m to the east	351248	8139764
30		130 m to the east	351259	8139691
31		250 m to the south-east	351348	8139576
32	Premium Villas	410 to the south-east	351447	8139427
33		140 m to the south-west	351064	8139554
34		200 m to the south-west	350998	8139521
35	Lifestyle Villas	250 m to the south-west	350859	8139618
36	Queenslander Lot (Farm-Stay Accommodation)	620 m to the north	350966	8140327

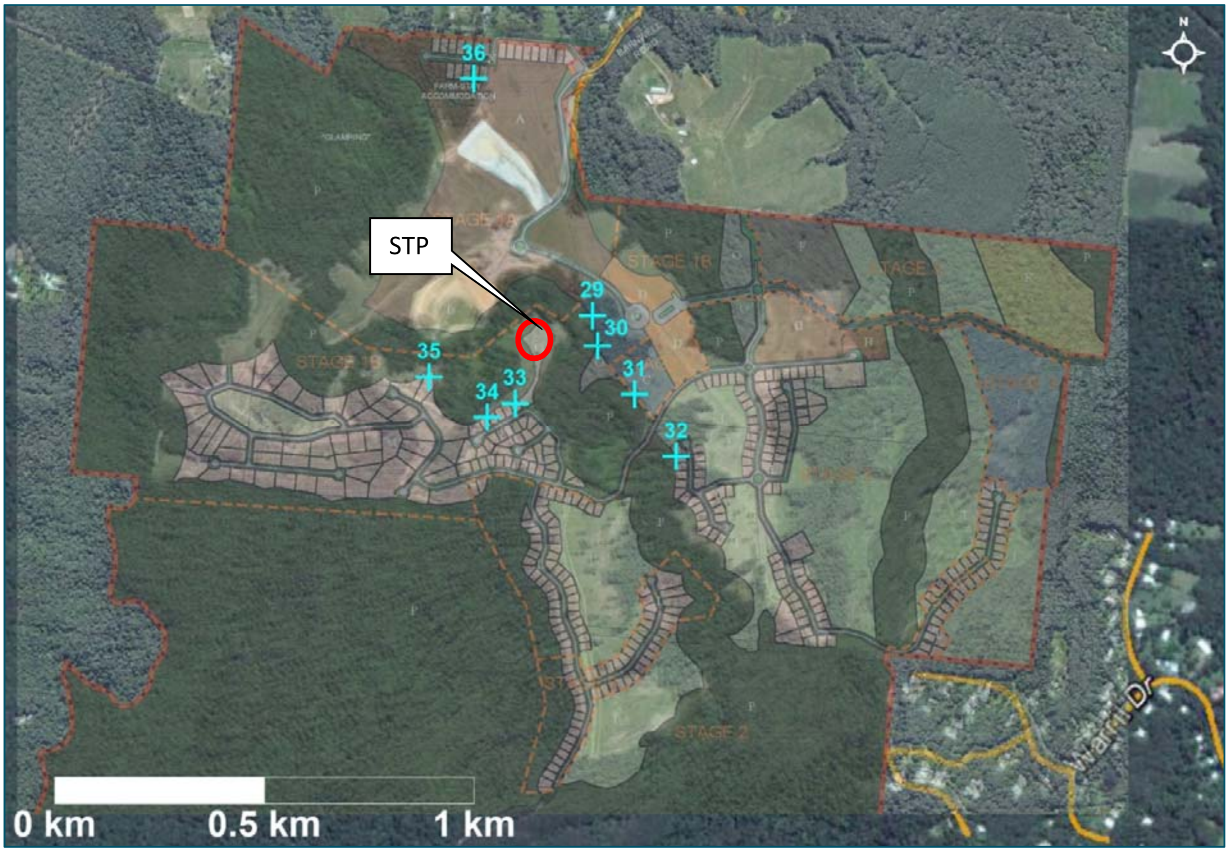

Figure 3.5 Location of Sensitive Receptors Near the Sewage Treatment Plant Site

The receptor locations listed in **Table 3.3** and identified in **Figure 3.5** are proposed receptors that have the potential to be impacted by the proposed STP. They were selected based on the future presence of a sensitive land use and the distance and direction of the proposed receptors from the proposed STP.

The wastewater from the southern zone will be pumped to the STP in the northern zone. The southern zone is a substantially smaller area with low density development and will only consist of recreational activities. The nearest sensitive receptor from southern zone STP is an existing hotel approximately 100 metres to the south-east as shown in **Figure 2.2**.

The current preliminary sewerage layout plan for the northern zone shows 24 sewage pump stations, which may require double this number of vents. This number is large due to the undulating terrain. However consideration is being given to a vacuum sewerage system which would likely only need one vent (at the outlet).

3.3.2 Potential Re-Use of Biosolids By-Product

The biosolids generated from the treatment of wastewater will be taken off-site by an external contractor. Approximately 95% of the biosolids will be applied to off-site land as a fertiliser and the rest will be disposed to landfill.

Odour may be emitted in the storage of the biosolids prior to removal on-site.

3.3.3 Irrigation of Recycled Water

Some of the treated water would be recycled as irrigation water for the golf course. Recommended water quality for the different classes of recycled water is specified in Table 6.2b of the Queensland Water Recycling Guidelines (QLD EPA, 2005) and is presented in **Table 3.4**

Table 3.4 Recommended water quality specifications for recycled water (QLD EPA, 2005)

Class	E. coli (media) cfu/100mL	BOD5 mg/L median	Turbidity NTU 95% ile (max.)	SS, mg/L median	TDS, mg/L or EC, µS/cm medians TDS/EC	pH
A	<10	20	2 (5)	5	1000/1600	6-8.5
B	<100	20	-	30	1000/1600	6-8.5
C	<1,000	20	-	30	1000/1600	6-8.5
D	<10,000	-	-	-	1000/1600	6-8.5

The Queensland Water Recycling Guidelines (QLD EPA, 2005) recommends the following buffer distances from the edge of the spray zone to publicly accessible areas during irrigation:

- 30 metres for Class B recycled water
- 50 metres for Class C recycled water
- 100 metres for Class D recycled water

No buffer distance has been recommended for the spraying of Class A recycled water. The buffer distances are to be amended appropriately to reflect the site-specific risks determined from a risk assessment.

Access by the public to spray-irrigated land should not be allowed until the surfaces have dried (QLD EPA, 2005).

For subsurface drip irrigation with Class B or C recycled water, there need not be controlled access to the irrigated land (QLD EPA, 2005).

The recycled water may emit odour depending on its quality. It is anticipated that the higher class treated water will have minimal potential to emit odour.

3.3.4 Power Generators and Boilers

Boilers that will operate on-site will emit combustion by-products through stacks. However, as these will only be sized to service the Project, it is anticipated these will be small in scale and the emissions will not be likely to cause an impact beyond the immediate vicinity of the exhausts.

The southern end of the resort Stage 1b areas will be powered completely by diesel generators. The anticipated maximum demand is 270 kVA.

Generators will also be used for the Stage 1a areas as back-up/top up to the batteries when solar is not sufficient and for some of the services of the cooking area or theme park equestrian centre. The generator to be used for Stage 1a will have a capacity of 0.13 MW and may be used more than 100 hours per year. After Stage 1b is completed, they will only be used for backup in the event of mains power failure, anticipated to be less than 100 hours per year including testing.

3.3.5 Solid Wastes

The putrescible solid wastes generated and stored on-site will have the potential to decay and cause odour nuisance. General waste and co-mingled recycling bins will be located throughout the operational precinct within the development. These will be internally collected and stored in the central waste and recycling storage facility prior to collection by the waste service provider. The location of the central waste and recycling storage facility is shown in **Figure 3.6**. The central waste and recycling storage facility will include the following:

- Maintenance hub, storage area and charging station for the electric collection vehicles (ECVs) and electric vehicles (EVs) servicing internal collection of general waste and co-mingled recycling
- Storage of extra bins
- A compactor unit to compact the general waste prior to storage
- Roll on roll off (RORO) containers for storage of compacted wastes and recyclables prior to collection
- Ramped access for ECVs to tip wastes and recyclables into the compactor or RORO containers
- Bin washing facilities.

The storage facility will be constructed with materials that will be easily cleaned and prevent the absorption of liquid and odours. The floors will be graded and drained to the sewerage system. A close-fitting and self-closing door or gate operable from within the rooms is recommended to be fitted to all waste and recyclable storage areas. The waste storage rooms, areas and containers will be constructed in a manner to prevent the entry of vermin. A mechanical exhaust ventilation system will be installed for the waste storage rooms exhausting at a rate of 5 $L/s/m^2$, with a minimum rate of 100 L/s.

3.3.6 Composting

Organic green waste from the golf course and resort landscaping or maintenance and organic manure and used bedding material from the equestrian centre stables will be composted on-site in the farm theme park and equestrian centre precinct and may use an open windrow or in-vessel composting technology. Composting is a potential odour and dust source.

Compost produced will be applied within the development such as in the golf course area and the garden.

The location of the composting area is shown in **Figure 3.6**.

3.3.7 Cooking Exhausts

Cooking exhausts on-site will emit odour and combustion by-products mainly through the exhaust vents.

3.3.8 Animal Farm

The animal farm is a potential source of fugitive odour from any spoilt animal feed and excreta. The unsealed roads and surfaces are also potential sources of fugitive dust.

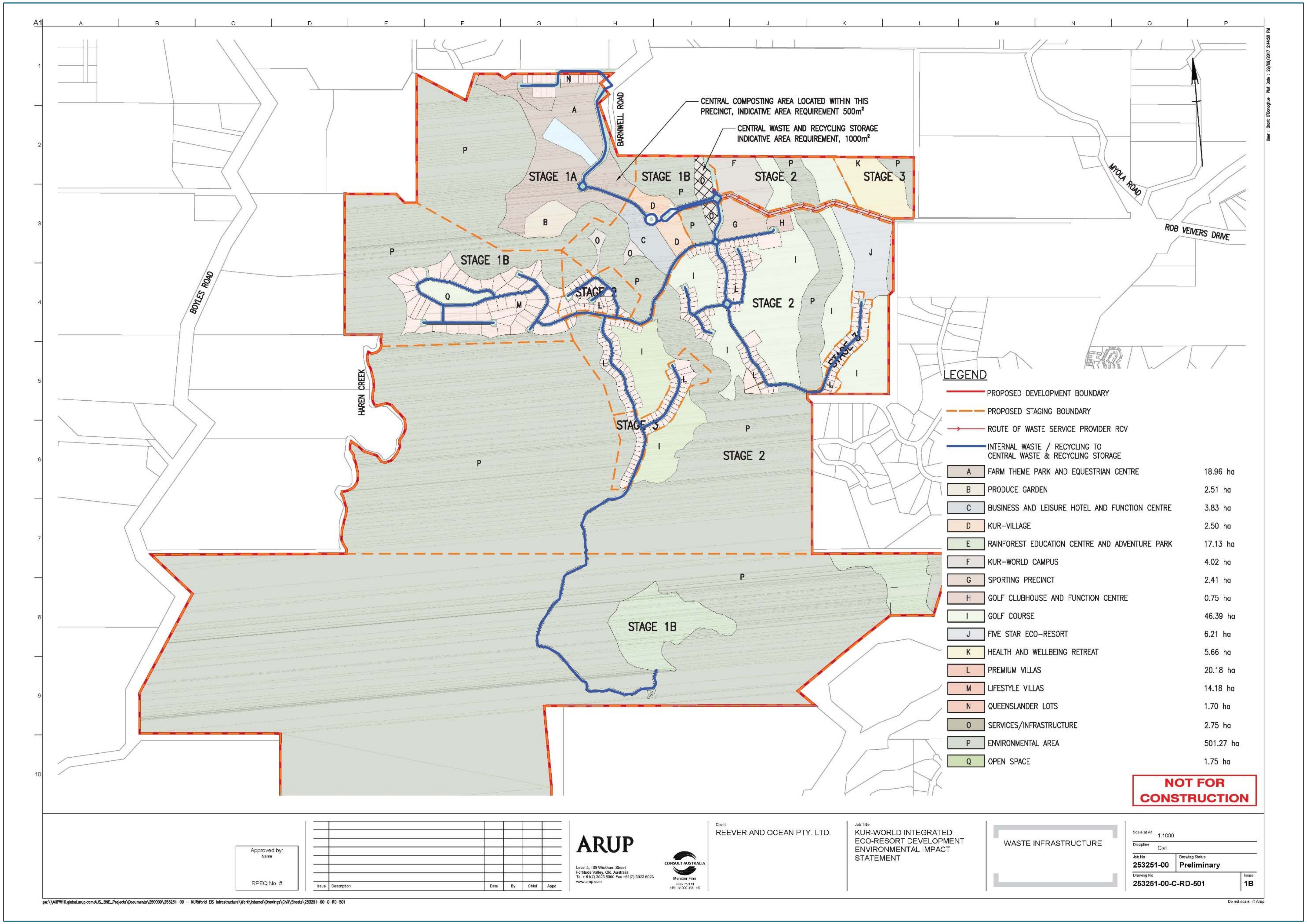

Figure 3.6 Locations of Central Waste and Recycling Storage and Central Composting Area

4. Qualitative Assessment of Impacts of Minor or Temporary Sources

4.1 Operational Impacts

Odour and dust from the farm are consistent with the existing activities on the site and sufficiently minor not to require quantitative modelling. With proper management, odour from solid waste storage and odour and waste from the animal farm can be prevented or minimised. Recommended control measures to facilitate proper management are contained in **Section 10.2**.

The diesel generators at the southern end of the development will need to be located away from sensitive receptors. Since little accommodation is proposed for the southern end of the resort and the Billabong Hotel is located a substantial distance away and separated by dense vegetation from the site, it is likely that the location of power generators at the southern zone can be chosen so as not to impact any sensitive receptor. Measures are still recommended to prevent people accommodated in the southern area to be exposed to the generators' emissions.

Similarly, the generators for Stage 1a will also need to be located away from sensitive receptors for the period that they are used to supplement normal power.

