AGL Gas Import Jetty Project

AGL Wholesale Gas Limited

Air Quality Impact Assessment

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AGL Gas Import Jetty Project - Port Activities

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Contents

Glossary and Abbreviations

Abbreviation	Expansion	Definition
AG	Australian Government	
AGL	AGL Wholesale Gas Limited	The Project proponent
Airshed		For the purpose of this report, the Port Phillip Air Quality Control Region as defined in the SEPP(AQM). The Project is located in the Mornington Peninsula Local Government Area; i.e., within the Airshed.
B(a)P	Benzo(a)Pyrene	
BoM	Bureau of Meteorology	
CH_2O	Formaldehyde	Molecular formula for formaldehyde
CO	Carbon monoxide	Molecular formula for carbon monoxide
DELWP	Department of Environment, Land, Water and Planning (Victorian Government)	
DoEE	Department of the Environment and Energy (Commonwealth)	
EETM	Emission Estimation Technique Manual	
EPA	Environment Protection Authority (Victoria)	
FSRU	Floating Storage and Regasification Unit	
GHG	Greenhouse Gas	
IRAE	Industrial Residual Air Emissions	Unintended emissions or IRAEs are often intermittent or episodic. Separation distances seek to avoid the potential consequences of emissions of IRAEs. An adequate separation distance should allow IRAEs to dissipate without adverse impacts on sensitive land uses (EPA, 2013).
LNG	Liquefied Natural Gas	LNG is natural gas, predominantly methane and smaller amounts of other hydrocarbons converted to liquid form by chilling for ease of storage or transport.
$\mu g/m^3$	microgram (1×10^{-6} grams) per cubic metre	
µm	micron (thousandth of a millimetre)	
NEPC	National Environment Protection Council	
NEPM	National Environment Protection (Ambient Air Quality) Measure	
NO	Nitric oxide	Molecular formula for nitric oxide
NO_2	Nitrogen dioxide	Molecular formula for nitrogen dioxide
NO_x	Oxides of nitrogen	Molecular formula for oxides of nitrogen
NPI	National Pollutant Inventory	
O_3	Ozone	Molecular formula for ozone
PAH	Polycyclic Aromatic Hydrocarbon	
PM_{10}	Particulate Matter 10	Particulate matter comprising particles with aerodynamic diameters less than 10 microns (µm) in size

Abbreviation	Expansion	Definition
$PM_{2.5}$	Particulate Matter 2.5	Particulate matter comprising particles with aerodynamic diameters less than 10 microns (µm) in size
ppb	Parts per billion	
ppm	Parts per million	
SEPP(AAQ)	State Environment Protection Policy (Ambient Air Quality); see VG (1999)	
SEPP(AQM)	State Environment Protection Policy (Air Quality Management); see VG (2001)	The key Victorian 2001 policy governing how air quality assessments are required to be undertaken in the state, including dispersion modelling methodology.
SO_2	Sulfur dioxide	Molecular formula for sulfur dioxide
U.S. EPA	United States Environmental Protection Agency	
VG	Victoria Government	
VOC	Volatile Organic Compound	The Australian NPI definition for VOC: *Total VOC are defined as any chemical compound based on carbon chains or rings with a vapour pressure greater than 0.01 kPa at 293.15 K (i.e. 20°C), that participate in atmospheric photochemical reactions* (AG, 2009). For example, VOCs on the NPI list include: benzene, toluene, and xylenes.

Executive Summary

Introduction

AGL Wholesale Gas Limited (AGL) is proposing to develop a Liquefied Natural Gas (LNG) import facility, utilising a Floating Storage and Regasification Unit (FSRU) to be located at Crib Point on Victoria's Mornington Peninsula. The project, known as the "AGL Gas Import Jetty Project" (the Project), comprises:

- The continuous mooring of a FSRU at the existing Crib Point Jetty, which will receive LNG carriers of approximately 300 m in length
- The construction of ancillary topside jetty infrastructure (Jetty Infrastructure), including high pressure gas unloading arms and a high pressure gas flowline mounted to the jetty and connecting to a flange on the landside component to allow connection to the Crib Point Pakenham Pipeline Project.

There are several other activities that are related to the Project. These include the Jetty Upgrade and the Crib Point Pakenham Pipeline Project (Pipeline Project) which are the subject of separate assessment and approval processes carried out by separate entities.

This report provides an assessment of the air quality impacts associated with the Project. The report has been prepared to support the:

- Referral under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
- Referral under the Victorian *Environment Effects Act 1978*
- Identification of requirements under the *Environment Protection Act 1970*.

Air quality assessment methodology

This report describes the air quality impact assessment undertaken to support the Project. The assessment was undertaken in accordance with Victoria's *State Environment Protection Policy (Air Quality Management)* (SEPP) and the Environment Protection Authority (EPA) Victoria guidelines for use of the regulatory model 'AERMOD'. Senior EPA air quality specialists were consulted about the data and methodology to be used for this assessment.

a. Local meteorology and existing air quality

The air quality study area for the Project ('Study Area', defined in the main text), is located in Western Port and the Port Phillip Bay Air Quality Control Region. The local meteorology and existing air quality for the Study Area are expected to be representative of conditions in the Port Phillip Bay Air Quality Control Region, due to the extensive transport of pollutants in the wider Melbourne region. Although, air quality in the Study Area should be slightly improved, with the more heavily trafficked roadways between Frankston and Dromana being approximately 15-20 kilometres distant.

A review of meteorological studies of conditions in the wider Melbourne region, and of EPA air quality monitoring data acquired at several monitoring stations around Port Phillip Bay, was used to describe the baseline conditions for the Study Area. Modelling was used to generate wind speed and wind direction data specifically for Crib Point; these were subsequently used as inputs to the dispersion modelling for the study. The review of EPA's air quality monitoring data was used to estimate background air pollutant concentrations for the Study Area. These were added to the model predictions due to the Project forming the cumulative air quality impact assessment.

b. Meteorological data

An EPA requirement for the assessment was to use five annual datasets of hourly average meteorological parameters as input to AERMOD. These datasets were generated in accordance with the EPA guidelines for the use of AERMOD, which therefore meant that the Project's air emissions scenarios were tested using approximately 43000 separate hourly average meteorological conditions.

FSRU operating scenario and air emissions data

Information about the proposed FSRU equipment and gas operations was provided by AGL. The FSRU will comprise four reciprocating engines with power outputs of 5500kW (engine 1 or 'MGE1'), and 11000kW (engines 2-4, or 'MGE2' to 'MGE4'). Indicative (Wartsila) engine specifications were reviewed and combined with air emissions data provided by AGL to calculate the parameters needed for air dispersion modelling for two scenarios:

1) Natural-gas fuelled FSRU; and
2) Liquid (diesel) fuelled FSRU.

Visiting LNG tankers dock alongside the FSRU to unload gas are main sources of air emissions for the Project, which were included in the assessment.

The higher risk air pollutants selected for assessment were: carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulate matter as PM_{10} and $PM_{2.5}$ (see Glossary for definitions), and the following hydrocarbons or Volatile Organic Compounds (VOCs): benzene, formaldehyde, and Polycyclic Aromatic Hydrocarbons (PAHs). All these substances were assessed for a liquid (diesel) fuelled FSRU option, whereas only CO and NO_2 were identified as requiring assessment for the natural gas-fuelled FSRU option.

The modelling for NO_2 for this Project was conservative: a high NO_2/NO_x ratio of 30% was assumed for the dispersion results, which were then added to the background value of 56 µg/m^3; effectively this made the NO_2/NO_x ratio higher than 30% (so even more conservative).

Air Quality Impact Assessment Results

A complete summary of the air quality impact assessment results is provided in the following points. The focus is on comparisons of AERMOD predictions for Ground Level Concentrations (GLCs) with SEPP (AQM) design criteria.

Option A – Natural gas fuelled FSRU and LNG tanker:

- AERMOD results for CO:
  - The highest CO result, including the background estimate of 1.04 mg/m^3, was 1.32 mg/m^3 (1.14 ppm at 25^{o}C), or 4.6% of the Design Criterion
  - 99.9 percentile hourly average CO did not exceed the SEPP(AQM) Design Criterion of 29 mg/m^3 (or 25 ppm at 25^{o}C), at any of the grid receptors, nor at any of the discrete (i.e. sensitive) receptors
  - AERMOD results for CO demonstrated compliance with the SEPP(AQM) design criterion for all receptors in the Study Area.
- AERMOD results for NO_2:
  - The highest NO_2 result for the discrete receptors, including the background estimate of 56.4 µg/m^3, was 138 µg/m^3 (72.6 ppb at 25^{o}C), or 72.6% of the Design Criterion
  - 99.9 percentile hourly average NO_2 exceeded the SEPP(AQM) Design Criterion of 190 µg/m^3 (100 ppb at 25^{o}C), but only at grid receptors near the facility, with most of those occurring off-shore
  - There were no exceedences of the Design Criterion for NO_2 at any of the discrete receptors, representing the nearest sensitive receptors to the facility.

Option B – Liquid (Diesel) Fuelled FSRU and LNG tanker:

- AERMOD results for CO:
  - The highest CO result, including the background estimate of 1.04 mg/m^3, was 1.57 mg/m^3 (1.35 ppm at 25^{o}C), or 5.4% of the Design Criterion
  - 99.9 percentile hourly average CO did not exceed the SEPP(AQM) Design Criterion of 29 mg/m^3 (or 25 ppm at 25^{o}C), at any of the grid receptors, nor at any of the discrete receptors

  - AERMOD results for CO demonstrated compliance with the SEPP(AQM) design criterion for all receptors in the Study Area.
- AERMOD results for NO_2:
  - The highest NO_2 result for the discrete receptors, including the background estimate of 56.4 µg/m^3, was 163 µg/m^3 (85.8 ppb at 25ºC), or 85.8% of the Design Criterion
  - 99.9 percentile hourly average NO_2 exceeded the SEPP(AQM) Design Criterion of 190 µg/m^3 (100 ppb at 25ºC), but only at grid receptors near the facility, with most of those occurring off-shore
  - There were no exceedences of the Design Criterion for NO_2 at any of the discrete receptors, representing the nearest sensitive receptors to the facility.
- AERMOD results for SO_2:
  - The highest SO_2 result for the discrete receptors, including the background estimate of 31.4 µg/m^3, was 161 µg/m^3 (61.5 ppb at 25ºC), or 35.8% of the Design Criterion
  - 99.9 percentile hourly average SO_2 exceeded the SEPP(AQM) Design Criterion of 450 µg/m^3 (or 170 ppb at 25ºC), but only at grid receptors near the facility, with all of those occurring off-shore
  - There were no exceedences of the Design Criterion for SO^2 at any of the discrete receptors, representing the nearest sensitive receptors to the facility.
- AERMOD results for PM_{10}:
  - The highest PM_{10} result for the discrete receptors was 64 µg/m^3 including the background estimate of 47.2 µg/m^3, the total being 80.0% of the Design Criterion
  - AERMOD results for 99.9 percentile hourly average PM_{10} exceeded the SEPP(AQM) Design Criterion of 80 µg/m^3, but only at grid receptors near the facility, with all of those occurring off-shore
  - There were no exceedences of the Design Criterion for PM_{10} at any of the discrete receptors, which represent the nearest sensitive receptors to the facility.
- AERMOD results for $PM_{2.5}$:
  - The highest $PM_{2.5}$ result for the discrete receptors was 26 µg/m^3 including the background estimate of 18.9 µg/m^3, the total being 52.0% of the Design Criterion
  - 99.9 percentile hourly average $PM_{2.5}$ exceeded the SEPP(AQM) Design Criterion of 50 µg/m^3, but only at grid receptors near the facility, with all of those occurring off-shore
  - There were no exceedences of the Design Criterion for $PM_{2.5}$ at any of the discrete receptors, which represent the nearest sensitive receptors to the facility.
- AERMOD results for VOCs: Benzene, Formaldehyde and PAHs – Gas and Liquid Fuel Scenarios
  - All the AERMOD Ground Level Concentrations (GLC) results for the higher risk VOCs tested; i.e., benzene, formaldehyde and PAHs, were very low – there were no predicted exceedences at any receptors, with consideration given to background levels. A summary of results is provided in the following points:
  - Benzene – AERMOD predicted GLCs for all grid and discrete receptors were very low – less than 5 µg/m^3 (Design Criterion 53 µg/m^3). Background benzene levels were not included in results, but are expected to be low also; approximately less than 1 µg/m^3 based on a review of data provided in EPAV (2012)
  - Formaldehyde – AERMOD predicted GLCs for all grid and discrete receptors were very low – grid point maxima were less than less than 1 µg/m^3 (Design Criterion 40 µg/m^3). Background formaldehyde levels were not included in results, but are expected to be low also; approximately less than 10 µg/m^3 based on a review of data provided in EPAV (2012)
  - PAHs – AERMOD predicted GLCs for all grid and discrete receptors were very low – grid point maxima were less than 10^{-4} µg/m^3 (Design Criterion 0.73 µg/m^3). Background PAH levels were not included in results, but are expected to be low also; approximately less than 1 ng/m^3 based on a review of data provided in Reisen *et al.* (2016).

Conclusions

The AERMOD results for the gas-fuelled and liquid (diesel)-fuelled FSRU scenarios demonstrated there were no exceedences of SEPP(AQM) Design Criteria at any of the discrete receptors, for any of the pollutants.

The AERMOD modelling assessment of the FSRU scenarios demonstrated there were no exceedences of SEPP(AQM) Design Criteria for nearly all grid points over land, with the only exceedences occurring around the FSRU, and off-shore. These results for 'low risk' exceedences, primarily off-shore, were obtained for the pollutants: NO_2 (for which conservative measures were taken in the assessment), SO_2, PM_{10}, and $PM_{2.5}$.

There were no exceedences for any of the grid receptors for any of the higher risk VOCs tested by modelling; benzene, formaldehyde, and PAHs.

The general conclusion of the air quality modelling assessment is there is a low risk of air quality impact from the Project's FSRU and LNG carrier operations for on-shore sensitive receptors near Crib Point. Air pollutant emissions from the Project will not have regionally or State significant effects on the air environment.

Schedule 1 of the *Environment Protection (Scheduled Premises) Regulation 2017* sets out a list of activities that require a Licence and/or a Works Approval. Relevantly, premises which exceed air emissions thresholds are included in the list of Scheduled premises. Assessment of the emissions from the FSRU, which is intended to be operated on LNG boil-off gas as the primary fuel, has shown that emissions of NOx, CO and VOCs exceed the thresholds prescribed for scheduled premises (Type L01 – general emissions to air). As such the expectation is the FSRU will require a Works Approval and a Licence for these air emissions. The EPA assessment process for these approvals will involve close consideration of the design of the FSRU and in general this would result in approvals with conditions regarding the design and operations of the FSRU.

EPA requirements for best practice emissions controls that will be adopted for the FSRU are discussed in the main part of the report. With respect to the application of best practice technology and operations for the Project, emissions information was sought from a number of candidate FSRU providers. Data were received from two suppliers confirming the emissions performance of the engines meet U.S. EPA Tier 3 emission standards as is generally required to comply with ECA emission requirements. This is considered industry best practice for FSRUs.

The EPA's Guidelines *Recommended separation distances for industrial residual air emissions*, apply to industrial land uses and are not clearly applicable to the Project and/or the FSRU. Moreover, the Project does not meet any of the industry descriptions for Industrial Residual Air Emissions (IRAE), but the most similar industrial activities with separation distances are:

- 'Other hydrocarbon production and refining' – 500 metres
- 'Petroleum refining (including liquefying gas)' – 2000 metres.

The nearest off-site sensitive receiver (resident) to the main FSRU gas processing area at Berth 2 is located at 103 The Esplanade Crib Point, which is located approximately 1.5 kilometres from the Project. This is more than the 500 metre buffer set for "other hydrocarbon production and refining", and less than the 2 kilometre buffer set for "petroleum refining". However, the Project has fewer emissions of IRAEs than would be associated with a traditional petroleum refinery where a 2 kilometre buffer zone may be needed. As such the existing buffer is considered adequate for management of any IRAE, and this would be quantified further as part of Project HAZOP studies during the Project design phase.

Recommended management and mitigation measures include air quality monitoring during operations; preparation of an Air Quality Monitoring Plan is recommended. These measures would be included in the conditions of any EPA approvals for the Project.

1. Introduction

1.1 Project Overview

AGL Wholesale Gas Limited (AGL) is proposing to develop a Liquefied Natural Gas (LNG) import facility, utilising a Floating Storage and Regasification Unit (FSRU) to be located at Crib Point on Victoria's Mornington Peninsula. The project, known as the "AGL Gas Import Jetty Project" (the Project), comprises:

- The continuous mooring of a FSRU at the existing Crib Point Jetty, which will receive LNG carriers of approximately 300 m in length
- The construction of ancillary topside jetty infrastructure (Jetty Infrastructure), including high pressure gas unloading arms and a high pressure gas flowline mounted to the jetty and connecting to a flange on the landside component to allow connection to the Crib Point Pakenham Pipeline Project.

There are several other activities that are related to the Project. These include the Jetty Upgrade and the Crib Point Pakenham Pipeline Project (Pipeline Project) which are the subject of separate assessment and approval processes carried out by separate entities.

1.2 Purpose of this Report

Jacobs Group (Australia) Pty Ltd (Jacobs) was engaged by AGL to prepare this assessment of the air quality impacts assessment associated with the Project. This report has been prepared to support a referral under the Victorian *Environment Effects Act 1978.*

This report was prepared in accordance with the following relevant Victorian legislation, policy and guidelines (more details are provided in Section 2):

- *Environment Protection Act 1970*
- State Environment Protection Policy (Air Quality Management), or 'SEPP(AQM)'
- EPA Victoria Guidelines on the use of AERMOD (2014)
- EPA Victoria Guideline, *Demonstrating Best Practice* (2017).

1.3 Study Area

The Project is to be located at the Crib Point Jetty in Western Port, 65km south-east of Melbourne (Victoria) on the Mornington Peninsula (Project Site). The Project Site is situated on the Western Port coastline within the Shire of Mornington Peninsula.

The air quality impact assessment considered the potential effects in a wider area than the Project Site. The air quality assessment study area is illustrated in Figure 1.1, referred to in this report as the 'Study Area'.

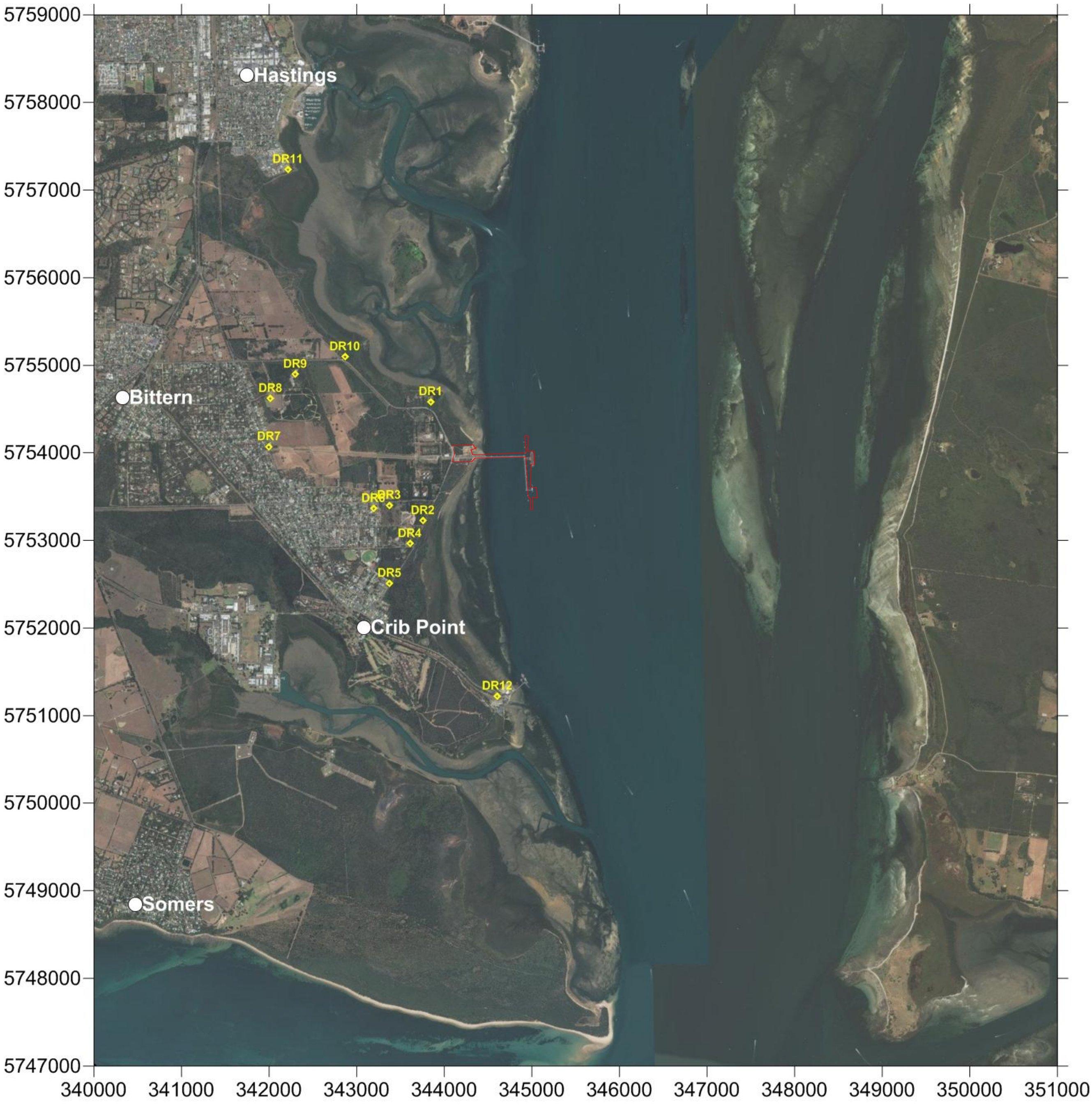

Figure 1.1 : Project air quality impact assessment Study Area*

*Note:

- The Study Area 'base map' shown in Figure 1.1 is aligned to grid north; axis labels: Horizontal axis – eastings as Map Grid Australia 1994 (MGA94) (metres); Vertical axis – northings as MGA94 northings (metres).
- Discrete Receptor (DR) locations indicated by 'DR1', 'DR2', etc. indicate locations of sensitive receptors e.g. individual residences or representative of residential area.
- The Project Site (red outline) is centrally located on the map on the shoreline between DR1 and DR2.

1.4 Project Description

The key Project components relevant to this air quality impact assessment are detailed below.

1.5 FSRU

Delivered LNG will be procured from a range of suppliers in Asia Pacific and globally. The composition and properties of the LNG will vary depending on the source. LNG will be transferred from the LNG carrier to the FSRU by flexible hoses between the vessels, delivering LNG from LNG carriers to the FSRU at a combined rate expected to be in the order of 8,000 to 11,000 m^3/hr. LNG will be vaporised and then pressurised on board the FSRU to deliver high pressure gas to the jetty via high pressure gas unloading arms.

The FSRU vessel will be continuously moored at Berth 2, shown in Figure 1-2.

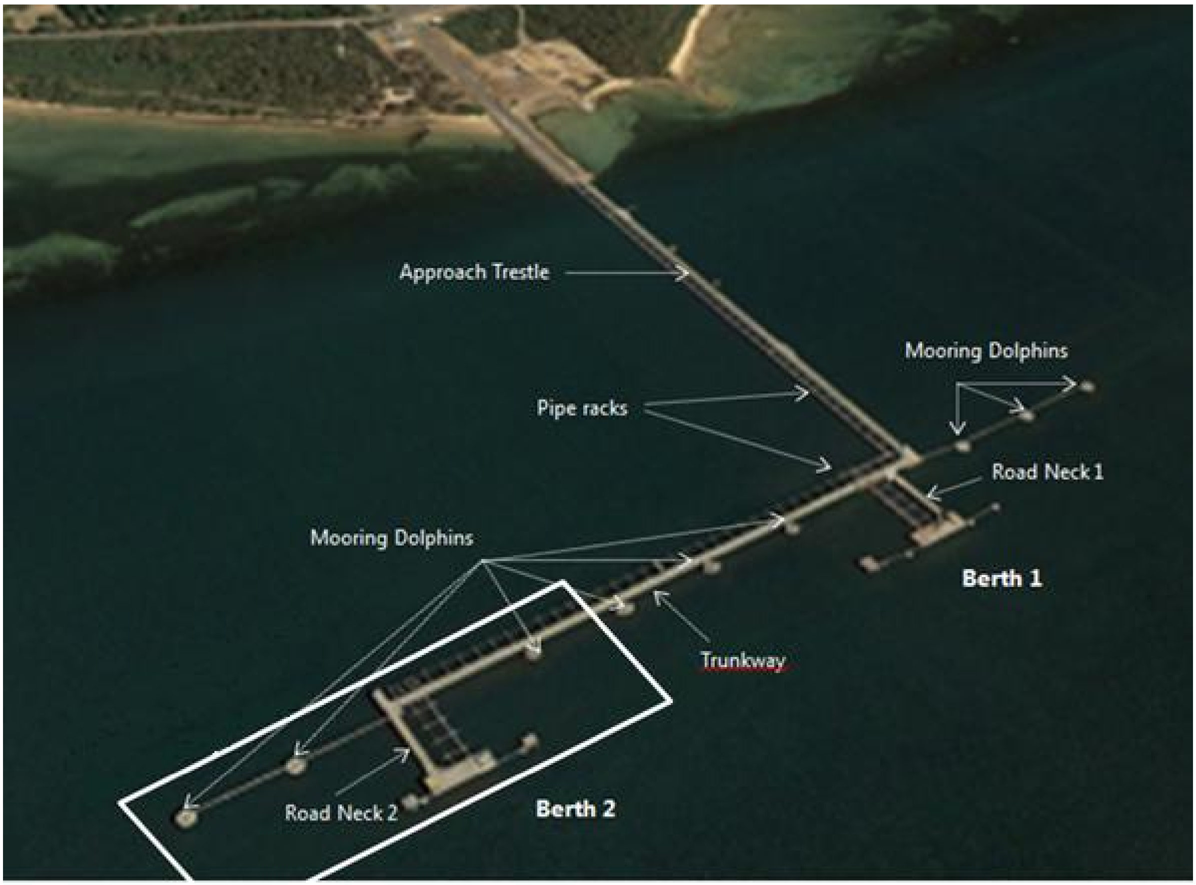

Figure 1-2 : Crib Point Jetty arrangement

The FSRU will include a regasification process that takes in and returns cooled sea water, manages boil off gas from the LNG cargo tanks, and will include power generation and the operation of four reciprocating gas engines. A review of carrier engine and emissions data from two candidate FSRUs was undertaken, and the larger of the two FSRUs selected as a conservative measure in the assessment.