4.2 Construction Impacts

The nearest existing sensitive receptor from the Stage 1A development site (Receptor 18) is approximately 50 metres to the north of the farm-stay accommodation. The nearest existing receptor downwind along the prevailing wind direction (Receptor 24) is approximately 300 metres to the north-west of the Stage 1B westernmost villa. All of the existing sensitive receptors are separated by dense trees from the development site apart from Receptors 18 and 19 which would likely be partially screened from the northernmost farm-stay by existing trees near the property boundaries.

The dense trees separating the receptors from the development site will act as barriers and natural filters preventing onsite emissions from readily reaching the receptors and hence would reduce the likely impacts. They could also act as wind breaks minimising wind erosion. As the winds are generally from the south-east quarter, onsite emissions will generally be blown towards the north-west where the separation distance to the receptors are likely to be large enough for the emitted pollutants to be dispersed to acceptable levels before reaching the receptors. The most susceptible receptors to elevated pollutant levels due to construction activities would be Receptors 18 and 19 due to their proximity to the development site and the absence of dense vegetation separating them from the development. However, the northernmost accommodation is relatively small and hence, construction works in the vicinity would only be of short duration, less than one year.

Construction activities in the southern zone will be minimal. The nearest existing sensitive receptor is located approximately 100 metres to the southeast of the site and surrounded by dense trees. Dominant winds would blow the construction emissions away from this sensitive receptor. This receptor is unlikely to be impacted by the short-duration construction activities in the vicinity.

Good practice control measures should be sufficient to avoid exceedance of criteria and complaints and are recommended in **Section 10.2**.

5. Air Quality Criteria

5.1 Odour

5.1.1 Mareeba Shire Planning Scheme

The Mareeba Shire Planning Scheme Version 1/2011 (Mareeba Shire Council, 2013) does not provide specific criteria for assessing odour impacts or impacts from STPs.

5.1.2 Queensland Odour Impact Assessment Guideline

In the absence of any Mareeba Shire Council criteria, the appropriate criteria are considered to be those contained in the Queensland Odour Impact Assessment Guideline (EHP, 2013a). The EHP (2013a) specifies an annoyance threshold for odour of 0.5 ou (odour units [2]) for wake-free stacks and 2.5 ou for other sources, to be compared to the 99.5 percentile one hour model predictions. EHP explains the basis for these criteria as being a 99.5 percentile 3-minute average of 5 ou, and a one-hour-to-three-minute peak-to-mean ratio of 10 for wake-free stacks and 2 for other sources.

The sources in this assessment are affected by the wake of buildings and trees, so the appropriate criterion is 2.5 ou.

The criterion is to be applied at existing or likely future sensitive receptors.

5.2 Other Relevant Pollutants

Construction activities have potential to generate particulates. Construction equipment exhausts will emit combustion products including sulphur dioxide (SO_2), nitrogen oxides (NO_x), particulates, carbon monoxide (CO) and volatile organic compounds (VOCs). VOCs may include benzene, benzo(a)pyrene, formaldehyde, toluene and xylene.

5.2.1 State Legislative Instruments

The Environmental Protection (Air) Policy (EPP Air) (2008) under the Environmental Protection Act (1994) provides objectives for air quality indicators (pollutants). Those objectives that are relevant to this project and human health and wellbeing have been summarised in **Table 5.1**.

Table 5.1 Air Quality Criteria (EPP Air) for Health and Wellbeing

Air Quality Indicator	Period	Criteria (µg/m^3)
benzene	1 year	10
CO	8 hours	11,000 [2]
formaldehyde	1 day	54
NO_2	1 hour	250 [2]
	1 year	62
$PM_{2.5}$	1 day	25
	1 year	8

[2] One odour unit is defined as the concentration at which 50% of the panellists in an odour analysis can detect the odour while the rest cannot.

Air Quality Indicator	Period	Criteria (µg/m^3)
PM_{10}	1 day	50 [1]
Total Suspended Particulates (TSP)	1 year	90

Notes: 1.Five allowable exceedances are currently allowed although the intent of this was to cater for regional events.

2. Allowance is made to exclude one day.

Note that the EPP Air also contains a criterion for visibility reducing particles, but this is a measure of regional air quality and is not relevant to point sources. The impact of visible particles from point sources is addressed by the $PM_{2.5}$ criteria.

5.3 National Environmental Protection (Ambient Air Quality) Measure

The EPP(Air) incorporates the goals nominated within the previous 2003 version of the National Environmental Protection (Ambient Air Quality) Measure. The current NEPM (Ambient Air Quality) dated February 2016 has multiple changes including the new standards and goals listed in **Table 5.2**. Exceedances of particulate standards are no longer allowed apart from the exceptional events defined below.

Table 5.2 New Standard and Goals in 2016 NEPM (Ambient Air Quality)

Air Quality Indicator	Period	Criteria (µg/m^3)
$PM_{2.5}$ goals for 2025	1 day	20
	1 year	7
PM_{10}	1 year	25

Notes: For the purpose of reporting compliance against PM_{10} and $PM_{2.5}$ 1 day average standards, jurisdictions shall exclude monitoring data that has been determined as being directly associated with an exceptional event (bushfire, jurisdiction authorised hazard reduction burning or continental scale windblown dust that causes exceedance of 1 day average standards).

These goals have not yet been adopted into the EPP(Air) so it is thus not clear how much reduction of existing background concentrations is expected to assist with achievement of the 2025 goals, and how much is to be achieved by restrictions on development. Thus these goals have not been adopted for this assessment.

5.4 National Environmental Protection (Air Toxics) Measure

The EPP(Air) also incorporates as standards, the investigation levels contained in the National Environmental Protection (Air Toxics) Measure.

5.5 Dust Deposition

Whilst there are no quantitative limits for dust deposition specified in legislation, there are guidelines designed to avoid nuisance caused by dust deposition fallout onto near horizontal surfaces.

The Department of Environment and Heritage Protection (EHP 2013b) suggests the guideline that deposited matter averaged over one month should not exceed 120 mg/m^2/day (3.6 g/m^2/month). For extractive industries, it is the insoluble component of analysed dust that is used.

It should be noted that this value is a guideline for the level that may cause nuisance at a sensitive receptor such as a residence or sensitive commercial land use. It is not normally necessary to achieve this level at the boundary, but boundary measurement can assist in the assessment of whether there is risk of nuisance occurring or not.

5.6 Summary of Air Quality Values and Criteria

Those criteria adopted for the assessment are summarised in **Table 5.3**.

Table 5.3 Adopted Criteria for this Assessment

Air Quality Indicator	Period	Criteria ($\mu g/m^3$)
benzene	1 year	10
CO	8 hours	11,000 [2]
formaldehyde	1 day	54
NO_2	1 hour	250 [2]
	1 year	62
$PM_{2.5}$	1 day	25
	1 year	8
PM_{10}	1 day	50 [1]
TSP	1 year	90
odour from fugitives	99.5% 1 hour	2.5 ou
dust deposition	1 month	120 $mg/m^2/day$

Notes:

1. *Five allowable exceedances are currently allowed although the intent of this was to cater for regional events.*
2. *Allowance is made to exclude one day.*

6. Meteorological Modelling

6.1 TAPM Meteorological Modelling

6.1.1 TAPM Fundamentals

The meteorological component of The Air Pollution Model (TAPM) was used to provide wind fields over the region.

The databases required to run TAPM are provided by CSIRO and include global and Australian terrain height data, vegetation and soil type datasets, sea surface temperature datasets and synoptic scale meteorological datasets.

The Australian terrain data is in the form of 9-second grid spacing (approximately 0.3 kilometres) and is based on data available from Geosciences Australia. Australian vegetation and soil type data is on a longitude/latitude grid at 3-minute grid spacing (approximately 5 kilometres) and is public domain data provided by CSIRO Wildlife and Ecology.

The synoptic scale meteorology dataset used is a six-hourly synoptic scale analysis on a longitude/latitude grid at 0.75 or 1.0-degree grid spacing (approximately 75 kilometres or 100 kilometres). The database is derived from US NCEP reanalysis synoptic product.

TAPM dynamically fits the gridded data for the selected region to finer grids taking into account terrain, surface type and surface moisture conditions. It produces detailed fields of hourly estimated temperature, winds, pressure, turbulence, cloud cover and humidity at various levels in the atmosphere as well as surface solar radiation and rainfall.

6.1.2 TAPM Configuration

The year 2006 has been used for the meteorological simulation as it experienced typical weather conditions, unlike more recent years which experienced unusually high rainfall periods, and less stable conditions. A detailed analysis (Adhkiari, 2013) of eight years of Townsville monitoring and modelling data sponsored by ASK found that 2006 was the most representative year. A comparison of the long-term wind roses at Cairns airport, shown in **Figure 6.1** and **Figure 6.2,** shows similar pattern to the 2006 Cairns airport data shown in **Figure 6.3.** Thus 2006 is considered representative and has been used for the meteorological simulation.

Wind data from the BoM monitoring station at Cairns airport is presented in **Figure 6.1** and **Figure 6.2**.

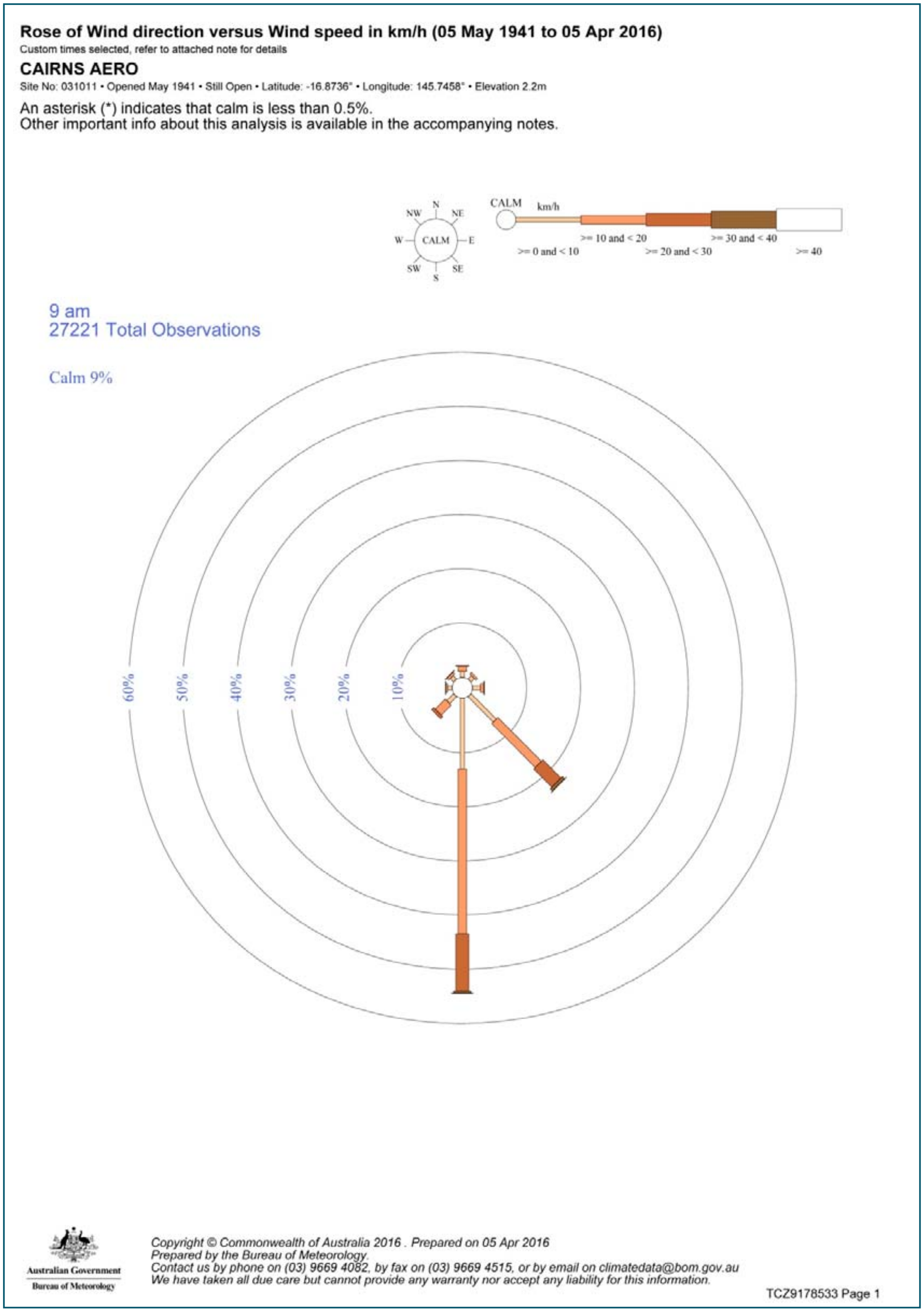

Figure 6.1 Morning (9am) Wind Rose from Cairns Airport

Rose of Wind direction versus Wind speed in km/h (05 May 1941 to 05 Apr 2016)
Custom times selected, refer to attached note for details

CAIRNS AERO
Site No: 031011 • Opened May 1941 • Still Open • Latitude: -16.8736° • Longitude: 145.7458° • Elevation 2.2m

An asterisk (*) indicates that calm is less than 0.5%.
Other important info about this analysis is available in the accompanying notes.