Boil off gas from the LNG cargo tanks within the FSRU will be compressed for recovery and use. Excess boil-off gas can be burned either in a disposal combustor or as fuel to the vessel power generation system, provided power can be exported from the FSRU to the local grid.

Four reciprocating gas engines, located on the FSRU, will be used to provide all the power required on board, i.e. for driving the compressors, pumps, ventilation fans, general utility, etc. The engines will also provide electric power for propulsion of the FSRU. Details of the engines are provided in Table 1.1.

The engines are modern high efficiency 4-stroke, non-reversible engines with indirect injection of gas fuel. Natural gas will fuel each of the gas engines. When no gas is exported, one engine will operate at reduced capacity to support all utility power needs on the FSRU. The other three engines will not be operational. Whilst gas is being exported, all four engines (MGE No.1, No.2, No.3 and No.4) will operate at varying capacities to support the gas vaporisation, pressurisation and export processes. The operating capacities will depend on the gas export rate.

Table 1.1 : Reciprocating gas engines

Gas engine parameter	MGE No.1	MGE No.2	MGE No.3	MGE No.4
Make & Model	Wärtsilä 6L50DF	Wärtsilä 12V50DF	Wärtsilä 12V50DF	Wärtsilä 12V50DF
Power (kW)	5,500	11,000	11,000	11,000
Rotational Speed	514	514	514	514
Fuel Type (Gas / Liquid)	Gas / Liquid	Gas / Liquid	Gas / Liquid	Gas / Liquid

There will also be two auxiliary boilers and an emergency diesel generator. These will only be used for back-up power requirements when MGE No.1 or other generators are off-line for maintenance.

Air pollution emissions associated with construction activities are considered minor and immaterial compared with the operational footprint of the Project and consequently construction air emissions are not quantified.

The FSRU delivers odourless gas from the Jetty to the onshore gas receival facilities via a high pressure pipeline. Within the onshore gas receival facilities the gas in odourised prior to being dispatched into Victoria’s natural gas transmission network. The environmental assessment of the onshore gas receival facilities, including gas odourisation is being undertaken as part of the Pipeline Project, hence is separate to this assessment.

1.6 Limitations

For the purposes of assessing the potential for the Project to impact upon air quality, Jacobs relied upon information provided by AGL regarding their proposed activities at the site. A conservative approach to assessment was undertaken – for example, a review of information from a number of sources was undertaken to provide a greater level of certainty for the air emissions estimates for each air quality indicator tested.

The air quality impact assessment was limited by, primarily, the FSRU equipment specifications and operational data provided by AGL. The details of the FSRU will not be known until procurement tenders are complete. For the purpose of this assessment Jacobs have reviewed ship engine and emissions data from two candidate FSRUs and picked the larger of the two for the purpose of the assessment.

Critical air emissions parameters such as stack heights, exhaust velocities and air pollutant emission rates were used to determine input emissions data for dispersion modelling, which formed the basis of the assessment.

Also, there was no information about LNG tankers unloading LNG to the FSRU for this Project. As such LNG tanker data were obtained from the air quality assessment supporting the Arrow LNG proposal for Port Curtis, near Gladstone in Queensland (Katestone, 2011).

2. Legislation, Policy and Guidelines

2.1 Overview

Legislation, policy and guidelines relevant to the air quality impact assessment for the Project are set out in Table 2.1. Key regulatory / policy requirements are outlined in more detail in Sections 2.2, 2.5 and 2.6.

Table 2.1 : Legislation, policy and guidelines – air quality impact assessment

Legislation / policy	Key policies / strategies	Implications for this project	Approvals required	Timing/ interdependencies
State				
Environment Effects Act 1978	The *Environment Effects Act 1978* provides for the assessment of actions that are capable of having a significant environmental effect. Actions which might have a significant environmental effect should be referred to the Victorian Minister for Planning, who decides if an Environment Effects Statement (EES) is required. An EES might be required where: · There is a likelihood of regionally or state significant adverse environmental effects · There is a need for an integrated assessment of social and economic effects of a project or relevant alternatives · Normal statutory processes would not provide a sufficiently comprehensive, integrated and transparent assessment. This Act also allows an applicant to write to the Secretary of the DELWP to confirm no EES is required.	Determine whether the emissions to air will have potential effects on the health, safety or well-being of a human community and if this would trigger the need for a referral under the *Environment Effects Act 1978*.	Based on the environmental assessments completed to date, the Project will not be likely to have regionally or State significant adverse effects on the environment, and therefore would not trigger the requirements for an EES. AGL will consult further with the government on any requirements under the *Environment Effects Act 1978*.	N/A

Legislation / policy	Key policies / strategies	Implications for this project	Approvals required	Timing/ interdependencies
Environment Protection Act 1970	The *Environment Protection Act 1970* (EP Act) provides a legal framework to protect the environment in the State of Victoria. It applies to noise emissions and the air, water and land in Victoria.	The EP Act requires a Licence and/or a Works Approval for premises scheduled under the Schedule 1 of the *Environment Protection (Scheduled Premises) Regulation 2017.* The SEPP AQM and SEPP AAQ are subordinate legislation made under the provisions of the EP Act to provide more detailed requirements for the application of the Act.	We understand that the FSRU will require a Works Approval and Licence for air emissions.	Engagement with EPA regarding Works Approval and Licence requirements in the planning phase. Licence approval required prior to FSRU operations commencing
Environment Protection (Scheduled Premises) Regulation 2017	Schedule 1 of the *Environment Protection (Scheduled Premises) Regulation 2017* sets out a list of activities that require a Licence and/or a Works Approval under the EP Act.	Premises which exceed air emissions thresholds are included in the list of scheduled premises	Assessment of the emissions from the FSRU, which is intended to be operated on LNG boil-off gas as the primary fuel, has shown that emissions of NOx, CO and VOCs exceed the thresholds prescribed for scheduled premises (Type L01 – general emissions to air). We understand that the FSRU will require a Works Approval and a Licence for these air emissions.	Engagement with EPA regarding Works Approval and Licence requirements in the planning phase. Licence approval required prior to FSRU operations commencing

Legislation / policy	Key policies / strategies	Implications for this project	Approvals required	Timing/ interdependencies
State Environment Protection Policy (Air Quality Management) (Victoria Government, 2001)	The SEPP(AQM) establishes a framework for managing air emissions and sets out a program for action to protect the environment and achieve regional air quality objectives of the State Environment Protection Policy (Ambient Air Quality)	The FSRU is a ship which falls within the meaning of a "mobile source", however, it will be stationary during its normal regasification, gas storage and cargo discharge activities. Accordingly, the emission limits in Schedule E of the SEPP AQM for new stationary sources were extended to the FSRU. Assuming that the SEPP AQM applies to the Project, assessment was undertaken in accordance with requirements of SEPP(AQM) and guidelines for the use of Victoria's regulatory model AERMOD.	Preliminary discussions with EPA's air quality specialists on 12 September 2017 confirmed some details of data and methodology	Discussions with EPA air quality specialists completed prior to commencement of air dispersion modelling (12 Sept. 2017)
State Environment Protection Policy (Ambient Air Quality) (Victoria Government, 1999); and variation (Victoria Government, 2016)	Sets out the state's regional air quality objectives for 'criteria' pollutants by adopting the requirements of the National Environment Protection Council (Ambient Air Quality) Measure	EPA / other authorities may request to see the PM_{10} and $PM_{2.5}$ results expressed as 24 hourly averages and annual averages to enable comparisons with the new particulate matter standards set out in VG (2016).	N/A	Further processing of AERMOD results for particulate matter may be requested by EPA / other authorities; this would take up to approximately one week to deliver.
EPA Publication 1517, Demonstrating Best Practice, February 2017	The SEPP AQM sets out what must be done to protect Victoria's air environment; sources of air discharges must be managed in accordance with 'best practice'	This Guideline provides guidance on demonstrating compliance with best practice requirements set out in the SEPP AQM. This report in Section 2.5 and Section 4.4 makes a project consideration of best practice.	N/A	N/A
EPA Publication 1518, Recommended Separation Distances for Industrial Residual Air Emissions (IRAEs) March *2013*	The EPA Publication 1518 March *2013 Recommended separation distances for Industrial Residual Air Emissions (IRAEs)* sets out separation distances for industrial land uses regarding 'unintended' or non-routine emissions that can be intermittent or episodic and may originate at or near ground level.	No specific IRAE separation distance for this industry type. Design phase HAZOP studies will need to establish the safety case for any unintended emission release.	N/A	Design phase

2.2 Environment Protection Act 1970

The *Environment Protection Act 1970* (EP Act) provides a legal framework to protect the environment in the State of Victoria. It applies to noise emissions and the air, water and land in Victoria.

The EP Act requires a licence and/or a works approval for premises scheduled under the Schedule 1 of the Environment Protection (Scheduled Premises) Regulation 2017.

2.3 Environment Protection (Scheduled Premises) Regulation 2017

Schedule 1 of the Environment Protection (Scheduled Premises) Regulation 2017 sets out definition of facilities that are considered Scheduled under the Regulation.

L01 (General Emissions to Air) provides the following scheduled premise definition:

Premises which discharge or emit, or from which it is proposed to discharge or emit, to the atmosphere any of the following:

a) *at least 100 kilograms per day of:*
   i. volatile organic compounds; or
   ii. particles; or
   iii. sulphur oxides; or
   iv. nitrogen oxides; or
   v. other acid gases (excluding carbon dioxide);
b) *at least 500 kilograms per day of carbon monoxide;*
c) *any quantity from any industrial plant or fuel burning equipment of any substance classified as a Class 3 indicator.*

2.4 State Environment Protection Policy (Air Quality Management)

The SEPP AQM is subordinate legislation made under the provisions of the EP Act to provide more detailed requirements for the application of the EP Act.

2.4.1 Emission standards

The Project, at Crib Point, is located within the Port Philip Air Quality Control Region (AQCR).

The FSRU is a ship which falls within the meaning of a "mobile source", however, it will be stationary during its normal regasification, gas storage and cargo discharge activities. If the FSRU is assessed as a new stationary source, then it must meet the emission limits in Schedule E of the SEPP AQM. A "stationary source" means a "source of emissions of wastes to air from commercial or industrial premises that is stationary during its normal operating mode". For the purposes of this assessment the air emissions from the FSRU have been assessed against the limits for stationary sources.

The SEPP(AQM) air emission limits for stationary sources are listed in Schedule E of the SEPP(AQM); the emission limits that are relevant to the Project (i.e. inside AQCRs) are listed in Table 2.2. These emission limits must be complied with unless EPA has specified conditions or approvals under which excess emissions from events such as commissioning, start-up or shut-down are permitted.

Table 2.2 : Project relevant SEPP(AQM) Schedule E emission limits for stationary sources in Victoria

Emissions source	Waste; applicable source	Emission limit (g/Nm^3) [1]
Recip. Engine	Particulate Matter (PM)	0.25
Gas Turbine less than 30 MW	Particulate Matter (PM)	0.25
	Carbon Monoxide (CO)	2.5
	Oxides of Nitrogen (NO_X) – gas fuel	0.09
	Oxides of Nitrogen (NO_X) – liquid fuel	0.15
Boiler	Particulate Matter (PM)	0.25
	Carbon Monoxide (CO)	2.5
	Oxides of Nitrogen (NO_X) – gas fuel	0.35
	Oxides of Nitrogen (NO_X) – liquid fuel	0.50

Note 1. Gas volumes are expressed at 25°C and at an absolute pressure of one atmosphere (1013.25 hPa).

Note 2. C_M is the measured NO_x concentration (g/m^3); O_2 concentrations expressed volumetrically.

Note 3. Dilution of wastes to meet emission limits shall not be permitted except where noted.

2.4.2 Ambient air quality design criteria

The SEPP(AQM) ambient air quality standards are set out as ‘indicators’ (substances) and their ‘Design Criteria’, the latter being limits for Ground Level Concentrations (GLCs). The Design Criteria for class 1, class 2 and class 3 indicators, for the purpose of assessing proposals for new emission sources or modifications to existing emission sources, are established in Schedule A of the SEPP(AQM). The Design Criteria are used in conjunction with the modelling procedures outlined in Schedule C of SEPP(AQM).

The indicators, Design Criteria, averaging periods and standards used in this air quality assessment supporting the Project are set out in Table 2.3.

Table 2.3 : Project relevant SEPP AQM design criteria

Substance	Reason for classification	Averaging time	Design criteria (mg/m^3) (1)	Design criteria (ppm)
Carbon monoxide (CO)	Toxicity	1 hour	29	25
Nitrogen dioxide (NO_2)	Toxicity	1 hour	0.19	0.1
Particulate Matter 2.5 ($PM_{2.5}$)	Toxicity	1 hour	0.050	–
Particulate Matter 10 (PM_{10})	Toxicity	1 hour	0.080	–
Sulfur dioxide (SO_2)	Toxicity	1 hour	0.45	0.17
Polycyclic Aromatic Hydrocarbons (PAH) as BaP	IARC Group 2A carcinogen	3 minutes	0.053	0.017
VOCs (2) benzene	IARC Group 1 carcinogen	3 minutes	0.00073	–
VOCs (3) formaldehyde	IARC Group 2A carcinogen	3 minutes	0.04	0.033

Note 1. Gas volumes are expressed at 25°C and at an absolute pressure of one atmosphere (1013.25 hPa).

Note 2,3. International Agency for Research on Cancer.

It should be noted that benzene and formaldehyde were selected from a risk assessment of emissions estimates for individual VOCs from gas engines due to being products of combustion.

2.5 EPA Requirements for Best Practice Emission Control

Under the *Environment Protection Act 1970* (the EP Act), State Environment Protection Policies (SEPPs) set out what must be done to protect Victoria's environment concerning potential impacts to air, water and land, and the control of noise. Sources of emissions or discharges to the environment must be managed in accordance with 'best practice'.

With respect to air pollutant emissions, the SEPP (AQM) defines 'best practice' as: '*the best combination of eco-efficient techniques, methods, processes or technology used in an industry sector or activity that demonstrably minimises the environmental impact of a generator of emissions in that industry sector or activity*'.

The SEPP (AQM) requires application of 'best practice' and continuous improvement for all relevant indicators and reductions to the 'Maximum Extent Achievable' (MEA) for the more hazardous air pollutants (class 3 indicators).

In the case of air emissions, best practice can be distinguished from the requirement to reduce emissions of hazardous air pollutants to their MEA. An MEA requirement gives less consideration to cost, and places more emphasis on minimising risk to human health than a 'best practice' or 'best practicable measures' requirement.

In contrast, a degree of pragmatism and cost effectiveness is implied in the EPA (2017) guideline '*Demonstrating Best Practice*', which assists with the assessment of best practice. The EPA's approach to assessing best practice is to use a risk based approach where the following items are considered:

- Scope – the activity being proposed and its relevant industry sector
- Options review – a broad summary outlining the range of options available for the proposed works (including the 'do nothing' option), and a brief indication of why they were considered or discarded
- Best practice analysis – a statement or detailed analysis commensurate to the priorities identified in the environmental risk assessment, describing how the proposal constitutes best practice
- Best practice assessment – having considered all available evidence, the assessment provides an integrated conclusion to the best practice analysis demonstrating the best combination of eco-efficient techniques, methods, processes or technology (as relevant) and summarising the justification of the preferred approach.

EPA (2017) outlines suggested evidence or analysis techniques that can be used to demonstrate an assessment of best practice for a Works Approval Application. Types of evidence include:

- Literature review
- Benchmarking
- Application of the wastes hierarchy
- Integration of economic, social and environmental considerations
- Integrated environmental assessment.

2.6 Industrial Residual Air Emissions (IRAEs)

The EPA Publication 1518 March *2013 Recommended separation distances for Industrial Residual Air Emissions (IRAEs)* apply to industrial land uses and are not clearly applicable to the Project and/or the FSRU. It sets out separation distances for 'unintended' or non-routine emissions that can be intermittent or episodic and may originate at or near ground level. The purpose of a separation distance is to avoid the potential consequences of IRAEs. An adequate separation distance should allow IRAEs to dissipate without adverse impacts on sensitive land uses.

The Project does not meet any of the industry descriptions for which the IRAE separation distances are set in EPA Publication 1518. The most similar industrial activities with separation distances are as follows:

- Other hydrocarbon production and refining – 500 m

- Petroleum refining (including liquefying gas) – 2000 m.

The nearest off-site sensitive receiver (resident) to the main FSRU gas processing area at Berth 2 is located at 103 The Esplanade Crib Point, approximately 1.5 km from the Project. This is more than the 500 metre buffer set for "other hydrocarbon production and refining", and less than the 2 kilometre buffer set for "petroleum refining". As outlined in Section 3, there are few sources of emissions including IRAEs associated with the Project, and fewer IRAEs than would be associated with a traditional petroleum refinery where a 2km buffer zone may be needed. As such the existing buffer is considered adequate for management of emissions of any IRAEs, and this would be quantified further as part of Project HAZOP studies during the Project design phase.

3. Method – Air quality Impact Assessment

This section sets out the Project air quality impact assessment methodology.

3.1 Inputs

Key input data required for the air quality impact assessment component of the Project were:

- Project FSRU equipment fleet and locations
- Details of FSRU operating regimes
- Existing air quality monitoring data and local meteorological data
- Land use and terrain elevations for the Study Area
- Locations of sensitive receptors, primarily locations of individual residences closest to the Project Site.

3.2 Assessment of Operational Air Quality Impacts

The air quality impact assessment methodology for the Project operations at Crib Point was based on the procedures set out in the *State Environment Protection Policy (Air Quality Management)*, or 'SEPP(AQM)', and in the EPA Guidelines for use of the regulatory model AERMOD (EPA, 2014a; EPA, 2014b).

Key aspects of the methodology and data to be used in the assessment were discussed and agreed with EPA air quality specialists on 12 September, 2017. This included using a five-year dataset of recent, hourly meteorological data for modelling, in accordance with EPA (2014a). This is discussed further in **Section 3.5** (Stakeholder Engagement), and Section 5.1.2 (Local Dispersion Meteorology).

The assessment of the Project's air emissions comprised these two main steps:

- Modelling the transport and dispersion of air pollutant emissions from key sources identified for the Project
- Comparisons of AERMOD predictions for Ground Level Concentrations (GLCs) for each pollutant with corresponding SEPP(AQM) Design Criteria, after existing (or 'background') air pollutant concentrations were added to the AERMOD results.

The key sources of air pollutant emissions identified for assessment were the large, gas-fuelled or liquid i.e. diesel-fuelled reciprocating engines of the FSRU and LNG tanker or carrier.

A detailed air emissions inventory was developed for use in the dispersion modelling assessment, in consultation with AGL. A review of Australian and international emissions factors for marine and large reciprocating engines was undertaken to ensure a reasonable degree of consistency between the emission rates calculated for the sources.

The Study Area lies within the Mornington Peninsula Local Government Area, therefore lies within the Port Phillip Air Quality Control Region (AQCR) (VG, 2001). Comparisons of the FSRU air emissions estimates were made with the emissions limits set out in the SEPP(AQM) for the Port Phillip Air AQCR (refer to Section 2.4.1).

The modelled sources were ship engine stacks or funnels, or 'point' sources as they are described in dispersion modelling. Air emissions estimates were calculated for the stacks for use with AERMOD.

3.3 AERMOD Modelling Methods

The latest version of AERMOD (Version 16216r; 17/1/2017), was used for predictions of air pollutant concentrations.

AERMOD is a 'steady-state' plume model: in the stable boundary layer the model assumes the concentration distribution to be Gaussian in both the vertical and horizontal. In the convective boundary layer the horizontal distribution is also assumed to be Gaussian, but the vertical distribution is described with a bi-Gaussian probability density function (U.S. EPA, 2004). AERMOD is applicable to rural and urban areas, flat and complex terrain, surface and elevated releases, and multiple sources (U.S. EPA, 2004).

Main AERMOD parameters and settings used for this Project are listed in Table 3.1.

Table 3.1 : Main AERMOD parameters and settings

Parameter	Value
AERMOD executable version	Version 16216r, 17/1/2017
Model domain	131 x 141 grid points; 13.0 km x 14.0 km
Horizontal grid resolution	100 metres
Terrain	Relatively flat terrain however Digital Terrain Model created using the Geoscience Australia Elevation Information System; http://www.ga.gov.au/elvis/, using the 1 second (approximately 30 metre) Shuttle Radar Topography Mission Digital Elevation Models Version 1.0 package.
Land use	Coastal, rural
Low wind speed algorithm	LOWWIND1
Wake/downwash effects	Building Profile Input Program used to provide wake effects around the FSRU and LNG carrier vessels, superstructure and funnels
Meteorological data	Five years of hourly meteorological data using BoM Cerberus meteorological observations and processed as input files for use with AERMOD in accordance with EPA (2014a).

Sensitivity tests were undertaken for the Project using the lower wind speed algorithms (‘LOWWIND’), in AERMOD. The LOWWIND algorithms were tested using FSRU NOx emissions data. The ‘LOWWIND1’ scheme was selected for use with the Project data, given its conservative, slightly higher results for predicted NOx GLCs.

Ship (airflow) wake effects and airflow downwash effects were tested in AERMOD using a Building Profile Input Program (BPIP). While the modelled airflow wake effects were negligible beyond approximately one kilometre from the Project Site, the BPIP effects were included in all the modelling scenarios as the ‘near-field’ results were significant; i.e., noticeable effects in the predicted air pollutant GLCs within approximately one kilometre of the Project Site.

The AERMOD modelling used NOx emissions estimates as input. The AERMOD predictions for NOx GLCs were converted to NO_2 to enable comparisons with the SEPP(AQM) Design Criterion for NO_2. A conservative scheme was used to calculate NO_2 GLCs from the AERMOD results for NOx. The review of NO_2 and NOx monitoring data for the Melbourne region demonstrated that high NO_2/NOx ratios are never detected for the high NOx concentrations, with the NO_2/NOx ratio trending downwards to approximately 15-20% for the highest NOx concentrations. As a focus of this assessment was on higher concentrations of NO_2, a fixed NO_2/NOx ratio of 30% (conservative, high), was used to convert the AERMOD predicted NOx GLCs to NO_2. The second step in the assessment of NO_2 GLCs was to add background NO_2 levels to the AERMOD predictions – effectively making the NO_2/NOx higher than 30%; i.e., more conservative again.

Emissions of PM_{10} and $PM_{2.5}$ from the gas-fired FSRU were assumed to be negligible – prior to modelling, the risk of air quality impact for each of the air pollutants could be determined by comparisons of emission rates with Design Criteria. As such the assessment of particulate matter emissions from the stacks was confined to the liquid-fuelled FSRU scenario.

The PM_{10} emission rates were determined using AGL data. A $PM_{2.5}$/PM_{10} ratio of 83.7% was determined using *EETM for Marine Operations* emission factors for a weighted average fuel (AG, 2012).

The AERMOD results for hydrocarbons or Volatile Organic Compounds (VOCs) were processed to determine fractions of the highest risk VOCs determined for the Project; i.e., benzene, formaldehyde and Polycyclic Aromatic Hydrocarbons (PAHs), the latter assessed as Benzo(a)Pyrene or ‘B(a)P’. The VOCs fractions were determined by analysis of emission factors for the individual VOCs set out in the *EETM for Combustion Engines* (AG, 2008), and the *EETM for Marine Operations* (AG, 2012).

3.4 Assumptions

Acknowledging air emissions from the high pressure flowline mounted on the Jetty (ship to shore) are expected to be minimal, no quantitative assessment including air dispersion modelling was undertaken for the pipeline.

Odourisation of the natural gas before dispatch into the Victorian gas transmission pipeline network is outside the scope of the Project being assessed here.

3.5 Stakeholder Engagement

Key aspects of the air quality impact assessment methodology, and data to be used with AERMOD, were discussed and agreed with EPA air quality specialists Dr. Paul Torre and Mr. Gavin Fisher, on 12 September, 2017. Key outcomes of this discussion with respect to the modelling assessment were:

- Use of AERMOD in accordance with EPA (2014b)
- Use of five years of hourly meteorological data with AERMOD in accordance with EPA (2014a)
- Identification and assessment of emissions of all higher risk substances identified for the Project
- Use of reasonable estimates for background air pollutant levels, with an acknowledgement that there were no air quality monitoring data available for the Study Area, or even for the wider Western Port area (background levels to be estimated based on a review of data from other locations).

4. Project Air Pollution Emissions

This section sets out the air emissions estimates for the Project with specific reference to FSRU and LNG carrier operations.

4.1 Main FSRU Operating and Air Emissions Parameters

The details of the FSRU and LNG carriers will not be known until procurement tenders are complete. For the purpose of this assessment Jacobs have reviewed ship engine and emissions data from two candidate FSRUs and picked the larger of the two for the purpose of the assessment.

The assessment of the FSRU emissions was based on a reference plant, which assumes continuous operations by an FSRU with four, large, marine reciprocating engines: one 6-cylinder Wärtsilä 6L50DF engine with power rating 5500 kilowatt (kW), and three Wärtsilä 12V50DF 12-cylinder engines with power ratings 11000 kW. The main FSRU engine operating parameters and main air emissions parameters provided by AGL are set out in Table 4.1.