3 pm
27169 Total Observations

Calm 2%

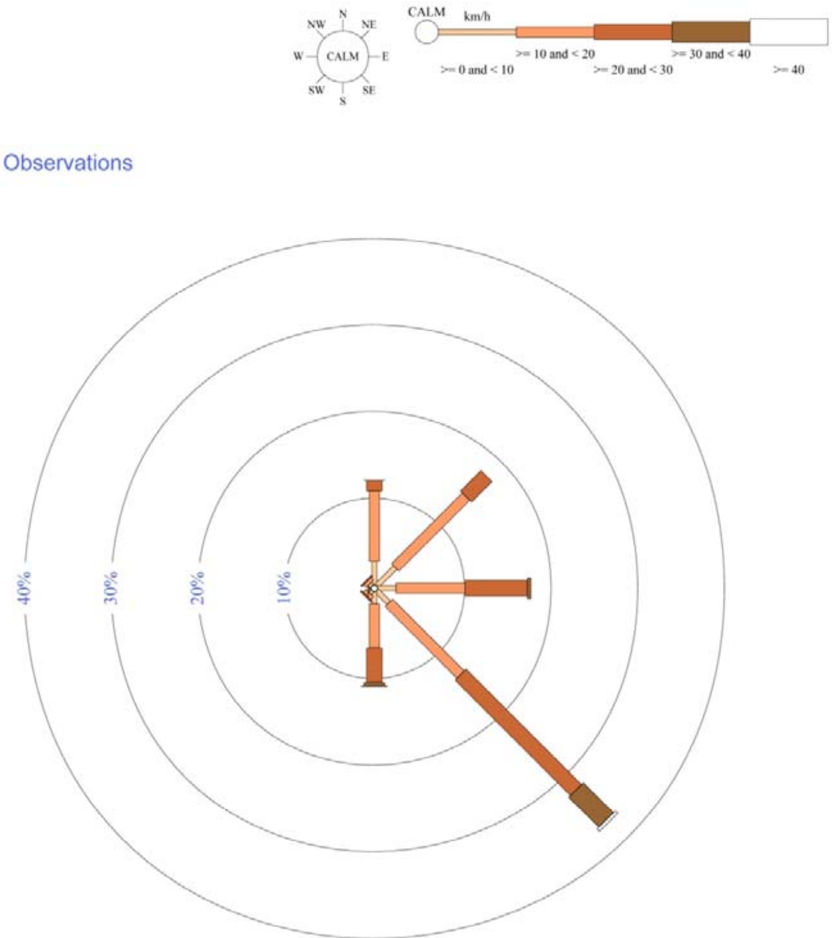

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Figure 6.2 Afternoon (3pm) Wind Rose from Cairns Airport

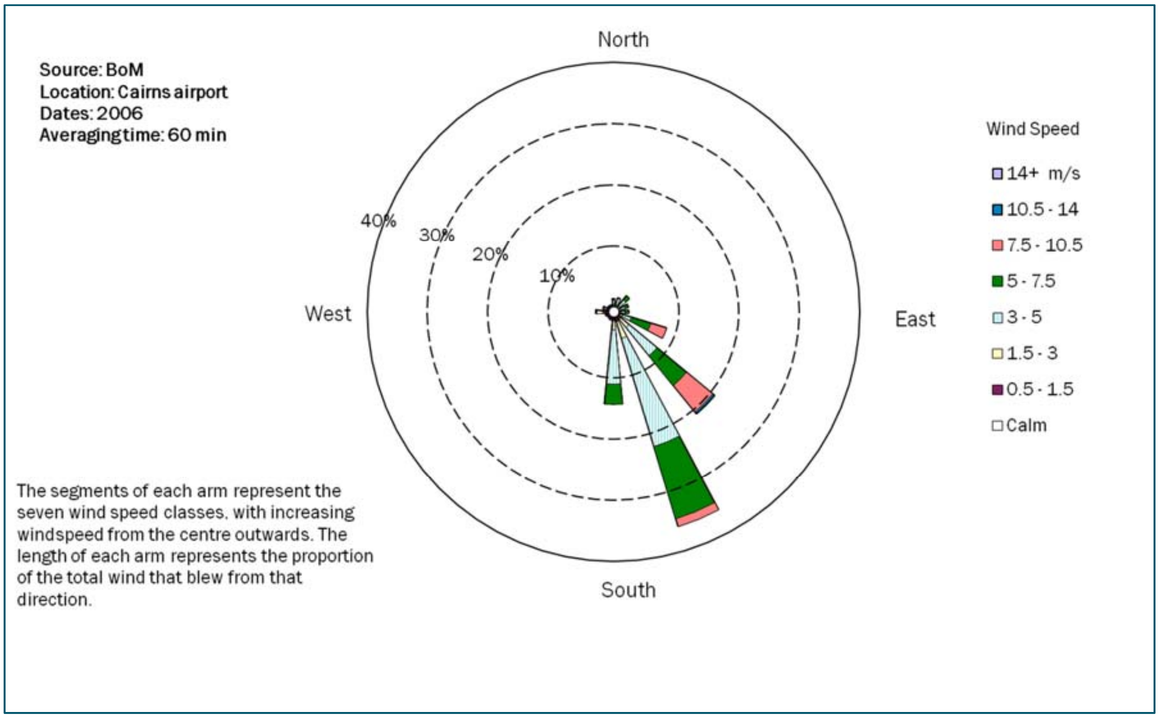

Figure 6.3 Continuous Data Cairns Airport Windrose

TAPM was setup using four nested 41 x 41 grids centred on latitude 16°50.0' south, longitude 145°36.0' east, which are coordinates in between the North and South zones of the development. The four nested grids were as follows:

- 574 km x 574 km with 14 km resolution
- 164 km x 164 km with 4 km resolution
- 41 km x 41 km with 1 km resolution
- 12.3 km x 12.3 km with 0.3 km resolution

Thirty (30) vertical levels were used with lower level steps at 10, 25, 50, 75 and 100 metres up to 8 kilometres in altitude. This is greater than normal number of vertical layers in order to provide better resolution of vertical layers. Boundary conditions on the outer grid were derived from the synoptic analysis. Non-hydrostatic pressures were ignored due to the gentle terrain and moderate resolution.

TAPM land use data was updated using the latest aerial photography available being December 2016 from the recent historical layers in Google Earth Pro.

6.1.3 Observational Data Assimilation

Meteorological data from the nearest weather stations with continuous wind speed and direction data were considered for assimilation into the model run:

- The BoM Cairns Aero station is located near the coast approximately 16 kilometres to the south-east of the development over significantly different terrain levels and features. This was not considered suitable for assimilation due to the different surrounding land use, and distance and intervening terrain.
- The BoM Mareeba Airport station is located approximately 32 kilometres to the south-west of the development over relatively complex terrain. This was not considered suitable for assimilation due to the large distance and intervening terrain.

- Note that the BoM metadata for Kuranda Railway Station does not list a continuous wind speed and direction sensor.

Thus the TAPM model run without assimilation was used for detailed modelling to avoid the introduction of non-representative meteorological data.

6.1.4 TAPM Validation

The TAPM GIS visualisation tool was used to examine the final windfields generated by the model. The last few hours of the year were reviewed to ensure the model completed the run correctly. The windfields in the inner grid throughout the month of June were examined in detail to understand the local wind patterns, influence of topography. The following patterns were observed:

- Topography to the south-east of the site around the Barron Gorge influenced the windfields substantially, with a reduced wind speed and directions tending to follow the local terrain. Other topographic features had minimal influence at the resolution modelled by TAPM.
- Morning winds were mostly light to moderate south-easterlies.
- Afternoon winds were mostly moderate south-easterlies.
- Night winds were mostly light south-easterlies.

6.2 Topography and Land Use

For the purpose of providing topographic data for the detailed modelling, the coordinates of a rectangular grid representative of the area around the proposed site were derived using WGS84 coordinates from Google Earth Professional. The south-west corner coordinates were (348400, 8136400), north-east corner coordinates were (353600, 8141600) and the grid interval was 80 metres with zero height receptors.

The WGS84 and GDA94 grids are identical to an accuracy of less than one metre. All coordinates in this report are rounded off to the nearest metre and are valid for both coordinate grids.

Gridded topographic data for Calmet was created using Global Mapper to process data from Geosciences Australia using the Kriging method and combine it with gridded LiDAR data. The Geosciences Australia data used was Shuttle Radar Topography Mission (SRTM) elevations on a 1-second grid (approximately 30 metre spacing) along with the LiDAR data for the development area provided by NRA Environmental Consultants.

6.3 Calmet Modelling Configuration.

The Calmet configuration used is consistent with NSW OEH guidance (TRC 2011).

The model was run over the full year of 2006 based on a 3-dimensional grid produced using the Caltapm utility program to convert TAPM data to MM5 format suitable for Calmet to read. The Calmet grid was set to grid spacing of 80 metres and 65 by 65 grid points. Twelve vertical layers were modelled with cell face heights of 0, 20, 40, 80, 160, 300, 450, 650, 900, 1200, 1700, 2300, and 3200 metres. This is greater than normal number of vertical layers in order to provide better resolution of vertical layers.

Mixing height calculation parameters were set to default values. Temperature prediction parameters were set to default.

Divergence minimisation was used. The critical Froude number was set to 1. Slope flow effects were included. The radius of influence of terrain features was set to 1.5 kilometres being approximately half the distance between ridges.

The output from Calmet was a three dimensional grid of wind-field data for incorporation into Calpuff.

6.4 Calmet Results

The frequency distributions of occurrences of winds for each direction sector and for each wind class (wind rose) as generated by Calmet are illustrated in **Figure 6.4**. These show predominant moderate winds from the east-south-east and south-east. The high bias in wind direction from the south-east quarter is consistent with winds recorded at Cairns Airport.

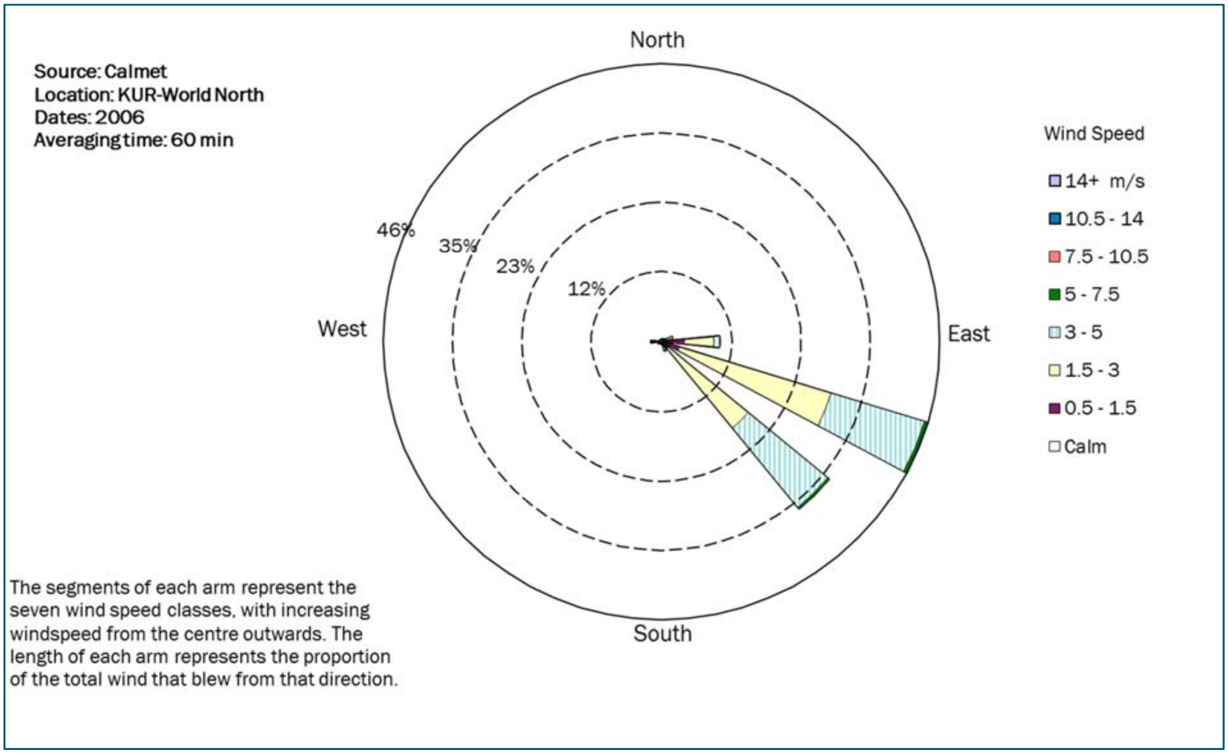

Figure 6.4 Wind Rose from Calmet for 2006

Figure 6.5 and **Figure 6.6** show, respectively, the frequency of stable conditions throughout the day, and the variation of mixing height throughout the day.

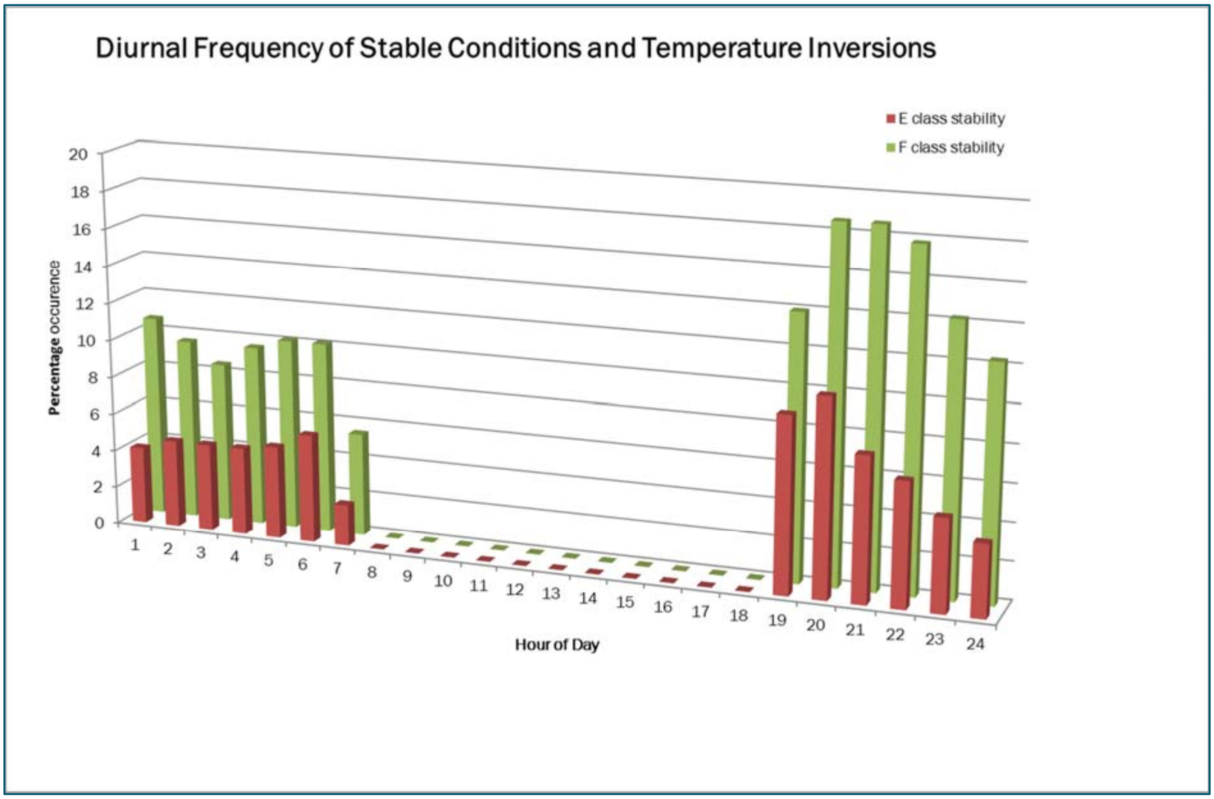

Figure 6.5 Diurnal Frequency of Stable Conditions

Day time conditions are either neutral or unstable. The frequency of E class stability is typical however that of F class stability is lower than typical. Majority of the night time hours in the area is therefore experiencing significantly more neutral than stable conditions. This is reflected in the nighttime mixing height of approximately 300 metres, which is higher than typical. In the morning the mixing height rises up gradually reaching an average of approximately 1.1 kilometre by the afternoon, then reforming at lower level again at nightfall. The relatively high mixing heights will also contribute to the low proportion of calm winds seen in **Figure 6.4**.