Table 4.1 : FSRU Engine operating and main air emissions parameters

Parameter & Measurement Basis	Exhaust 1	Exhaust 2	Exhaust 3	Exhaust 4
Engine name	MGE No 1	MGE No 2	MGE No 3	MGE No 4
Engine make & model	Wärtsilä 6L50DF	Wärtsilä 12V50DF	Wärtsilä 12V50DF	Wärtsilä 12V50DF
Power rating	5500 kW	11000 kW	11000 kW	11000 kW
Rotational speed	514 RPM	514 RPM	514 RPM	514 RPM
Fuel type	Gas | Liquid	Gas | Liquid	Gas | Liquid	Gas | Liquid
Height above deck	24.7 m	24.7 m	24.7 m	24.7 m
Outlet orientation	Vertical	Vertical	Vertical	Vertical
Diffuser description	Silencer	Silencer	Silencer	Silencer
Outlet area	0.64 m^2	1.33 m^2	1.33 m^2	1.33 m^2
Discharge rate; 100%	7.3 Nm^3/s | 8.9 Nm^3/s	14.5 Nm^3/s | 17.8 Nm^3/s	14.5 Nm^3/s | 17.9 Nm^3/s	14.5 Nm^3/s | 17.10 Nm^3/s
Exhaust temp. (Wärtsilä)	378^o C | 347^o C	378^o C | 347^o C	378^o C | 347^o C	378^o C | 347^o C
Emissions, 75% Load				
Particulates ISO 9096 | 5% O_2	0.027 g/Nm^3	0.027 g/Nm^3	0.027 g/Nm^3	0.027 g/Nm^3
NOx | 5% O_2	0.5 g/Nm^3	0.5 g/Nm^3	0.5 g/Nm^3	0.5 g/Nm^3
CO | 5% O_2	0.492 g/Nm^3	0.492 g/Nm^3	0.492 g/Nm^3	0.492 g/Nm^3
VOCs	No data	No data	No data	No data
H_2S	No data	No data	No data	No data
SO_2	0.1	0.1	0.1	0.1

To assist with setting air emissions estimates for dispersion modelling, a review was undertaken of air emissions estimates for marine engines and cross-checked with the FSRU data set out in **Table 4.1**. Sources reviewed included the National Pollutant Inventory (NPI) emission factors set out in the Emissions Estimation Technique Manual (EETM) for Combustion Engines (AG, 2008), the *EETM for Marine Operations* (AG, 2012), and U.S. Environmental Protection Agency (U.S. EPA) exhaust emission standards for Category 3 engines (U.S. EPA, 2017).

The U.S. EPA (2017) 'Tier 3' emissions factor limits (which the Wärtsilä engines are stated to comply with) reviewed for use in the assessment were:

- For NOx – regardless of fuel type, NOx (g/kWh) = 9.0 x $n^{(-0.2)}$, where '*n*' is engine speed in the range 130-2000 RPM (FSRU engine speed is 514 RPM)
- For CO – regardless of fuel type, the CO emissions factor limit is 5.0 g/kWh
- Hydrocarbons – standard for Tier 2 and later engines is 2.0 g/kWh (diesel fuelled); natural gas fuelled engines 'must comply with hydrocarbon standards based on non-methane hydrocarbon emissions' (for this Project an adjustment was made accordingly, to the diesel limit of 2.0 g/kWh).

More details of the air emissions estimates used in the modelling for the two FSRU scenarios; i.e., natural gas-fuelled and diesel-fuelled, are set out the tables in the following two sub-sections.

4.2 FSRU Emissions

The FSRU is intended to be operated on LNG boil-off gas as the primary fuel. The candidate FSRU used for assessment purposes has dual fuel engines, with the primary fuel natural gas and back-up fuel diesel which would be used in the event of a gas outage.

4.2.1 Gas-fuelled FSRU

The air emissions estimate for NOx, CO, VOCs (VOCs), determined for the gas-fuelled FSRU scenario, are set out in Table 4.2. Particulate matter and SO_2 were omitted from the assessment of emissions from the gas-fuelled FSRU, due to their small emissions with a low risk of air quality impact; i.e., the ratios of mass emissions rates to their design criteria were low. Also included in Table 4.2 are the calculated daily emissions. It can be seen that emissions of NOx, CO and VOCs exceed the thresholds prescribed for scheduled premises as specified in the Environment Protection (Scheduled Premises) Regulation 2017 (refer to Section 2.2).

The total VOC emission limits for gas and diesel are the same (US EPA Tier 2/3), set at 2.0 g/kWh. As such speciated VOCs are assessed as part of the liquid (diesel) fuelled scenario.

Table 4.2 : Calculated air emission rates for the gas-fuelled FSRU (g/sec)

Substance	MGE 1	MGE 2	MGE 3	MGE 4	MGE1-4 (kg/day)	Notes
NOx	3.7	7.3	7.3	7.3	2212	Based on U.S. Tier 3 emission limit
CO	3.6	7.1	7.1	7.1	2151	Based on U.S. Tier 3 emission limit
VOCs	3.06	6.11	6.11	6.11	1848	Scaled Tier 3 emissions limit#

4.2.2 Liquid-fuelled FSRU

The air emissions estimate for particulate matter as PM_{10} and $PM_{2.5}$, NOx, CO, SO_2, TVOCs, benzene, formaldehyde and PAHs determined for the liquid-fuelled FSRU scenario, are set out in Table 4.3.

To determine the $PM_{2.5}$ emission rate, a $PM_{2.5}/PM_{10}$ ratio of 83.7% was calculated from emission factors for marine engines (weighted average burn), provided in AG (2012).

The benzene, formaldehyde and PAH fractions of TVOCs were determined by ratios between AG (2008) emission factors for large diesel engines.

It is noted that the FSRU will most likely use gas fuel (boil off gas) for combustion in the power plant engines. Liquid fuel (marine gas oil – MGO) would be used in back-up circumstances and is included in the modelling for completeness.

Table 4.3 : Calculated air emission rates for the liquid-fuelled FSRU (g/sec)

Substance	MGE 1	MGE 2	MGE 3	MGE 4	Notes
PM_{10}	0.24	0.48	0.48	0.46	No Tier 3 limits; used AGL data
$PM_{2.5}$	0.20	0.40	0.40	0.39	Used $PM_{2.5}/PM_{10}$ = 83.7%
NOx	16.0	32.0	32.0	32.0	Based on U.S. Tier 3 emission limit
CO	7.6	15.3	15.3	15.3	Based on U.S. Tier 3 emission limit
SO_2	0.89	1.78	1.79	1.71	No Tier 3 data; used AGL data
VOCs	3.06	6.11	6.11	6.11	Based on U.S. Tier 3 emissions limit
Benzene	0.030	0.059	0.059	0.059	Based on NPI fractions for diesel eng.
Formaldehyde	0.003	0.006	0.006	0.006	Based on NPI fractions for diesel eng.
PAHs	4.4E-07	8.8E-07	8.8E-07	8.8E-07	Based on NPI fractions for diesel eng.

4.3 Air Emissions Estimates for Liquid-fuelled LNG Tanker

The air emissions estimates determined for the liquid-fuelled LNG carrier (or tanker) unloading to the FSRU were based on those from Katestone (2011), for the Arrow LNG proposal. The LNG tanker data used in the modelling assessment for the Project are set out in Table 4.4.

Table 4.4 : Air emission rates and other data for the liquid-fuelled LNG carrier

Substance	LNG Carrier, Main Engine	LNG Carrier, Auxiliary Engine	Notes
Emission rates (g/sec.)			
$PM_{2.5}$	0.89	0.67	
PM_{10}	2.38	1.78	
NOx	44.02	33.01	
CO	3.48	2.61	
SO_2	19.51	14.63	
Benzene	2.41E-02	1.81E-02	
Formaldehyde	1.12E-03	8.38E-04	
PAHs	1.90E-10	1.43E-10	Using emission factors from NPI EETM for Combustion Engines (AG, 2008)
Other data			
Single stack co-ordinate location		Easting 345067 m.; Northing 5753943 m.	
Stack height		37.0 m Above Sea Level	
Stack diameter		1.70 m	
Exhaust gas temperature		155° C	
Exhaust gas velocity		6.7 m/s	

4.4 Consideration of Project Best Practice

As outlined in Section 2.5 with respect to air pollutant emissions, the SEPP (AQM) defines 'best practice' as: '*the best combination of eco-efficient techniques, methods, processes or technology used in an industry sector or activity that demonstrably minimises the environmental impact of a generator of emissions in that industry sector or activity*'.

With respect to review of literature a Lloyd's Register guidance document *Floating Storage and Regasification Units Version 1.3 / June 2017* (Lloyd's 2017) provides a recent summary of FSRU operations including industry best practice. The following provides a summary of elements of this document with comparison to this Project so as to consider and assess best practice with respect to project air pollution emissions and their management.

Lloyd's, 2017 states that FSRUs are not new in the gas sector. They have been traditionally used as enablers for opening up new markets to LNG suppliers. Drivers that affect the approach (seaborne or land-based) adopted for bringing gas to the end consumers are many and need to be understood. These are project-specific and a combination of market-driven technological, geopolitical and environmental factors.

Seaborne storage and regasification through FSRUs is still a niche market. However, there has been significant recent growth, and market developments indicate further expansion and more business opportunities. This market evolution depends on the supply and demand developments for gas. From the supply side, this refers to developments in the production and liquefaction stage and developments in the transportation of seaborne LNG. From the demand side, it refers to the development at end consumers.

Lloyd's 2017 states that compared with land based LNG storage and regasification, FSRU's offer "lighter environmental footprints".

With respect to air pollution emissions the main project emission sources are the FSRU engines used for both power and propulsion. Lloyd's 2017 states that the power generation requirements for floating units begin at just above 1,500 kW and can go up to 40,000 kW. This depends on the power consumers and the unit's designation. As outlined in Table 4.1 for the purpose of this assessment power generation for the reference plant is assessed at the upper end of this range at 38,000 kW.

The ability of floating units to use cargo LNG as fuel is a common feature, as this offers the ability to manage boil-off gas (BOG) even on units with regasification plants at times when the plant is not operating. The use of BOG is further driven by the fact FSRUs operate in international waters including MARPOL designated Emission Control Areas (ECAs) where compliance with strict sulfur oxides (SO_X) and nitrogen oxides (NO_X) requirements is needed. Therefore, suitable considerations for dual-fuel technologies is generally made, with emissions of SO_X and NOx being lower gas fired engines compared with liquid fuelled e.g. MGO engines.

As outlined above for this project, emissions information was sought from a number of candidate FSRU providers. Data was received from two suppliers confirming the emissions performance of the engines meet US EPA Tier 3 emission standards as is generally required to comply with ECA emission requirements. This is considered industry best practice for FSRUs.

The reference plant is an FSRU with one 6-cylinder Wärtsilä 6L50DF engine with power rating 5500 kW, and three Wärtsilä 12V50DF 12-cylinder engines with power ratings 11000 kW. Wärtsilä are leading suppliers of large marine diesel engines. For the Wärtsilä 50DF engine range operating on gas, NO_X and CO_2 emissions are substantially lower than for diesel engines.

Stringent International emission regulations demand the reduction of NO_X emissions compared with traditional engines. In an internal combustion engine this means controlling peak temperature and residence time, which are the main parameters governing NO_X formation. In the Wärtsilä 50DF engine, the air-fuel ratio is very high (typically 2.2). Since the same specific heat quantity released by combustion is used to heat up a larger mass of air, the maximum temperature and consequently NO_X formation are lower. The mixture is uniform throughout the cylinder since the fuel and air are premixed before introduction into the cylinders, which helps to avoid local NO_X formation points within the cylinder. Benefiting from this unique feature, NO_X emissions from the Wärtsilä 50DF are extremely low and comply with the most stringent existing international legislation for large marine engines,

5. Existing Conditions

This section describes aspects of local meteorology important for the dispersion of air emissions, and existing, pre-Project or 'baseline' levels of air pollutants expected to be emitted by the Project.

5.1 Local Meteorology

5.1.1 Larger scale meteorological influences

Crib Point is located on the Mornington Peninsula in relatively flat terrain approximately 30 kilometres north-east of the open waters of Bass Strait (Figure 5.1). With terrain elevations in the study area being relatively shallow, Crib Point's winds are affected by, primarily, meteorological causes on a significantly larger scale. These include larger synoptic scale effects, and mesoscale effects such as Port Phillip Bay's ocean and bay breezes (Abbs, 1986; Abbs and Physick, 1992), and at least two mesoscale eddy formations (McGregor and Kimura, 1989).