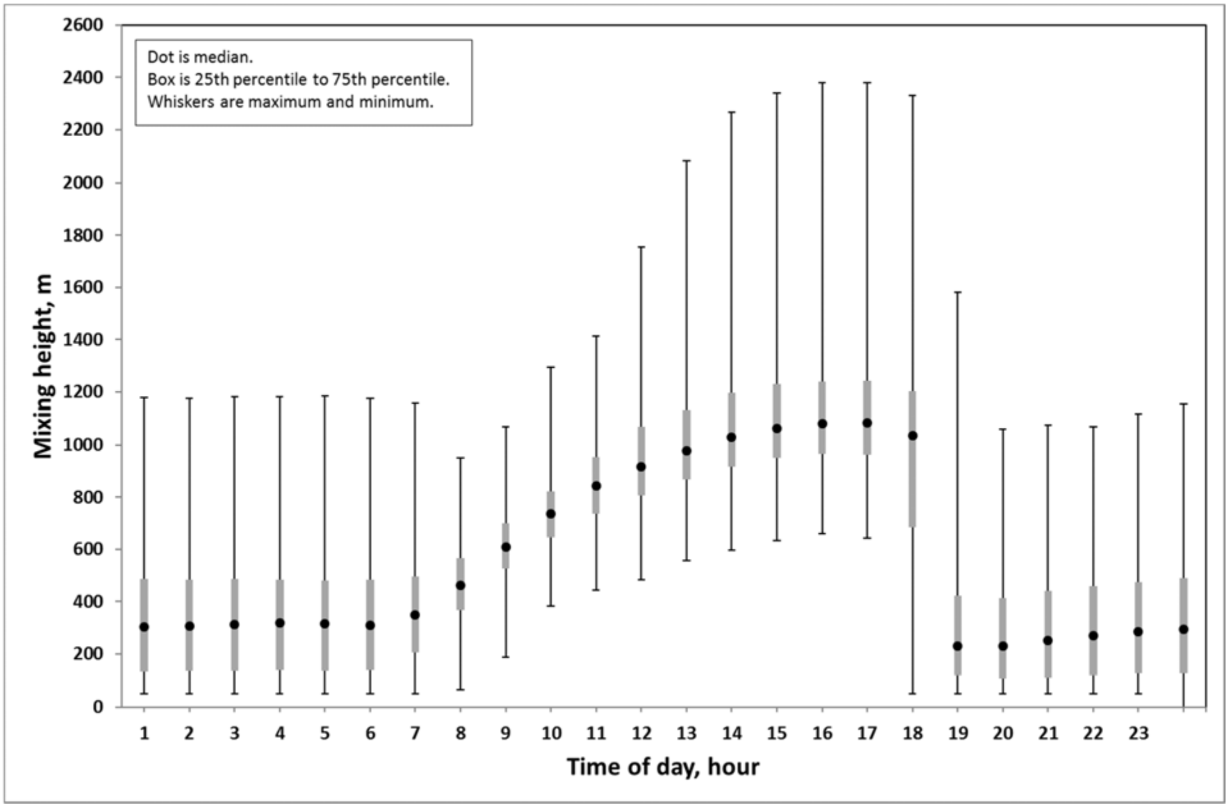

Figure 6.6 Prediction of Mixing Height from Calmet Model

7. Existing Air Quality

7.1 Overview

Based on the rural nature of the regional area, it is expected that the air quality for the study area would be acceptable for the majority of the time with possible exceptions including dust and particulates. The existing air quality would be influenced by sporadic traffic on unsealed roads as well as bushfires and controlled burning. Although, localised or short-term degradation of the air quality environment would most likely be due to smoke and dust from fires, it could also be affected by emissions from the construction and operation of the project. Some construction and operational activities have not been modelled as part of this assessment as the impacts are likely to be short-term and low-risk.

7.2 Local Air Emission Sources

As discussed in **Section 2.3**, no medium impact air quality sources were observed within 300 metres of the site. Low to medium impact air quality sources are widely dispersed and surrounded by dense trees. These sources are very unlikely to have any impact on the site but some of these have minor potential to impact the sensitive receptors nearest them, which are sufficiently far from the site that the activities onsite are unlikely to cause discernible contribution to the impacts.

7.3 Odour

The only regional sources of odour are occasional vegetation fires. Unlike other air quality criteria, odour criterion relates to the source under assessment and any associated odours. Odours from other sources are not considered a cumulative impact unless associated with a similar source.

For the purpose of comparison with criterion, regional background odour is normally assumed to be zero.

7.4 Monitoring Data from other Locations

7.4.1 Overview of Available Air Quality Data

Available local and regional monitoring data have been used to review the existing background. In the absence of continuous monitoring data, it is recommended by Victoria (2001) to use the 70th percentile as a background concentration for dispersion modelling.

The nearest ambient air monitoring station operated by Department of Science, Information Technology and Innovation (DSITI) was Earlville in western Cairns in the 1990s, and more recently DSITI has monitored at three stations in Townsville, as discussed in the sections below.

7.4.2 Earlville

Monitoring of TSP was undertaken in Mulgrave Road, Earlville, until 1999. The monitoring site is approximately 4 kilometres to the west of the wharf adjacent to a busy road and near light industry uses. The average concentration from 1995 to 1999 was 24 µg/m^3:

- 26 µg/m^3 in 1995
- 31 µg/m^3 in 1996
- 21 µg/m^3 in 1997
- 20 µg/m^3 in 1998
- 21 µg/m^3 in 1999.

This is considered to be the most representative long-term monitoring site in the region, although surrounding land uses will tend to generate more particulates than at the development site. The TSP measurements from this location have been adopted as a conservatively high background.

7.4.3 Townsville Coast Guard

Monitoring at the Townsville Coast Guard site began in 2007 as part of the Townsville Dust Monitoring Program, implemented in response to community concerns about dust impacts from the Port of Townsville operations. In May 2014 the Townsville Coast Guard station and the Townsville Port monitoring station were amalgamated into one joint monitoring station at the Townsville Coast Guard. Due to the high activity levels from freight shipping including bulk handling, this location is likely to have higher pollutant concentrations than in the development area. The station measures:

- meteorological data
- PM_{10}
- TSP
- metals.

7.4.4 Townsville Port

Established by the Port of Townsville Limited in 1994, the Townsville Port monitoring station was located on the western boundary of the Townsville Harbour. It monitored the impact of port activities on nearby residential areas. In May 2014 this station was amalgamated with the Townsville Coast Guard station to form one joint monitoring station at the Townsville Coast Guard. It was classified as a peak (port operations) station and due to the high activity levels from freight shipping including bulk handling, is likely to have higher pollutant concentrations than in the development area. The station measured:

- meteorological data
- PM_{10}
- TSP.

7.4.5 Pimlico

The Pimlico monitoring station was established in June 2004 to measure air pollutants in the Townsville area. It is classified as a neighbourhood station and was located at Latitude: -19.2871; Longitude: 146.7813 within the TAFE North Pimlico Campus grounds until the site was redeveloped in February 2016. The station measured:

- meteorological data
- ozone
- sulfur dioxide
- oxides of nitrogen
- $PM_{10.}$

This is considered to be the most representative site for PM_{10} and acid gases, and the measured concentrations are presented in **Table 7.1**.

Table 7.1 Concentrations Recorded by Queensland DSITI Air Quality Monitoring Station at Pimlico in Townsville from 2007 until 2015

Year	75th percentile 1-hour NO_2 concentration (µg/m³)	Annual NO_2 concentration (µg/m³)	75th percentile 1-hour SO_2 concentration (µg/m³)	75th percentile 24-hour SO_2 concentration (µg/m³)	Annual SO_2 concentration (µg/m³)	75th percentile 24-hour PM_{10} concentration (µg/m³)
2007	30	8	5	3	3	15
2008	32	11	3	0	0	19
2009	36	9	3	3	0	18
2010	30	9	5	3	0	16
2011	not available	11	10	5	3	18
2012	32	9	5	3	3	16
2013	24	8	3	3	0	18
2014	26	8	5	3	3	17
2015	28	8	5	3	3	21
Average	30	9	5	3	1	18

7.4.6 Gladstone Memorial Park

Established in 2009, the Memorial Park station uses differential optical absorption spectroscopy (DOAS) equipment to monitor pollutants over a light path from the Entertainment Centre to Memorial Park. It is classified as a neighbourhood station and is located at Latitude: -23.8426; Longitude: 151.2534. The station measures:

- ozone
- nitrogen oxides
- sulfur dioxide
- air toxics (organic pollutants).

This is considered to be the most representative site for organic pollutants, and the measured concentrations are presented in **Table 7.2**.

Table 7.2 Concentrations Recorded by Monitoring Station at Gladstone Memorial Park

Year	Annual average benzene (µg/m³)	Maximum 24h toluene (µg/m³)	Annual average toluene (µg/m³)	Maximum 24h xylene (µg/m³)	Annual average xylene (µg/m³)	Maximum 24h formadehyde (µg/m³)
2009	i.d.	5	i.d.	34	i.d.	6
2010	i.d.	8	i.d.	33	i.d.	5
2011	i.d.	7	4	39	29	5
2012	i.d.	27	i.d.	149	i.d.	5
2013	i.d.	11	i.d.	79	i.d.	6
2014	4	18	8	127	51	5
2015	5	11	7	90	52	5

Year	Annual average benzene (µg/m³)	Maximum 24h toluene (µg/m³)	Annual average toluene (µg/m³)	Maximum 24h xylene (µg/m³)	Annual average xylene (µg/m³)	Maximum 24h formadehyde (µg/m³)
Average	**5**	**12**	**6**	**79**	**44**	**5**

Note: i.d. = insufficient data

7.4.7 South Gladstone

Established in 1992, the monitoring station is located in the grounds of the South Gladstone State School in a residential district. Since the Townsville and Mackay monitoring stations do not include $PM_{2.5}$, the South Gladstone station is considered the most representative for the development and the measured concentrations at this station are presented in **Table 7.3.**

Table 7.3 Concentrations of Fine Particulates ($PM_{2.5}$) Recorded by Queensland DSITI Air Quality Monitoring Station at South Gladstone for 2009-2015

Year	75th percentile 24-hour $PM_{2.5}$ concentration (µg/m³)	Annual $PM_{2.5}$ concentration (µg/m³)
2009	10.5 [1]	9.2 [1]
2010	7.6	6.2
2011	7.6	7.5
2012	5.9	5.2
2013	6.3	5.6
2014	7.5	6.0
2015	5.2	4.3
Average	**6.7**	**5.8**

Note: 1 This data was not included in the average since the DSITI NEPM report for 2009 stated that there was a much higher than normal incidence and severity of wind blow dust events throughout Queensland.

7.4.8 Toowoomba

The Toowoomba DSITI monitoring station located at Willowburn Oval was the only CO monitoring station in Queensland outside of the Brisbane CBD, but closed down recently due to flooding. It was surrounded by residential and light industry areas. It is considered the most representative station and will be used for estimating background levels of CO for the purposes of this assessment. **Table 7.4** shows that the averaged maximum 8-hour background CO is 2.2 ppm (2750 µg/m³).

Table 7.4 Concentrations of Carbon Monoxide Recorded by Queensland DSITI Air Quality Monitoring Station at Toowoomba for 2003-2010

Year	Maximum 8-hour average CO (ppm)
2003	2.6
2004	3.4
2005	2.3
2006	1.9
2007	2.2
2008	1.9
2009	1.8

Year	Maximum 8-hour average CO (ppm)
2010	1.7
Average	**2.2**

7.4.9 Dust Deposition

Dust deposition varies substantially depending on local sources and season. Any dust deposition data for the local area is not publicly available. In industrial areas, insoluble dust deposition levels are typically in the order of 50 mg/m^2/day. For this locality in a well-forested area with few local sources, background insoluble dust deposition levels are assumed to be 30 mg/m^2/day.

7.5 Assumed Background Concentrations

The estimated background air quality for key pollutants has been summarised with the estimated concentrations listed in **Table 7.5**, based on long term average at the stations with the most representative data. These are well within the criteria contained in **Table 5.3**. It is anticipated that the criteria would only be exceeded during regional events such as bushfires, dust storms or the afternoon cane fire haze events during harvesting season.

Table 7.5 Estimated Background Air Quality

Pollutant	Averaging period	Assumed Background (µg/m^3)
TSP	1 year	24
PM_{10}	24 hours	18
$PM_{2.5}$	24 hours	6.7
	1 year	5.8
NO_2	1 hour	30
	1 year	9
SO_2	1 hour	5
	24 hours	3
	1 year	1
CO	8 hours	2.2
Benzene	1 year	5
Toluene	24 hours	12
	Annual average	6
Xylene	24 hours	79
	Annual average	44
Formaldehyde	24 hours	5
Benzo(a)pyrene	Annual average	0.1 ng/m^3
Dust deposition	Annual average	30 mg/m^2/day

8. Pollution Modelling Methodology

8.1 Overview

In order to predict what happens to the pollutants after they are emitted to air, a mathematical model is used to simulate their dispersion and deposition. It is accepted by regulatory agencies that this type of modelling has associated uncertainties. These are normally addressed by using statistics over long simulation times, and deriving emission rates based on published emission factors or data representing high emission conditions.