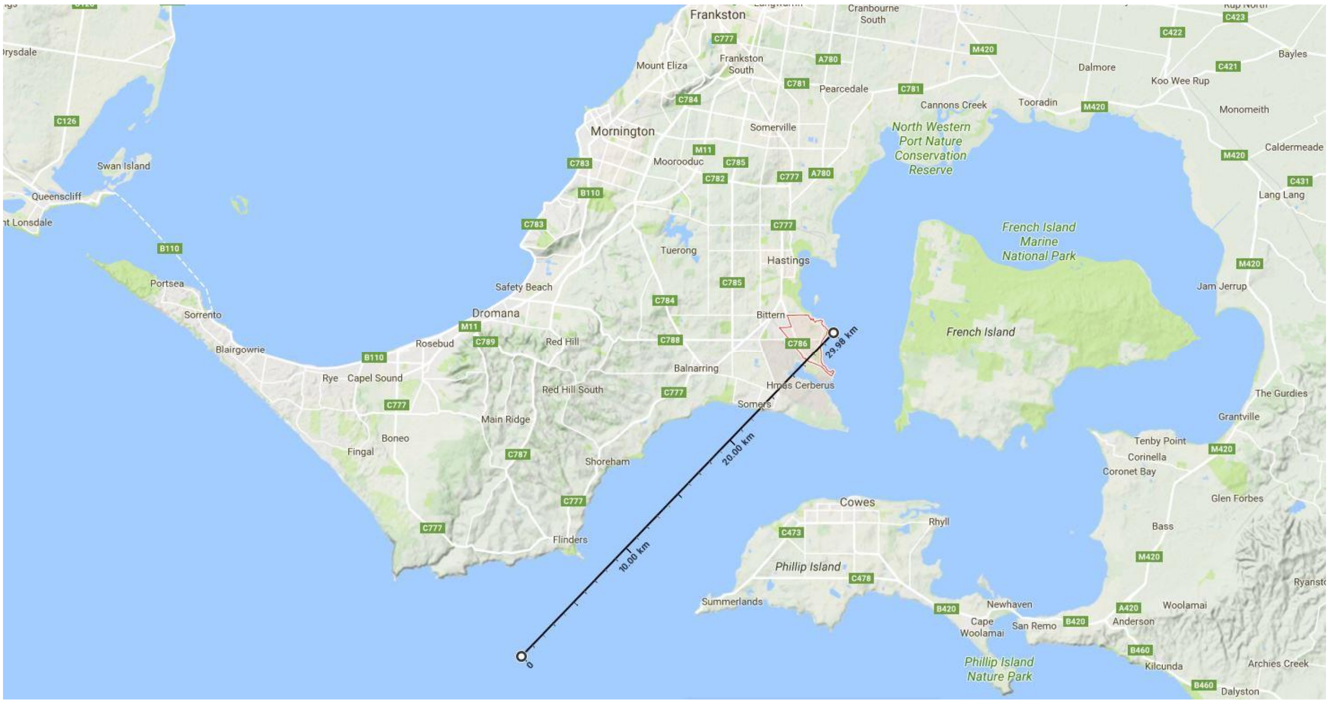

Figure 5.1 : Crib Point location on Mornington Peninsula

30km scale bar

The nocturnal, commonly occurring Spillane Eddy is a pattern of air circulation in the Melbourne region caused when easterly or north-easterly winds are forced around Melbourne's high terrain. Port Phillip Bay's bay and ocean breezes, and these eddies, can worsen air quality in the Melbourne region by recirculating and therefore concentrating the air pollutants; e.g., Tory et al. (2004).

Figure 5.2 illustrates the high terrain in The Great Dividing Range to the north-east of Melbourne, from Mt Kosciusko south-west and running downhill towards the Yarra Ranges; terrain which is relevant for influencing winds in the Melbourne region, including Western Port.

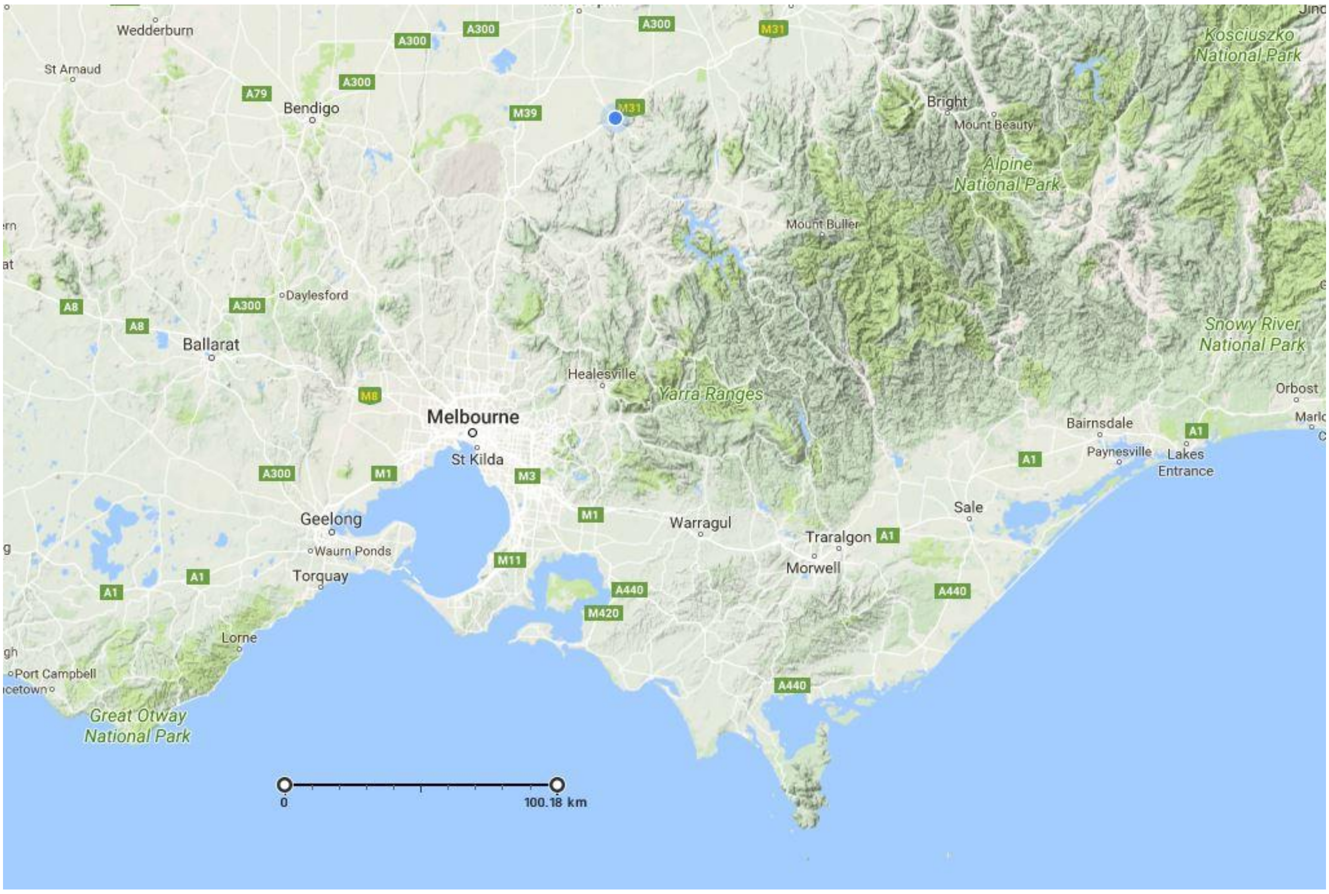

Figure 5.2 : Great Dividing Range – affects airflows in Port Phillip Bay and Western Port

100km scale bar

5.1.2 Local dispersion meteorology

Local meteorological conditions are important for determining the direction and dispersion of plumes of air pollutants, in a study area. Among other variables used by AERMOD, key meteorological parameters are wind speed, wind direction, temperature, and mixing layer height. For the air quality impact assessment for this Project, five years of hourly meteorological data were required to tested by modelling; i.e., up to approximately 43848 hourly records. This meant that almost all possible meteorological conditions, including seasonal and annual variations, were considered in the simulations.

The data used for this assessment were collected from the automatic weather station at the Bureau of Meteorology (BoM) Cerberus monitoring station, (No. 086361), located approximately 4.5 kilometres south-west of the AGL site (BoM, 2017). BoM Cerberus data from 2012 to 2016 were obtained from the BoM and processed into a form suitable for the AERMOD air dispersion model, and in accordance with the EPA (2014a) guideline (pDs, 2017).

The annual and seasonal wind patterns as measured by the BoM Cerberus weather station for 2016 are provided in Figure 5.3. Annual wind roses for all five years are provided in Appendix A, and seasonal wind roses in Appendix B. Inspection of the wind roses reveals westerly winds are dominant for the Study Area on an annual basis. South-westerly winds tend to be dominant in summer, and north-westerly winds tend to be dominant in winter.

There is a high degree of variability in the wind patterns, and the relatively low wind speeds overall indicate wind conditions could be conducive to air quality impacts at any time of the year. The annual average wind speed for the site varied between 3.0 m/s to 3.3 m/s over 2012-2016. Monthly statistics for daily average wind speed and maximum wind gust for BoM Cerberus over 2002-2017, are shown in Figure 5.4.

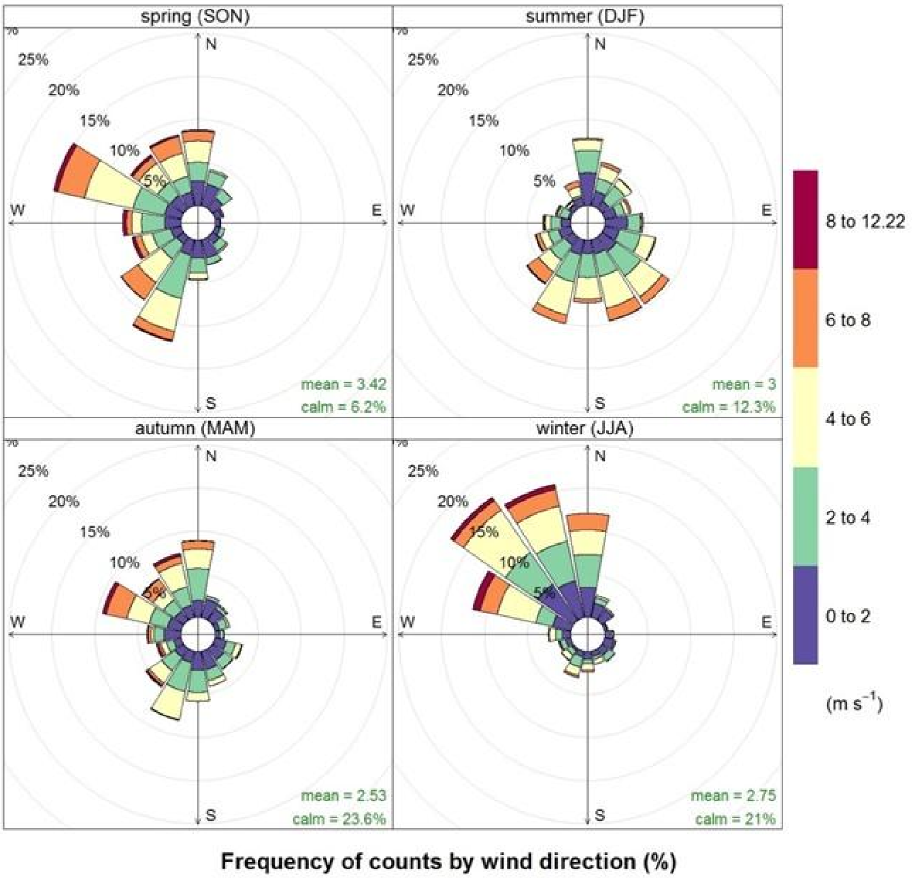

Figure 5.3 : Typical wind patterns for the Study Area: Seasonal wind roses for BoM Cerberus 2016

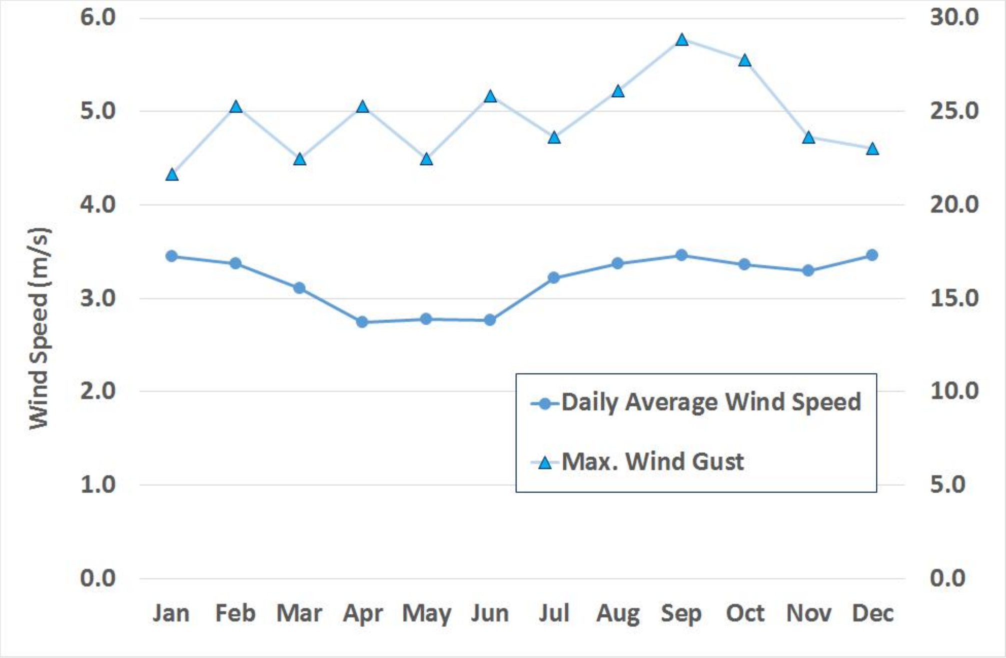

Figure 5.4 : BoM Cerberus monthly average wind speed and maximum wind gusts: 2002-2017

5.2 Existing Air Quality

There are no air quality monitoring data available in the Western Port area. However, the expectation from the review of meteorology for the Melbourne region is that air emissions from all parts of the Airshed will be transported around the whole of the Port Phillip Bay area, including in Western Port. Therefore, air quality conditions in Western Port are expected to be similar to those for air quality monitoring locations around Port Phillip Bay, although air quality should be better in Western Port given the distances to the majority of Melbourne's main air pollution sources, such as roadways.