With sources close to ground level, the critical wind conditions tend to be near-calm i.e. low wind speeds. Gaussian plume models such as Ausplume and Aermod cannot model calm conditions and have low accuracy in light winds, especially in valleys where katabatic flows are present and where drainage flows turn to follow the valley. Calpuff, being a non-steady-state Lagrangian puff model, is able to simulate stagnation over time, which is critical in near-calm conditions. Its meteorological pre-processor Calmet performs diagnostic simulation of terrain effects on the wind field. It has a specific slope flow algorithm that predicts katabatic flows (Scire, J.S. & Robe, F.R., 1997).

Due to the low source height for emissions sources associated with the Project, the worst conditions may be near-calm conditions. In near-calm conditions there is little turbulent mixing and less dilution by incoming wind.

Thus Calpuff (Version 7.2.1) was chosen as the most appropriate model.

8.2 Calpuff Configuration

The three dimensional wind fields from Calmet were entered into Calpuff for the full year 2006. For the modelling of the emissions from the sewage treatment plant, Calpuff was run over a smaller computational grid (3.68 kilometres x 3.44 kilometres) with spacing of 80 metres, and with a sampling grid over a 3.28 kilometres x 2.24 kilometres domain with a nesting factor of 2 to achieve a resolution of 40 metres. For the modelling of the emissions from the road construction, Calpuff was run over a smaller computational grid (0.96 kilometres x 0.96 kilometres) with spacing of 80 metres, and with a sampling grid over a 0.72 kilometres x 0.64 kilometres domain with a nesting factor of 4 to achieve a resolution of 20 metres.

Wind speed profile was set to the Industrial Source Complex (ISC) Rural exponents. Light wind conditions were not invoked until the wind speed dropped below 0.2 m/s. Transitional plume rise and partial penetration of boundary layers were included. Briggs rise algorithm was used since the sources are not very hot.

The emissions were modelled as puffs (not slugs). Puff-splitting was turned off.

Dispersion coefficients were derived by the model using turbulence generated by micrometeorology. The Heffter curve was used to compute time-dependent dispersion beyond 550 metres. The partial plume height adjustment method was used to allow winds to approach hills as terrain increases.

The minimum turbulence velocity, sigma v, was set to 0.2 m/s.

8.3 Odour Emission Inventory

Plans for the STP are not available at the time of writing of this report. Most of the operational STPs however have similar components and operations. It has been assumed that the proposed STP for the development would have similar components and operation to a similar-sized STP in Canungra previously assessed by ASK (2017). The modelled odour sources of the STP are graphically presented in **Figure 8.1** and summarised in **Table 8.1**. The STP in Canungra has a design capacity of 1,500 equivalent persons (EP) (SKM, 2010). The development will have a maximum occupancy of 4,000 people and an estimated average dry weather flow (ADWF) of 0.5 ML/day to 1.1 ML/day (Arup, 2017). Arup (2017) recommends a design capacity for an ADWF of approximately 0.5 ML/day, which corresponds to 2,500 EP. To maintain conservatism, the proposed STP has been assessed by scaling the area of the existing STP components in Canungra by 4,000/1,500. The odour emissions were determined based on a review of publicly available odour impact assessments for similar STP's.

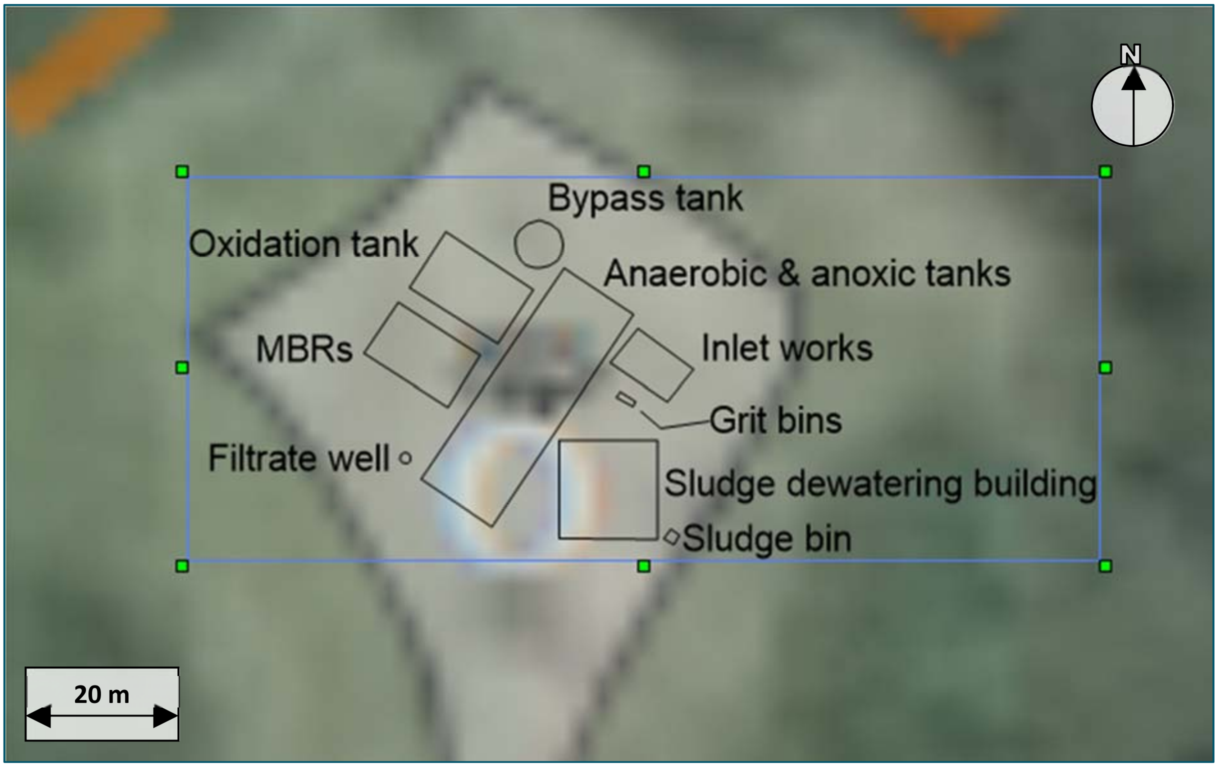

Figure 8.1 Modelled odour emission sources of the STP

8.3.1 Inlet Works

The odour emission rate for the inlet works (primary screening) was assumed to be 5.6 ou.m^3/m^2/s, which is the maximum of the emission rates presented in McDonald et al (2009). The emissions from the inlet works will be fugitive. The area applied for the calculation of the emission rate is based on half the total anticipated horizontal area of inlet works, which is considered a conservative assumption.

8.3.2 Belt Press Filter

The odour emission rate for the belt filter press was assumed as the maximum of the emission rates presented in McDonald et al (2009). The belt filter press was modelled as a volume source and the odour emission was modelled to occur constantly 24 hours per day, seven days per week whereas on typical small plants the belt press filter may only activate a few days per week, for several hours per day.

8.3.3 Bypass Tank

The bypass tank will be used to store excess untreated wastewater, either during wet weather events or for scheduled maintenance. The odour emission rate for untreated wastewater in the bypass tank was assumed to be 2.4 ou.m^3/m^2/s, based on information obtained from MWH Global for review of another STP, and emission rates published in McDonald et al (2009).

To represent the statistical occurrence of emission from the bypass tank, a variable emission rate has been used for this source, with odour emissions modelled to occur two hours each day, staggered from 5am to midday, and from 3pm to 10pm, Sunday to Saturday (a total of 14 hours per week). Over the course of a full year, this will result in a total emission time of 728 hours, which allows for the scheduled maintenance (9 hours per week, 468 hours in a year) and approximately 11 days (260 hours) of storage for other upset events.

8.3.4 Filtrate Well

Odour is emitted from the filtrate well when untreated wastewater (with the exception of primary treatment) is bypassed and released. Due to the turbulence in the well, odour is typically stronger from this source than from the bypass tank (ASK, 2017), and therefore a higher odour emission rate of 9.9 $ou.m^3/m^2/s$ was applied based on the results of odour measurements by CEE (2006) of a flow splitter located at the Merrimac WWTP. To represent the statistical occurrence of emissions from the filtrate well, odour emissions were modelled to occur two hours every day during summer months (between 8am to 11am and 3pm to 6pm), totalling 180 hours per year, or approximately 7.5 days.

8.3.5 Sludge Bin

The odour emission rate applied for the dewatered sludge bin was 9 $ou.m^3/m^2/s$, based on the odour emission rate applied for sludge by CEE (2006) for the assessment of the Pimpama WWTP. Potential for overspill was taken into account in the estimation of the source dimension.

8.3.6 Treated Wastewater

It has been assumed that the quality of the treated wastewater onsite will be equivalent to Class A and is likely to have insubstantial odour. No odour emissions were included from treated wastewater in storage areas.

8.3.7 Summary

The odour emission rates for other sources were obtained via review of emission rates presented in the SKM odour assessment for Canungra, and odour impact assessments for Pimpama WWTP (CEE, 2006) and Googong WWTP (MWG Global, 2009) and the emission rates presented in McDonald et al (2009).

The modelled emissions for the STP are presented in **Table 8.1**. With the exception of the dewatering belt filter press, all sources were modelled as area sources.

Table 8.1 Odour Emission Factors Derived

Odour Source	Specific Odour Emission Rate (SOER) ($ou.m^3/m^2/s$)	Modelled Unit Quantity	Exposed Area (per unit) m^2	Total Odour Emission Rate ($ou.m^3/s$)	Publication Source	Emission Variability
Inlet Works	5.6	1	53.3	299	Canungra STP (SKM, 2010), McDonald *et al* (2009)	Constant
Grit Bins	5.0	3	0.67	10	Pimpama WWTP (CEE, 2006)	Constant
Anaerobic Tank	2.7	1	130.7	357	Canungra STP (SKM, 2010), McDonald *et al* (2009)	Constant

Odour Source	Specific Odour Emission Rate (SOER) (ou.m^3/m^2/s)	Modelled Unit Quantity	Exposed Area (per unit) m^2	Total Odour Emission Rate (ou.m^3/s)	Publication Source	Emission Variability
Anoxic Tank	1.6	1	248.0	397	Canungra STP (SKM, 2010), McDonald *et al* (2009)	Constant
MBR	0.2	2	53.3	21	Googong WWTP (MWH, 2009)	Constant
Oxidation Tank	0.3	1	122.7	37	Canungra STP (SKM, 2010), Rubyanna (Bundaberg) WWTP (SKM, 2013)	Constant
Bypass Tank	2.4	1	32.0	77	Benowa Pump Station (MWH, 2017), McDonald *et al* (2009)	2 hours per day, staggered as per discussion
Filtrate Well	9.9	1	2.1	21	Pimpama WWTP (CEE, 2006)	2 hours per day for summer months
Belt Filter Press[1]	n/a	1	n/a	137	McDonald *et al* (2009)	Constant
Sludge bin	9.0	1	2.7	24	Pimpama WWTP (CEE, 2006)	Constant

Notes: 1. Modelled as a volume source.

8.4 Road Construction Inventory

The proposed road that will connect Myola Road to the development will be constructed in three sections. The construction of the section of the road in front of the identified residences (shown in **Figure 3.2**) was modelled to determine likely impacts of the road construction onto the residences. The construction of this section will be completed within 4 to 6 months and construction activities will occur from 7:30am to 6pm on weekdays and 7:30am to 2pm on Saturdays. Scraper, haul truck and grader traversing the road segment will be completed within 12 to 16 weeks at the section directly in front of the houses. To simplify the assessment and incorporate conservatism, construction operations were modelled from 7:30am to 6pm on weekdays and Saturdays throughout the modelled year. The scraper and grader were assumed to traverse the road section once every hour. However, emission rates were calculated assuming construction will be completed within 12 weeks for 10.5 hours per week. This results in conservative emission rates as more activities will have to be conducted for a shorter time.

The amount of materials to be removed off-site was estimated using the dimension of the road easement along this section (658 metres in length x 20 metres in width) and assuming a depth of 30 centimetres.

The emission sources included in the model are the following:

- Scraper in travel mode
- Scraper scraping earth
- Dozer
- Excavator loading to trucks
- Grader

- Wheel-generated dust from truck movements
- Wind erosion

Equations used to calculate the emission rates are presented in **Appendix B**.

8.4.1 Source Configuration

Wind erosion was modelled as an area source with a dimension of 658 metres by 20 metres, initial sigma z of 1 metre and an effective height of 0.

All the other sources were modelled as volume sources evenly spread along the road section.

The dust emissions from the excavator loading to trucks were modelled as volume sources with effective height of 5 metres, initial sigma y of 4.7 metres and initial sigma z of 4.7 metres.

All other emission sources were modelled with an effective height of 2.6 metres, initial sigma y of 4.7 metres and initial sigma z of 2.4 metres.

8.4.2 Summary of Emission Inventory

A summary of the emission inventory used in the model is provided in **Table 8.2**. A 50% control efficiency for dust emissions was applied assuming watering at a rate of less than 2 litres/m^2/h.

Table 8.2 Total Controlled Emission Rates for First Quarter of the Calendar Year (Jan to Mar 2015)

Source	TSP (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	Benzene (g/s)	CO (g/s)	Formaldehyde (g/s)	NO_x (g/s)
Dozer	0.32	0.064	3.32E-02	1.91E-04	5.39E-02	4.27E-03	1.97E-01
Wheel generated dust	0.11	0.042	4.18E-03	4.53E-06	8.07E-04	3.70E-05	1.39E-03
Scraper in travel mode [1]	0.56	0.076	1.72E-02	-	-	-	-
Scraper removing soil	0.049	0.012	1.53E-03	2.24E-04	9.84E-02	1.13E-02	3.00E-01
Grader	0.035	0.016	1.08E-03	8.96E-05	3.81E-02	2.99E-03	1.77E-01
Loading to trucks with Overburden [2]	0.061	0.029	4.36E-03	2.06E-05	4.15E-03	1.84E-04	1.71E-02
Wind erosion [3]	0.061	0.029	4.36E-03	-	-	-	-

Notes:

1.Gas exhausts emissions are included in the "Scraper removing soil" source.
*2. Emission rates at wind speeds less than 1.54 m/s. Dust emission rates for wind speeds greater than 1.54 m/s were calculated using the equation provided in **Appendix B**.*
*3. Emission rates at wind speeds between 5.14 to 8.23 m/s. Dust emission rates for wind speeds less than 5.14 were zero and dust emission rates for wind speeds greater than 8.23 m/s were calculated using the factors provided in **Appendix B**.*

8.5 Nitrogen Dioxide Modelling

8.5.1 Overview

Most of the NO_x emitted by combustion engines are in the form of nitric oxide (NO). This reacts with other gases in the atmosphere to form NO_2. Because the fraction of NO_2 emitted by vehicles is highly dependent on the configuration of each individual vehicle, emission factors are only available as NO_x.

A typical proportion of NO_2 in urban airsheds during peak concentration events is 20%. This includes both regional sources and local sources. The contribution from regional sources would have built up over a longer time period i.e. NO emissions would have had substantial time to react to form NO_2. In a rural environment, the proportion would be lower.

The rate of conversion from NO to NO_2 is related to a large number of factors. The most critical are ozone concentration, hydrocarbon concentration and the amount of sunlight, which increases the rate of the reverse reaction. Both hydrocarbons and ozone can be responsible for oxidising NO to form NO_2. Generally, the conditions that favour NO_2 formation are when ozone concentrations are high and sunlight low. This scenario could occur in the late afternoons following a clear day. In rural areas, ozone concentrations are low, so NO_2 formation is not favoured.

8.5.2 Goldstone Method

An equation for estimating the concentration of NO_2 based on NO_x concentrations has been derived from monitoring data by M. Goldstone (1988). This is:

$$[NO_2] = 5.27 \times \ln[NO_x] - 3.6 \text{ ppb}; (r^2 = 0.71)$$

The equation is based on concentrations of NO_x reaching 200 ppb. That corresponds to a NO_2 concentration of 24 ppb or 12% of NO_x. Peak concentrations predicted in this study are of similar magnitude. There is considerable scatter in the data as indicated by the coefficient of determination, r^2=0.71. Therefore it is considered appropriate to be conservative and allow for a 15% conversion rate from NO_x to NO_2.

8.5.3 Janssen Method

The Janssen Method (Middleton et al 2007) is a popular technique for estimating conversion of nitrogen oxides to NO_2 downwind of a source. It is based on aircraft-based measurements taken downwind of power stations. A plot of NO_2/NO_x ratios against distance for different ozone concentrations is provided as Figure 1 in Middleton et al (2007).

8.5.4 TMR Method

TMR (2014) have defined a method for calculating the proportion of NO_x that is NO_2:

(1) Assume 10% at 20 metres.

(2) For freeways, assume it increases linearly to 20% and 30% at 60 metres for morning and evening peak periods respectively. For other roads assume it increases to 30% and 45% at 60 metres for morning and evening peak periods respectively.

(3) At greater than 60 metres, assume it increases linearly to 100% at 100 metres.

ASK considers this method highly conservative but adequate for the purposes of screening.

8.5.5 Ambient Ratio Method 2 (ARM2)

The Ambient Ratio Method 2 (ARM2) uses NO_2 and NO_x data from ambient monitoring stations. The NO_2:NO_X ratios are plotted against the corresponding NO_X concentrations. The upper bound 98th percentile NO_2:NO_X ratios are used to generate an equation equating the NO_2:NO_x ratio to NO_x concentration. Although the NO_2:NO_x ratios derived from known NO_x concentrations using this method are conservative, the results are more realistic than the TMR Method and hence, ARM2 was utilised in this assessment.

Brisbane City Council is currently developing a local version of the ARM2 Method using data from South Brisbane station. The following equation was derived (BCC, 2017):

$$\frac{NO_2}{NO_x} = 10.281 \times (NO_x[as\ \mu g/m^3])^{-0.585}$$

This is intended to be applied to the 99.9th percentile 1-hour average concentration and a 70th percentile background concentration (BCC, 2017). The minimum NO_2/NO_x is to be the emitted NO_2:NO_x ratio and maximum is to be 0.9 (BCC, 2017).

8.5.6 Conversion Relevant to this Study

This assessment utilised the ARM2 Method for calculating the NO_2 levels at the receptors assuming a minimum of 20% NO_2 to NO_x emitted.

9. Dispersion Modelling Results

9.1 Limitations

The uncertainties associated with this type of assessment are normally only dealt with in a qualitative manner, but include:

- source strength variability
- meteorological data variability
- inherent uncertainty in dispersion modelling.

Typically 95% confidence intervals are estimated to require a multiplicative factor of 2 or 3. In this case, the uncertainty is mostly due to assumptions regarding the details of emission sources and operating information. This has been addressed by assuming emission rates compared to those measured from similar operations.

9.2 Odour Results

The results of the modelling of odour from the operation of the proposed STP are illustrated in **Figure 9.1** by pollution contours overlayed onto an aerial photo. Predicted odour levels at sensitive receptors associated with the proposed development are shown in **Table 9.1** and are well within the criterion of 2.5 ou.

Table 9.1 Predicted Odour Concentrations

Receptor ID#	99.5th Percentile Odour Concentration (OU)
Criterion	2.5
Background	0.0
1	0.0
2	0.0
3	0.0
4	0.0
5	0.0
6	0.0
7	0.0
8	0.0
9	0.0
10	0.0
11	0.0
12	0.0
13	0.0
14	0.1
15	0.0
16	0.0
17	0.0
18	0.1
19	0.1
20	0.1
21	0.1

Receptor ID#	99.5th Percentile Odour Concentration (OU)
22	0.2
23	0.1
24	0.1
25	0.1
26	0.0
27	0.0
28	0.0
29	1.0
30	1.3
31	0.3
32	0.1
33	0.1
34	0.1
35	0.7
36	0.1

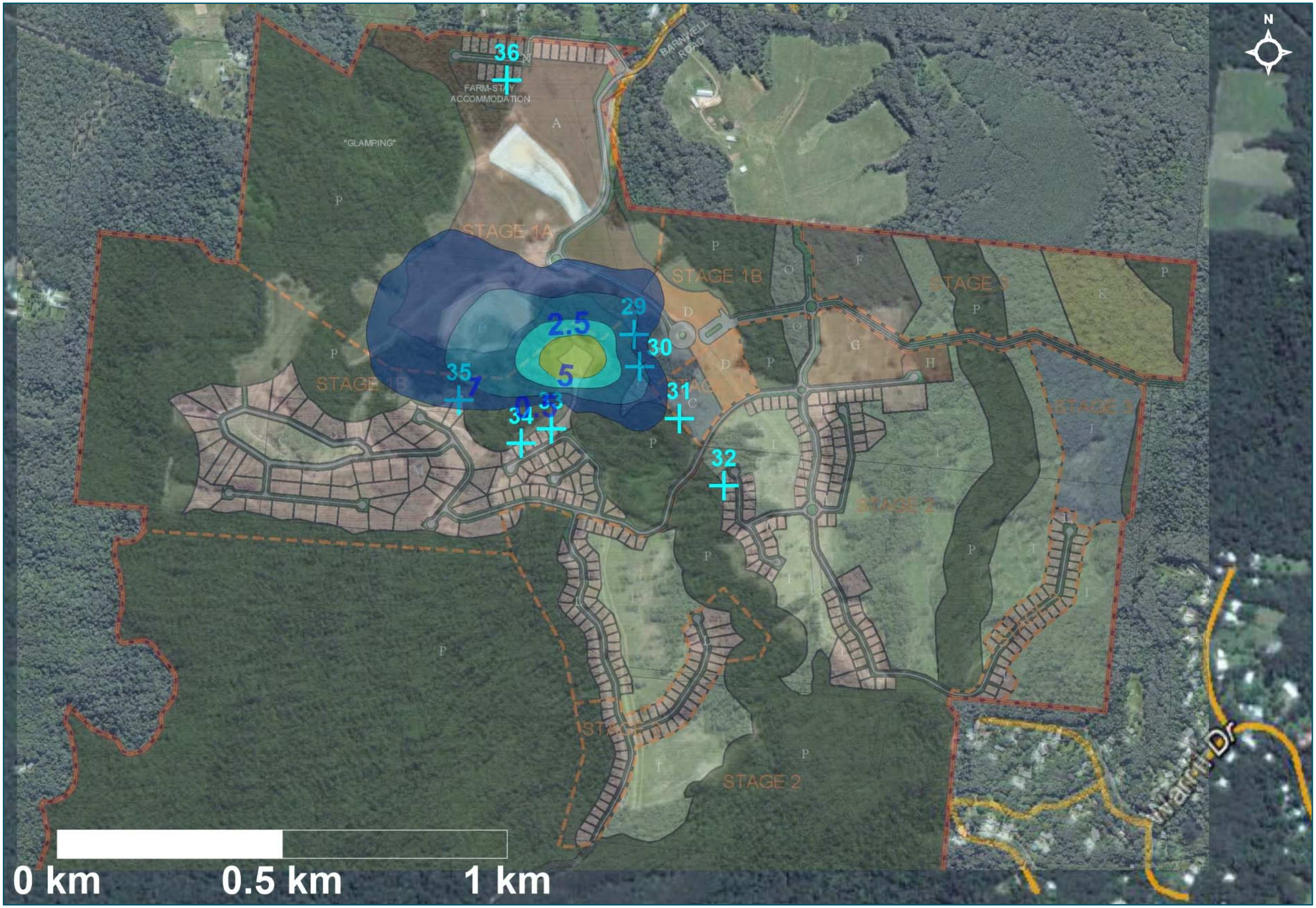

Figure 9.1 Predicted 99.5th Percentile Odour Concentrations Due to STP Operation

9.3 Suspended Particulate Results

The predicted concentrations at sensitive receptors are shown in **Table 9.2** along with the criteria. The estimated background levels are listed separately and not included in the predicted concentrations. The predicted concentrations at the sensitive receptors suggest that suspended particulates are not likely to exceed their respective criteria due to the road construction activities although the predicted 24-hour average PM_{10} and annual average $PM_{2.5}$ concentrations approach the criteria. The 24-hour average PM_{10} and annual average $PM_{2.5}$ results of the modelling are illustrated in **Figure 9.2** and **Figure 9.3**, respectively.

Concentrations provided in tabular form are a prediction at a point in space and hence more accurate than the contours, which are graphical interpolations.

Table 9.2 Predicted Suspended Particulate Concentrations

Receptor ID#	Receptor Height (m)	Annual Average TSP (µg/m³)	Maximum 24 h average PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³) Maximum 24 h Average	$PM_{2.5}$ (µg/m³) Annual Average
Criterion		90	50	25	8
Background		24	18	6.7	5.8
1	0	7	14	3.3	0.5
1	0.5	7	14	3.3	0.5
1	1.0	7	14	3.3	0.5
1	1.5	7	14	3.3	0.5
2	0	15	10	2.5	1.2
2	0.5	15	10	2.5	1.2
2	1.0	15	10	2.5	1.2
2	1.5	15	10	2.5	1.2

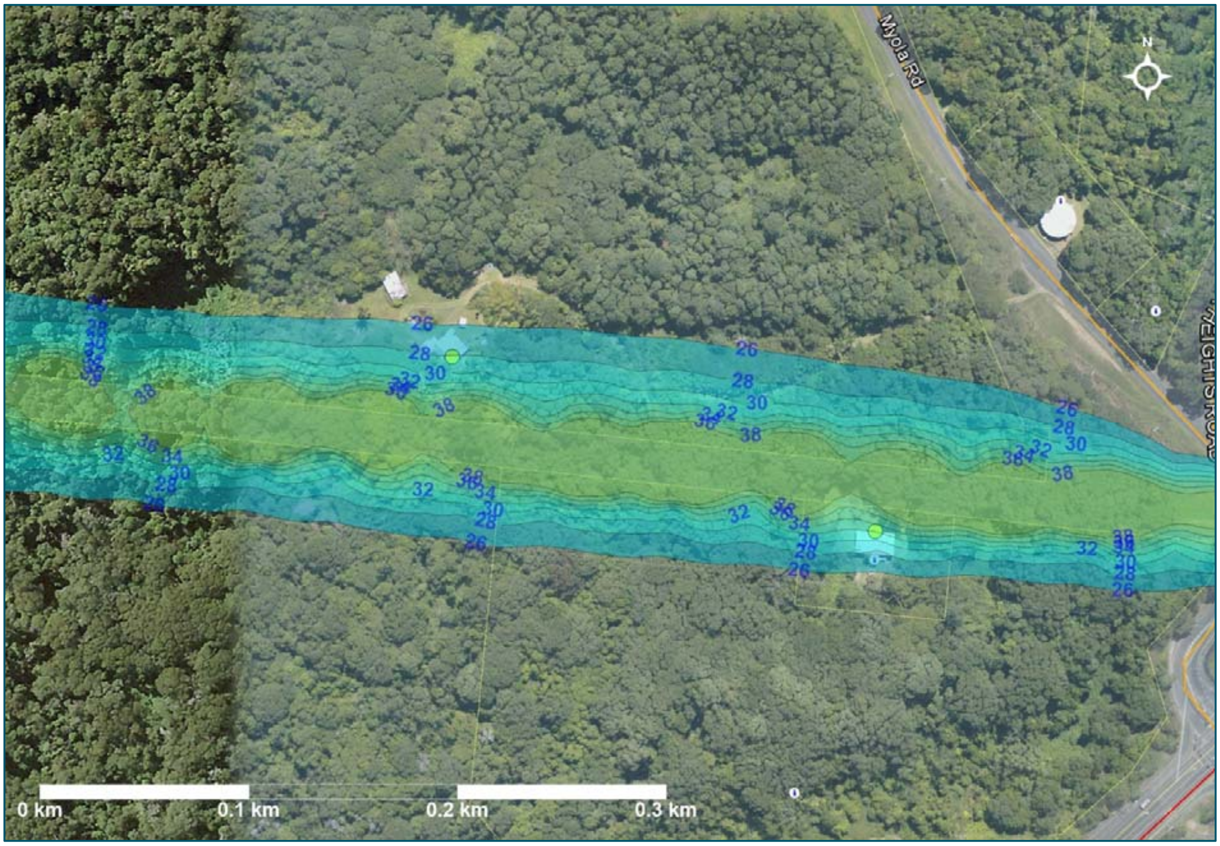

Figure 9.2 Predicted Maximum Cumulative 24-Hour PM_{10} Concentrations (µg/m^3)