5.2.1 Statistical summaries for key air pollutants

The following figures are extracts from the current EPA annual air quality summary (EPA, 2016). The figures show long term trends in air pollutant concentrations as determined from the EPA's records from several monitoring stations around Port Phillip Bay. An analysis of these trends was undertaken to determine conservative (high) estimates of the background air pollutant concentrations for Crib Point to be used in the modelling assessment.

Ozone (O_3) was not assessed for this Project – O_3 is formed in the atmosphere over periods of hours from many sources, primarily from emissions from Melbourne's road vehicle traffic, and dispersed over large areas. The assessment of O_3 is a task for regional air quality management. However, monitoring results for O_3 are shown in Figure 5.7, as emissions of NO_x and other pollutants from the Project are relevant for the formation of O_3 – in the Melbourne region, O_3 exceeds its ambient air quality standards occasionally, whereas NO_2 does not.

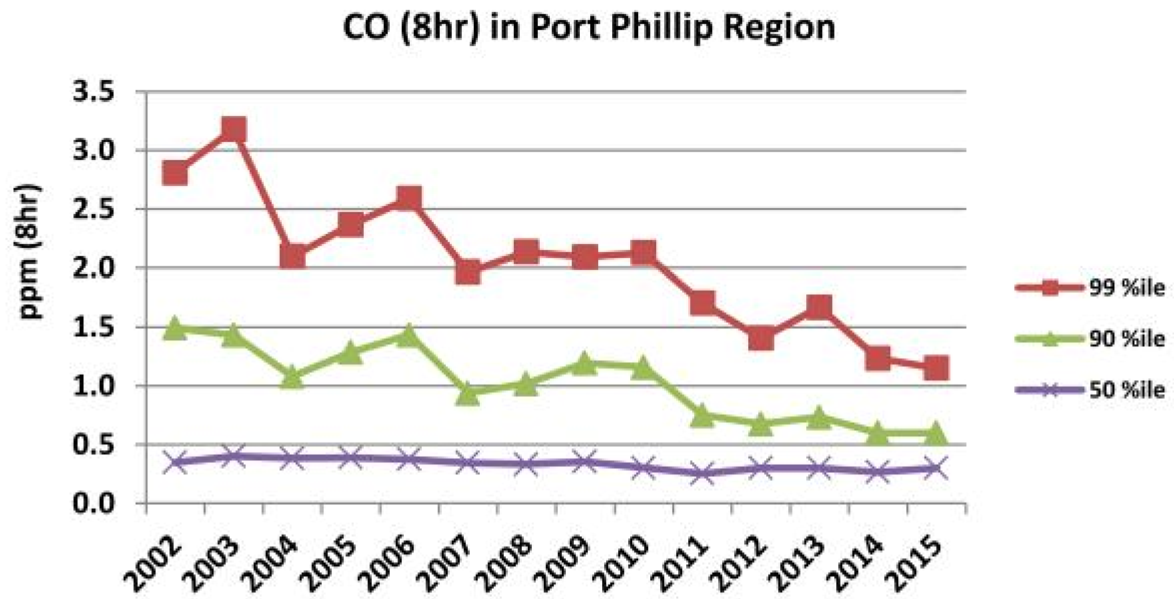

Figure 5.5 : EPA (2016) Daily maximum CO: Average of Port Phillip Stations 2002–2015

SEPP(AAQ) 8-hourly average objective for CO – 9.0 ppm.

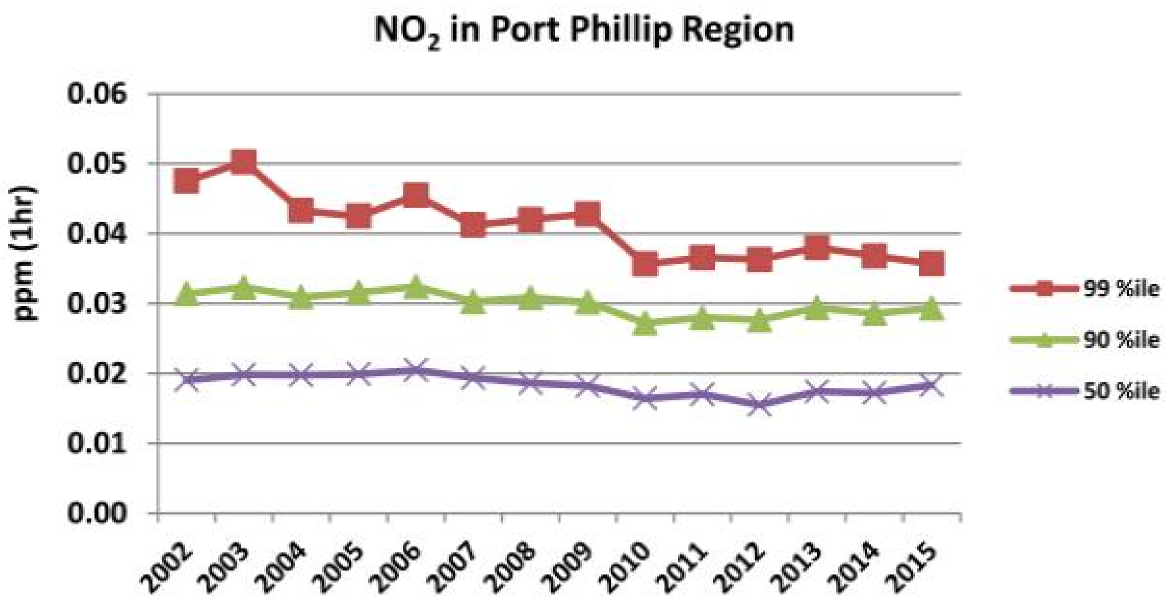

Figure 5.6 : EPA (2016) Daily maximum NO_2 (ppm): Average of Port Phillip Stations 2002–2015

SEPP(AAQ) 1-hour average objective for NO_2 – 0.120 ppm.

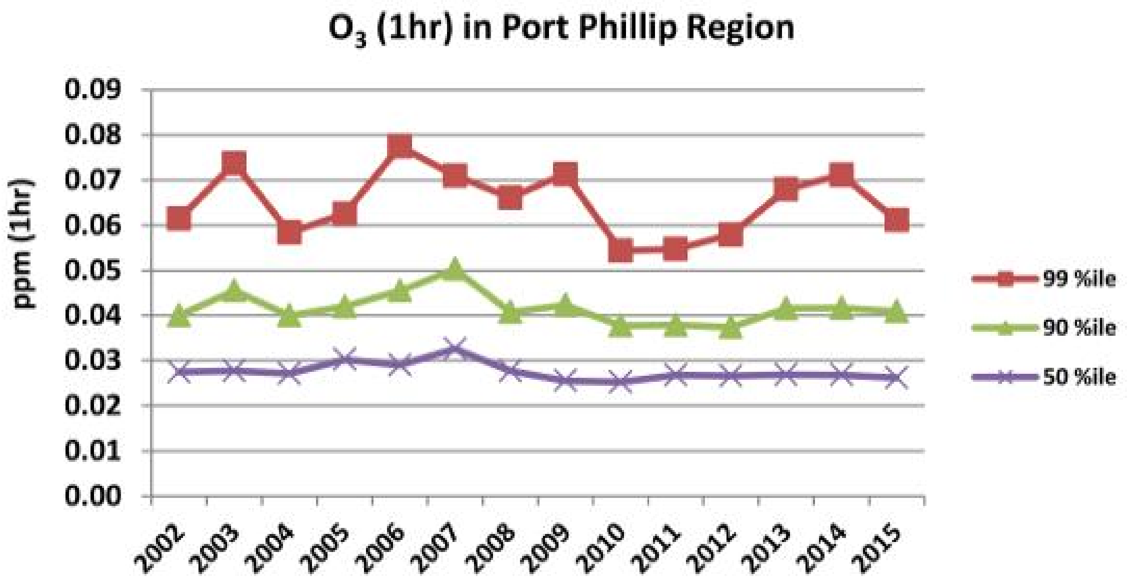

Figure 5.7 : EPA (2016) One Hour Average O_3 (ppm): Average of Port Phillip Stations 2002–2015

SEPP(AAQ) 1-hour average objective for O_3 – 0.100 ppm.

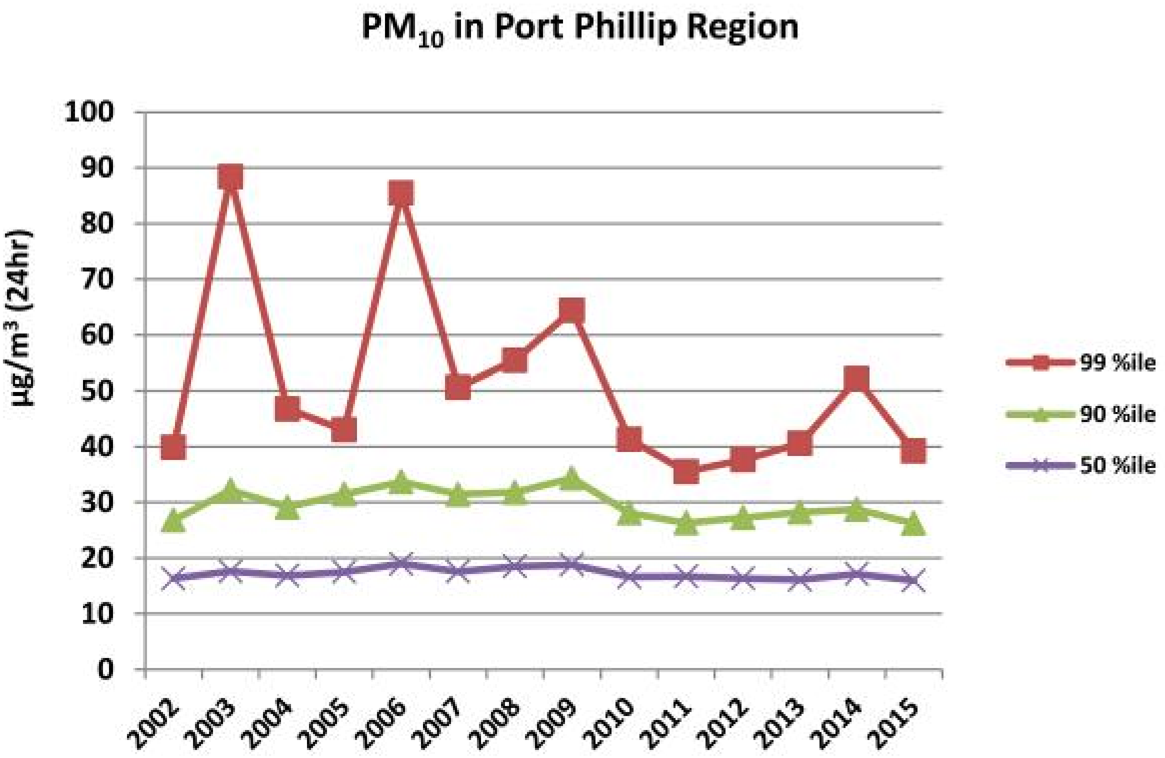

Figure 5.8 : EPA (2016) 24-Hour Average PM_{10} (µg/m^3): Average of Port Phillip Stations 2002–2015

SEPP(AAQ) 24-hour average objective for PM_{10} – 50 µg/m^3 (2016 variation)

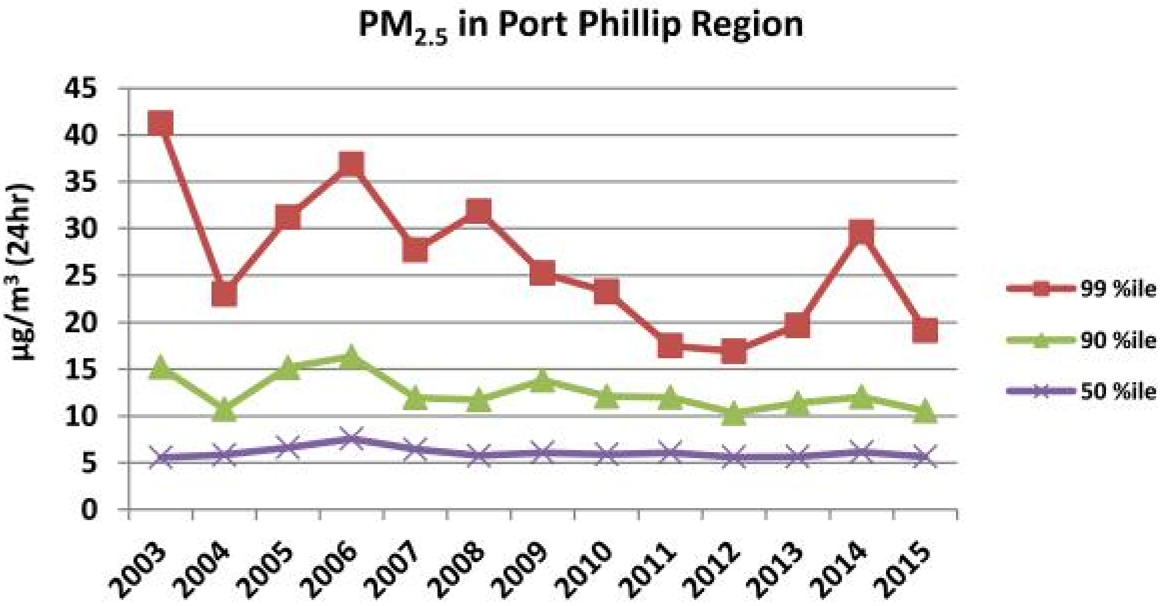

Figure 5-9 EPA (2016) 24-Hour Average $PM_{2.5}$ (µg/m^3): Average of Port Phillip Stations 2003–2015

SEPP(AAQ) 24-hour average objective for $PM_{2.5}$ – 25 µg/m^3 and 20 µg/m^3 by 2025 (2016 variation)

5.2.2 Estimates for background air pollutant concentrations for inclusion in modelling

Conservative (high) background values were estimated for use in the modelling based on the trends shown in the figures. The statistics used as background values were the 90th percentile statistics; this was considered to be a conservative measure in the assessment as the SEPP(AQM) requirement is to use the less stringent 70th percentile of one year of hourly average concentration data as background; i.e., where no appropriate monitoring data are available (as is the case for Crib Point).