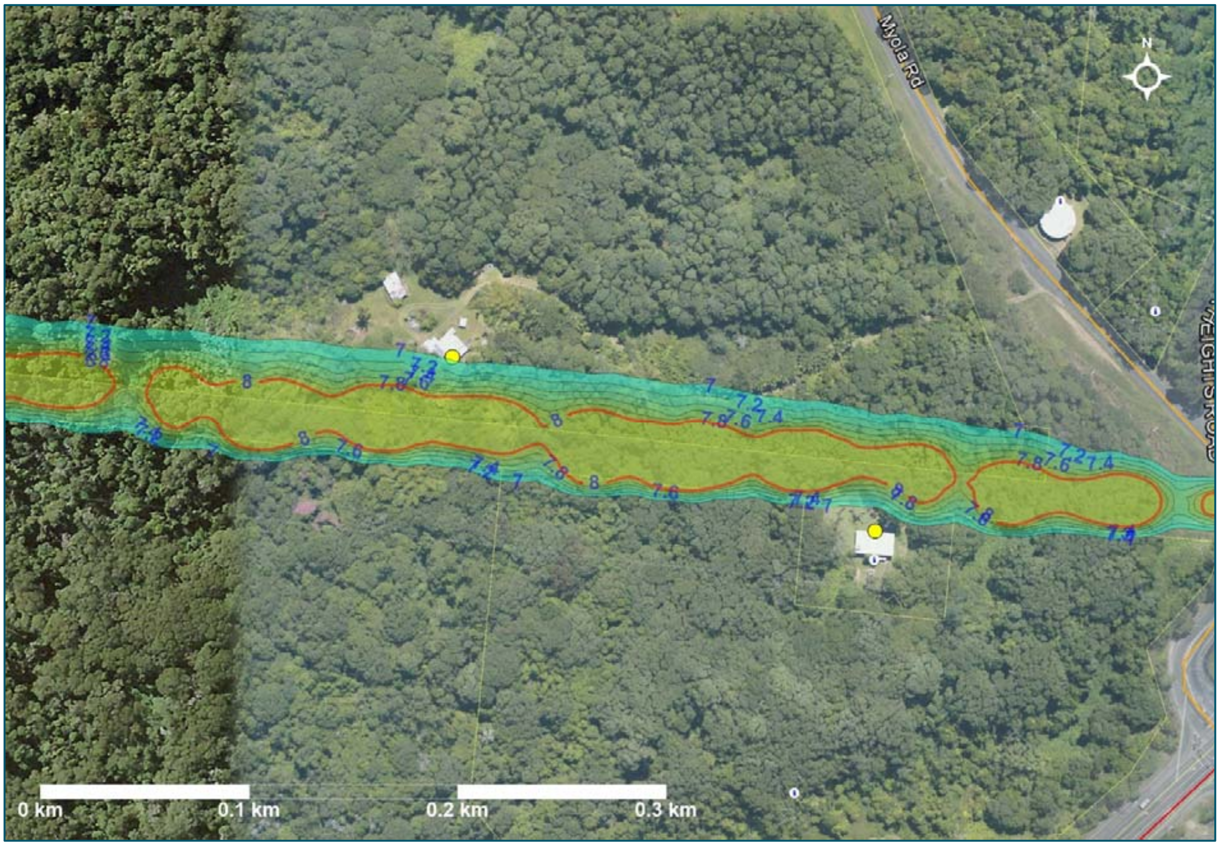

Figure 9.3 Predicted Cumulative Annual Average $PM_{2.5}$ Concentrations (µg/m³)

9.4 Gas Concentration Results

The predicted gas concentrations at sensitive receptors are shown in **Table 9.3** along with the criteria. The estimated background levels are listed separately and not included in the predicted concentrations. As shown, all the modelled gases are well within the criteria at the sensitive receptors.

Table 9.3 Predicted Gaseous Concentrations

Receptor ID#	Receptor Height (m)	Formaldehyde (µg/m³)	Benzene (µg/m³)	CO (µg/m³)	NO_2 (µg/m³)	
Averaging Period		24 Hours	1 Year	8 Hours	1 Hour (99.9th Percentile)	1 Year
Criterion		54	10	11,000	250	62
Receptor\Background						
1	0	1.0	0.003	23	68	4
1	0.5	1.0	0.003	23	68	4
1	1.0	1.0	0.003	23	68	4
1	1.5	1.0	0.003	22	68	4
2	0	0.7	0.007	14	68	9
2	0.5	0.7	0.007	14	68	9
2	1.0	0.7	0.007	14	68	9
2	1.5	0.7	0.007	14	68	9

9.5 Dust Deposition Results

The results of the dust deposition modelling are illustrated in **Figure 9.4**. The predicted dust deposition levels at sensitive receptors are shown in **Table 9.4** along with the criterion and estimated background levels. The estimated background levels (30 mg/m^2/day) are listed separately and not included in the predicted concentrations. The maximum monthly cumulative levels including background at the two receptors are 165 and 208 mg/m^2/day, exceeding the criterion of 120 mg/m^2/day. Assuming a water application of greater than 2 L/m^2/h is applied during road construction, a 75% control efficiency is to be expected and the maximum monthly cumulative levels including background at the two receptors will be 98 and 119 mg/m^2/day, just below the criterion of 120 mg/m^2/day. The results of the dust deposition modelling with 75% control efficiency are illustrated in **Figure 9.5.** With proper mitigation measures such as water application of more than 2 L/m^2/h and ceasing operations when dust is generated and blown towards the sensitive receptors, the dust deposition criterion can be complied with at the sensitive receptors. It is also important to note that dispersion modelling does not take into account the dense vegetation that will help reduce the dust levels from reaching Receptor 2.

Table 9.4 Predicted Dust Deposition Levels Not Including Background

Receptor ID#	Annual Average Dust Deposition (mg/m^2/day)	Maximum monthly deposition (mg/m^2/day)	Maximum monthly deposition (mg/m^2/day) at 75% control efficiency
Averaging Period	Annual average	30 days	30 days
Criterion		120	120
Receptor\Background		30	30
1	65	135	68
2	148	178	89

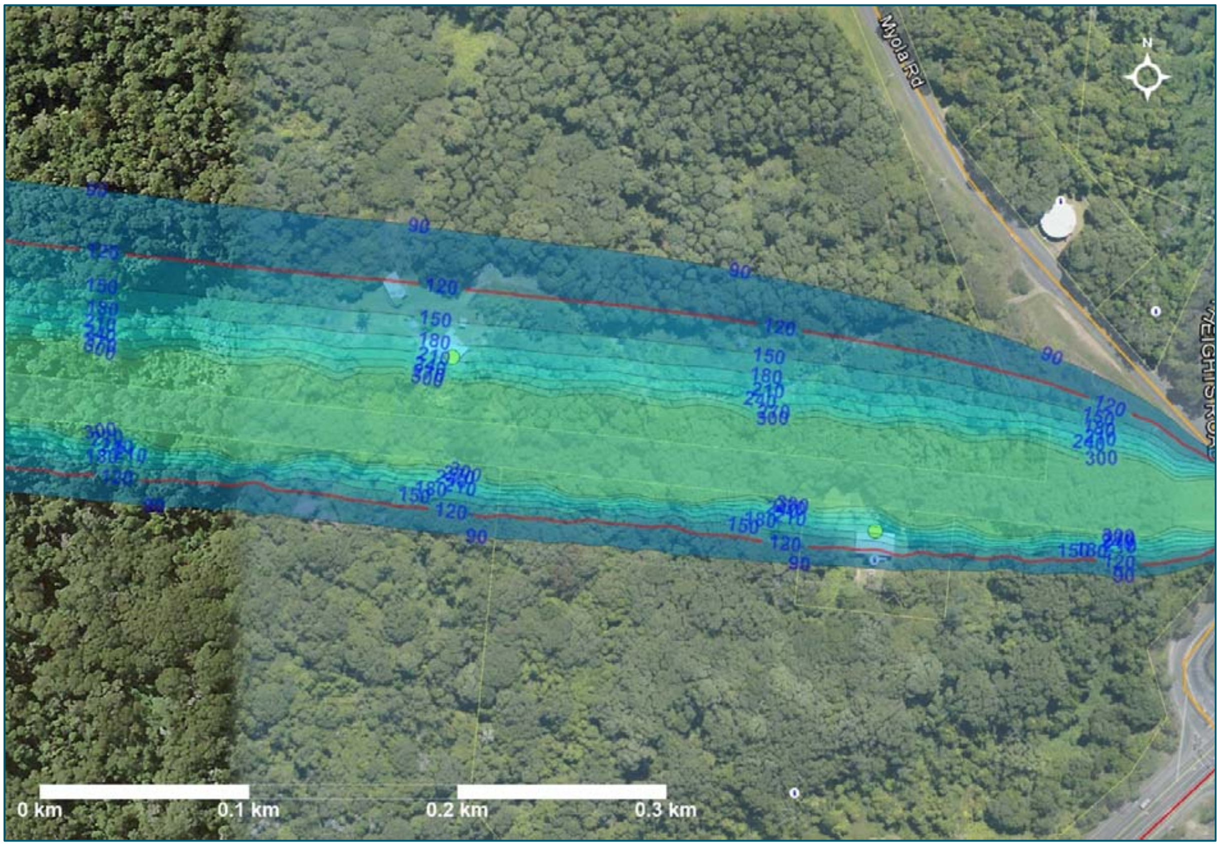

Figure 9.4 Predicted Cumulative 30-day Average Dust Deposition Levels (mg/m²/day) – 50% Control Efficiency

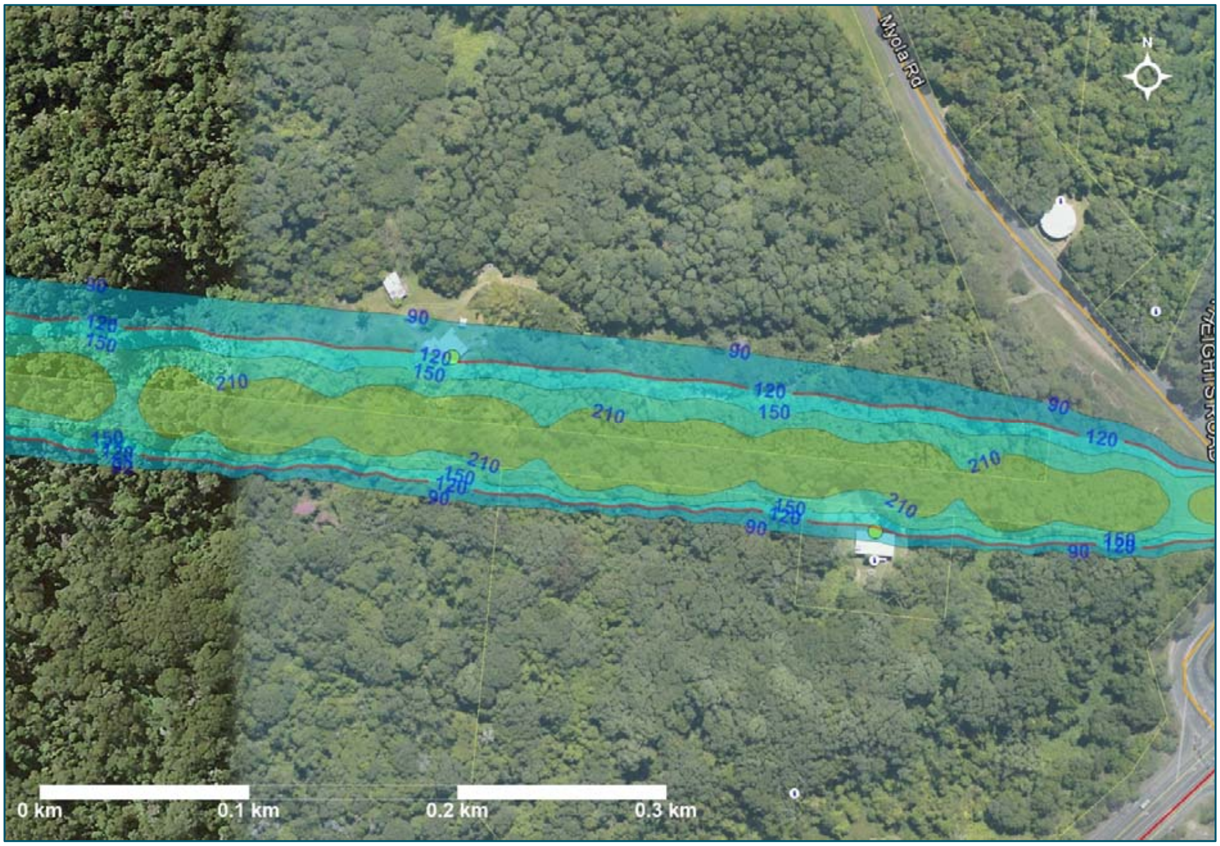

Figure 9.5 Predicted Cumulative 30-day Average Dust Deposition Levels (mg/m^2/day) – 75% Control Efficiency

10. Discussion

10.1 Summary of Modelling Results

The 99.5th percentile odour concentration at the worst-affected receptor due to the operation of the STP is 1.3 ou, well within the criterion of 2.5 ou.

The predicted pollutant levels at the worst-affected receptors due to the primary access road construction activities are summarised in **Table 10.1**.

Table 10.1 Summary of predicted levels at the worst affected receptor

Pollutant	Averaging period	Assumed Background ($\mu g/m^3$)	Concentration at worst affected receptor ($\mu g/m^3$)	Cumulative concentration at worst affected receptor ($\mu g/m^3$)	Criteria ($\mu g/m^3$)
TSP	1 year	24	15	39	90
PM_{10}	24 hours	14	14	32	50
$PM_{2.5}$	24 hours	6.7	3.3	10	25
	1 year	5.8	1.2	7	8
NO_2	1 hour	30	68	98	250
	1 year	9	9	18	62
CO	8 hours	2.2	23	25	11,000
Benzene	1 year	5	0.007	5	10
Formaldehyde	24 hours	5	1.0	6	54
Dust deposition (Watering <2 $L/m^2/h$)	Annual average	30 $mg/m^2/day$	178 $mg/m^2/day$	208 $mg/m^2/day$	120 $mg/m^2/day$
Dust deposition (Watering >2 $L/m^2/h$)	Annual average	30 $mg/m^2/day$	89 $mg/m^2/day$	119 $mg/m^2/day$	120 $mg/m^2/day$

10.2 Recommendations

10.2.1 Mitigation Measures

Mitigation measures that are recommended for the project are listed in **Table 10.2**.

Table 10.2 Mitigation Measures Applicable to the Project

Source	Activities	Mitigation Measures
Construction	Excavation and filling	Water with truck-mounted sprays.

Source	Activities	Mitigation Measures
	Material handling including loading and unloading of gravel and sand	Water prior to loading, minimise drop height, cease operation or minimise activity during dry, windy conditions
	Wheel-generated dust from hauling on unsealed road surfaces	Water with truck-mounted sprays.
	Wind erosion from stockpiles and unsealed roads	Water with sprays, create windbreaks using shade cloth on stockpiles or strategically locating stockpiles next to dense trees. Revegetate as soon as practical using hydraulic mulch seeding.
	Engine exhaust	Regularly maintain equipment. Turn-off engines when not in use.
	Monitoring	The construction site manager and relevant sub-contractors should undertake daily visual monitoring to identify if dust or exhaust plumes reach the site boundary, and initiate additional control measures if this occurs.
Sewage Treatment Plant	-	Prevent anaerobic conditions other than in the anaerobic and anoxic tanks by ensuring proper aeration and/or minimising detention times of wastewater, minimise storage times of biosolids onsite.
Sewage Reticulation	-	Due to the large number of rising mains required, a vacuum system is preferred. Assessment should be undertaken to determine a suitable odour treatment of ventilation point(s), including analysis of detention times. A separation distance of at least 50 metres from vents to the sensitive receptors should be achieved unless: • odour filters are installed and 30 metres separation is provided • site-specific dispersion modelling demonstrates less is acceptable.
Storage and Handling of Biosolids	Handling and storage of biosolids	Locate biosolids storage and handling in an area at least 50 metres away from sensitive receptors.
Composting and application of composts	Composting of green wastes and manure	Ensure aerobic conditions are maintained, using an enclosed composter that has a mechanism to agitate the waste. Locate activity at least 50 metres away from sensitive receptors. Schedule processing and application of composts when wind conditions are favourable (i.e. non-calm conditions and no sensitive receptors downwind)
Irrigation of Recycled Water	Irrigation of treated water to golf course areas	Use high quality recycled water (Class A only) for irrigation, apply appropriate buffer distance recommended in **Section 3.3.3** and keep public off irrigated areas until the surface covering is dry.
Power Generator	-	Turn off equipment when not needed. Locate vents away from sensitive receptors.
Boilers	-	Vents should be located on rooftops.
Solid Wastes	Disposal and storage of solid wastes	Bins for wastes are to be placed in dispersed locations, bin contents are to be regularly emptied, big bins for storage of wastes prior to removal onsite are to be placed in locations at least 6 metres away from sensitive receptors. Ensure at least weekly removal of wastes onsite.

Source	Activities	Mitigation Measures
Cooking Exhausts	-	Exhaust system should be designed such that exhausts are away from sensitive receptors if practicable and not blowing towards any windows or doors and located high enough for proper dispersion to occur before plume reaches any publicly accessible ground-level. A separation distance of 6 metres from sensitive uses should be adopted for the vents. In the absence of a guidance in the local planning scheme, this is based on requirement from Brisbane City Plan 2014 Centre or Mixed Use Development Code.
Animal Farm	-	Surface regular vehicle access points with bitumen, concrete or crushed rock. Keep paved areas clean of build-up of dirt or waste. Where practical, plant trees with interspersed shrubs to provide windbreaks and dust screens. Water unsealed surfaces as required to minimise dust emissions. If practical, use a mineral such as zeolite in stable floor cover to reduce odour. Remove manure, uneaten food and urine-affected bedding daily to a covered temporary manure storage facility located at least 50 metres away from residences. Ensure weekly removal of manure and disinfection of this storage area to appropriate composting/disposal facilities or for appropriate agricultural reuse. Regularly clean farm and farm animals. Investigate any complaints to determine likely causes. If complaints may be valid, prepare and implement an action plan to minimise the likelihood of reoccurrence of the cause.

10.2.2 Vegetation Buffers

The site will have dense vegetation interspersed with the residential, recreational and auxiliary facilities/areas and most surrounding properties also have dense vegetation. This vegetation will reduce both dust and odour by increasing mixing and deposition onto vegetation surfaces.

10.2.3 Dust Monitoring

Dust deposition monitoring should be undertaken for at least 3 months (and preferably 12 months) prior to construction and also during construction at the following locations:

- At 78 Monaro Close or on the site boundary in the vicinity during construction of Stage 1a.
- At 11 Myola Road and 27 Myola Road or on the site boundary in the vicinity during construction of the primary access road.
- At 2 Warril Drive or on the site boundary in the vicinity during construction of Stage 2 and the secondary access road.
- At 77 Barnwell Road or on the site boundary in the vicinity during construction of Stage 3.

10.2.4 Feedback and Complaints Register

It is recommended to encourage existing residents around the development site and clients of the resort to provide feedback to the resort by provision of feedback and complaints hotline, email address and forms. Feedback and complaints shall be recorded in a register. This would allow management of the resort to be aware of issues, provide solution to address issues and track the effectiveness of the actions taken. A complaints driven system is a suitable method of monitoring achievement of air quality objectives given the relatively low risk to an odour impact.

10.3 Conclusions

- There are no medium-impact sources existing close enough to the development site that are likely to cause or contribute to unacceptable ambient air quality levels in the vicinity.
- Among the air quality impact sources proposed as part of the development and presented in this assessment, the construction activities and sewage treatment plant have the most potential to impact the sensitive receptors.
- As discussed in **Section 4**, the on-site construction activities are short-lived and the measures specified in **Section 10.2** should be sufficient to manage emissions. Dense trees surrounding the development site would reduce the likely construction impacts that will be experienced at most of the existing sensitive receptors.
- Dispersion modelling has been conducted to predict the likely odour impacts due to the operation of the northern STP. The predicted results are well within the criterion at the existing and future sensitive receptors suggesting that the operation of the northern STP is not likely to cause odour nuisances at these locations.
- Dispersion modelling has also been conducted to predict road construction impacts. The predicted results are well within the criterion apart from the deposited dust levels. It is possible to minimise deposited dust levels by watering using more than 2 $L/m^2/h$ and constant visual monitoring to immediately cease operations when substantial dust is generated and being blown towards the receptors.
- Other sources in the proposed development, such as sewage reticulation vents, diesel generators and waste storage are manageable using appropriate separation distances, and control measures.

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Appendix A Glossary

Parameter or Term	Description
ASK	ASK Consulting Engineers Pty Ltd
BoM	Bureau of Meteorology
CO	Carbon monoxide
DSITI	Department of Science, Information Technology and Innovation
EHP	Queensland Department of Environment and Heritage Protection
EPA	Queensland Environmental Protection Act 1994
EPP (Air)	Queensland Environmental Protection (Air) Policy 2008
EP	Equivalent persons
L/s	Litres per second
MBR	Membrane Bioreactor
NO_x	Oxides of nitrogen including nitric oxide and nitrogen dioxide
OCF	Odour control facility
ou	Odour Units
SO_2	Sulphur dioxide
STP	Sewage treatment plant
TAPM	The Air Pollution Model developed by CSIRO and used by ASK for meteorological modelling
UTM	Universal Transverse Mercator coordinate system

Appendix B Emission Inventory Equations for Particulates

Loading Overburden to Trucks by Excavator

Equation 10 of Environment Australia (2012) has been used because it provides a method of varying emission rates with wind speed.

$$E = 0.0016\, k \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

where

E = Emission Factor with units kg/t of overburden

U = mean wind speed (m/s)

M = soil moisture content (%)

k = 0.74 for TSP

k = 0.35 for PM_{10}

Bulldozing Overburden

Equations 16 and 17 of Environment Australia (2012) have been used.

$$E_{TSP} = 2.6 \times \frac{(s)^{1.2}}{(M)^{1.3}}$$

$$E_{PM_{10}} = 0.34 \times \frac{(s)^{1.5}}{(M)^{1.4}}$$

where

E = Emission factor with units kg/h/vehicle

s = Material silt content (%)

M = Soil moisture content (%)

Wheel Dust Generation from Light Vehicles on Unpaved Roads

From Section A1.1.11 of Environment Australia (2012):

$$E = k \times \frac{\frac{s}{12} \times \left(\frac{S}{48}\right)^{B}}{\left(\frac{M}{0.5}\right)^{C}} - 0.0013$$

Where: E = Emission factor
k = Constant (1.69 for TSP, and 0.51 for PM_{10})
B = 0.6 for TSP and 0.5 for PM_{10}
C = 0.3 for TSP and 0.2 for PM_{10}
s = Material silt content (%)
S = vehicle speed (km/h)
M = Moisture content (%)

Grader

From Section A1.1.14 of Environment Australia (2012):

$$E = 0.0034 \times S^k$$

where

E = Emission factor with units kg/vkt (vkt = vehicle kilometre travelled)

k = 2.5 for TSP

k = 2.0 for PM_{10}

S = Mean Vehicle Speed (km/h)

Scraper in Travel Mode

From Section A1.1.12 of Environment Australia (2012):

$$E = k \times s^{1.3} \times W^{2.4}/1{,}000{,}000$$

where

E = Emission factor in kg/km

k = 9.6 for TSP

k = 1.32 for PM_{10}

s = Material silt content (%)

W = Empty vehicle weight (tonnes)

Topsoil Removal by Scraper

From Section A1.1.13 of Environment Australia (2012):

$$E = 0.029 \frac{kg}{t} \; (TSP)$$

$$E = 0.00725 \frac{kg}{t} \; (PM_{10})$$

Wind Erosion from Un-vegetated and Unsealed Surfaces

Environment Australia (2012) provides an NPI method for estimating annual emissions of dust from wind erosion based on either a default value published in 1983 or an equation published in 1998, which has several variables including number of rain days and average wind speed. However dispersion modelling is normally based on hourly time-steps and using this equation, the model will predict a small quantity of wind-blown dust every hour of the year. In reality, peak emissions of wind-blown dust will occur only during high wind speeds conditions during dry periods. During low wind speed conditions when particulates from other sources can accumulate, wind-blown dust will be negligible. Thus using the NPI equations will lead to inaccurate and un-timely contribution of wind-blown dust to the peak 24 hour predictions.

ASK calculates variable wind-blown dust emissions from exposed surfaces based on equations 2 and 3 of USEPA (2006), which combine to become:

$$E = k \times \left(58 \times (u^* - u_t^*)^2 + 25\,(u^* - u_t^*)\right)$$

Where: E = Emission factor with units g/m^2/disturbance hour

k = Constant (1.0 for TSP, 0.5 for PM_{10} and 0.075 for $PM_{2.5}$)

u^* = surface friction velocity (m/s)

u_t^* = threshold friction velocity (m/s)

The surface friction velocity can be calculated for different wind speed classes (at 10 metre anemometer height, based on Equations 13.2.5-6 and 13.2.5-7 of AP-42 (USEPA 2006) using the following three factors:

(4) Based on Table 13.2.5-3 the ratio of surface wind to 10 metre approach wind over a steep stockpile area ranges from 0.2 to 1.1. Parts of the stockpile where the ratio is 0.2 will likely never be eroded by wind. Overburden will only trigger when the ratio reaches 1.1, which is 4% of the stockpile.

(5) Using equation 13.2.5-7, the surface friction velocity is one tenth of the surface wind.

(6) However these calculations are based on "fastest-mile" wind speeds, which approximate the fastest 1-minute mean wind speed (Graybeal 2006). The wind speeds used in modelling are one hour means. Ratios ("G_{60}") of 1 minute means to one hour means are estimated by Ashcroft (1984) for different terrain types. For mostly open, fairly level terrain with a few buildings, G_{60} = 1.26.

Therefore for overburden, the surface friction velocity is calculated as 1.1 x 0.1 x 1.26 times the 10 metre approach wind. For coal the ratio is assumed to be 0.6 x 0.1 x 1.26 x the 10 metre approach wind.

For each wind speed category, the geometric mean surface friction velocities are shown in **Table 10.3**.

Table 10.3 Wind Speeds and Corresponding Surface Friction Velocities (m/s) for 4% of Exposed Earth and Overburden

Pasquill Wind Speed Class	Corresponding Surface Friction Velocities	Mean Surface Friction Velocity
0 – 1.54	0 – 0.21	0.11
1.54 – 3.09	0.21 – 0.43	0.30
3.09 – 5.14	0.43 – 0.71	0.55
5.14 – 8.23	0.71 – 1.14	0.90
8.23 – 10.80	1.14 – 1.50	1.31
> 10.80	> 1.50	1.52

The threshold friction velocity (Table 13.2.5-2, USEPA 2006) for overburden is 1.02 m/s. The resultant emission rates for different Pasquill wind speed classes are given in **Table 10.4**.

Table 10.4 Wind Erosion Emission Rates for Exposed Surfaces

Source	Pasquill Wind Speed Class (m/s)	TSP (kg/ha/hour)	PM_{10} (kg/ha/hour)	$PM_{2.5}$ (kg/ha/hour)
Overburden dumps	5.15 – 8.23	0.7	0.3	0.03
Overburden dumps	8.24 – 10.80	5	2	0.2
Overburden dumps	> 10.80	10	5	0.4