The EPA's monitoring results for PM_{10} and $PM_{2.5}$ showed weaker trends than for the other air pollutants, and the results for some years were clearly affected by smoke from bushfires. In estimating the background PM_{10} and $PM_{2.5}$ concentrations used in the modelling, the sporadic data from years affected by bushfires were avoided. In this way the effects of particulate emissions from the Project could be assessed using 'normal' background PM_{10} and $PM_{2.5}$ levels; see Figure 5.8 (PM_{10}) and Figure 5-9 ($PM_{2.5}$).

The results of the analysis of trends shown in the figures are set out in Table 5.1, and the final estimates for background air pollutant concentrations used in the assessment (included in the modelling results), are provided in Table 5.2.

Table 5.1 : Analysis of existing air quality trends – Melbourne Airshed

Substance	**Trend for 90th Percentile**	**Averaging period, Unit**	**Conversion Factor to 1h avg. (Borgas, 2000)**	**Trend for 90th Percentile, 1 hour average**
CO	0.6	8h, ppm	1.52	0.91
SO_2	12	1h, ppb	1	12
NO_2	30	1h, ppb	1	30
O_3; for info. Only	40	1h, ppb	1	40
PM_{10}	25	24h, µg/m³	1.89	47.2
$PM_{2.5}$	10	24h, µg/m³	1.89	18.9

Table 5.2 : Estimates for background air pollutant concentrations for use in assessment

Substance	**Port Phillip Bay 2002-2015 Trend 90th Percentile One Hour Average (µg/m³; 25 °C)**	**Port Phillip Bay 2002-2015 Trend 90th Percentile One Hour Average (volumetric units)**
CO	1041.2	0.91 ppm
SO_2	31.4	12 ppb
NO_2	56.4	30 ppb
O_3; for info.	78.5	40 ppb
PM_{10}	47.2	--
$PM_{2.5}$	18.9	--

6. AERMOD Modelling Results

6.1 Overview

This section provides the AERMOD results as contour plots of GLCs for direct comparisons with the SEPP(AQM) Design Criteria. The results presented in this section used the 2016 meteorological data as input – contour plots of GLCs for the remaining years are provided in Appendix C.

There were minor differences between the contour plots for each of the five annual meteorological datasets 2012-2016; for brevity, the AERMOD results using the most recent meteorological data (2016) and presented as contour plots of GLCs, were provided in the following sub-sections. However, the sub-sections provide statistical results for the AERMOD grid receptors for all the meteorological case study years (2012-2016), in tables. The results for the discrete receptors for all meteorological case study years are provided in Appendix D.

This AERMOD results provided as contour plots of GLCs for the 2016 meteorological case are provided for the following scenarios and air pollutants:

- AERMOD results for CO:
  - Gas-fuelled FSRU and liquid-fuelled LNG carrier
  - Liquid-fuelled FSRU and liquid-fuelled LNG carrier
- AERMOD results for NO_2:
  - Gas-fuelled FSRU and liquid-fuelled LNG carrier
  - Liquid-fuelled FSRU and liquid-fuelled LNG carrier
- AERMOD results for SO_2:
  - Liquid-fuelled FSRU and liquid-fuelled LNG carrier (liquid fuelled only)
- AERMOD results for PM_{10}:
  - Liquid-fuelled FSRU and liquid-fuelled LNG carrier (liquid fuelled only)
- AERMOD results for $PM_{2.5}$:
  - Liquid-fuelled FSRU and liquid-fuelled LNG carrier (liquid fuelled only)
- AERMOD results for Benzene:
  - Liquid-fuelled FSRU and liquid-fuelled LNG carrier (liquid fuelled only)
- AERMOD results for Formaldehyde:
  - Liquid-fuelled FSRU and liquid-fuelled LNG carrier (liquid fuelled only)
- AERMOD results for PAHs:
  - Liquid-fuelled FSRU and liquid-fuelled LNG carrier (liquid fuelled only)

6.2 AERMOD Results for CO – Gas-fuelled FSRU

The AERMOD results for 99.9 percentile one-hour average CO GLCs, for the gas-fuelled FSRU and liquid-fuelled LNG carrier scenario, are provided in Figure 6.1 (using 2016 meteorological data). A statistical summary of the results for the grid receptors is provided in Table 6.1. The results for the discrete receptors, for the meteorological case studies 2012-2016, are listed in Appendix D.

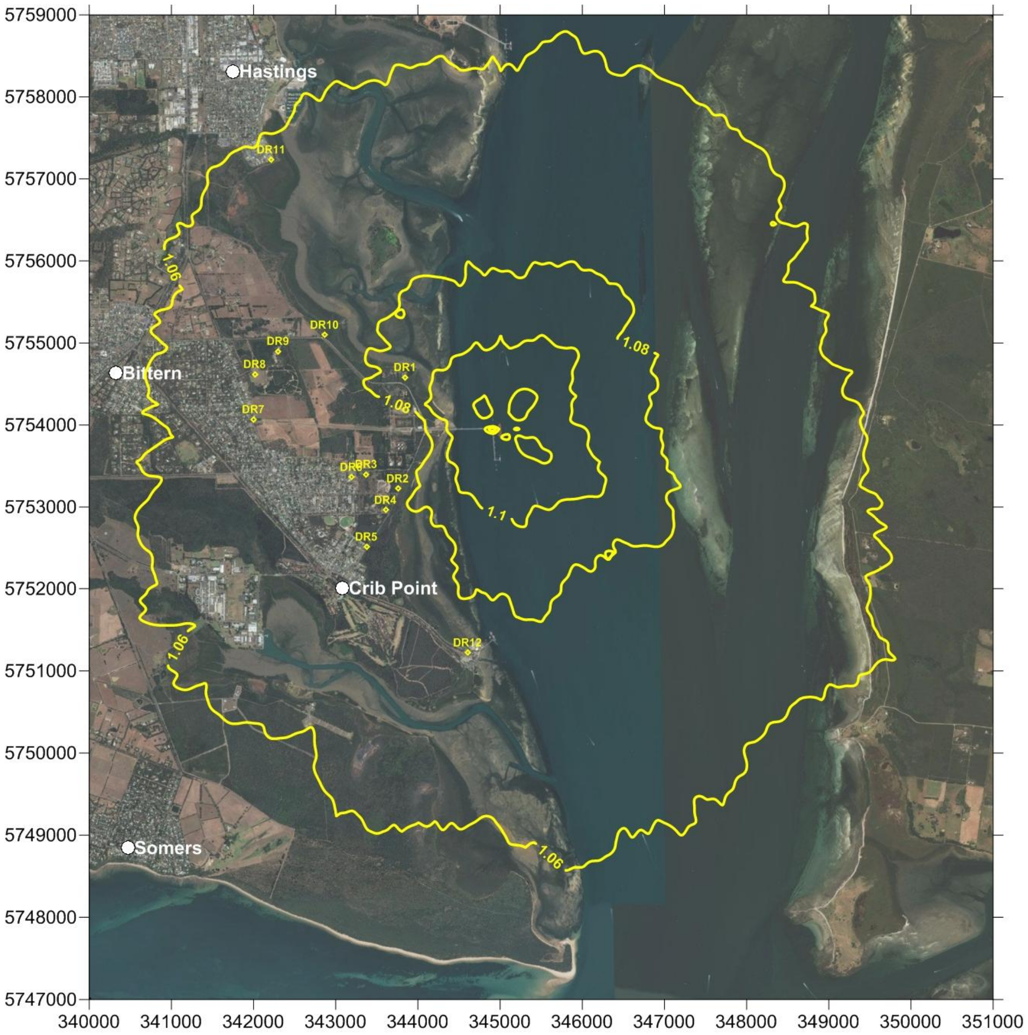

Figure 6.1 : AERMOD results 99.9 percentile 1hour CO GLCs (mg/m^3) – FSRU gas fuel (2016)

Table 6.1 : Grid point results 99.9 percentile 1hour CO GLCs (mg/m^3) – FSRU gas fuel

Statistic	2012	2013	2014	2015	2016
Maximum	1.32	1.32	1.32	1.31	1.30
90th Percentile	1.07	1.07	1.07	1.07	1.07
70th Percentile	1.06	1.06	1.06	1.06	1.06
Average	1.06	1.06	1.06	1.06	1.06
Median	1.06	1.06	1.06	1.06	1.06

SEPP(AQM) CO Design Criterion – 29 mg/m^3 (no exceedences).

6.3 AERMOD Results for CO – Liquid-fuelled FSRU

The AERMOD results for 99.9 percentile one-hour average CO GLCs, for the liquid-fuelled FSRU and liquid-fuelled LNG carrier scenario, are provided in Figure 6.2 (using 2016 meteorological data). A statistical summary of the results for the grid receptors is provided in Table 6.2. The results for the discrete receptors, for the meteorological case studies 2012-2016, are listed in Appendix D.

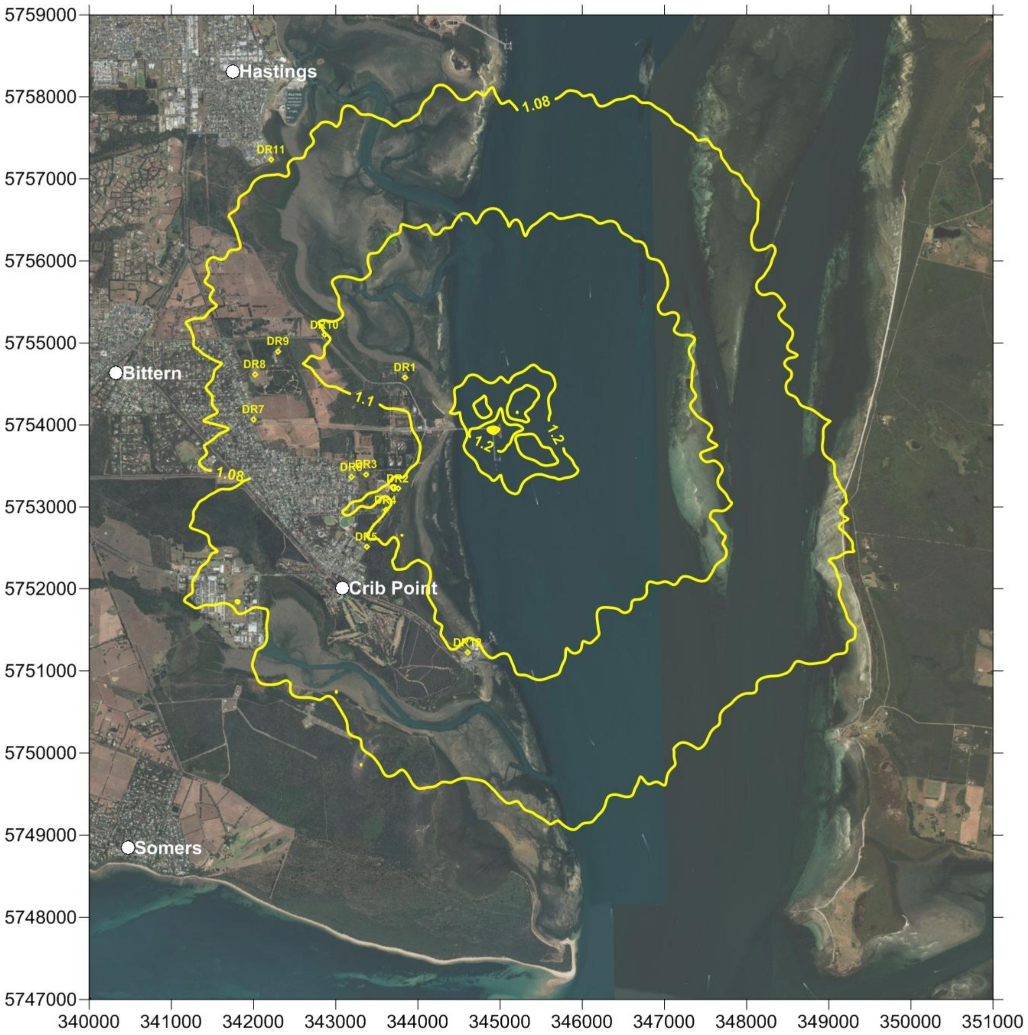

Figure 6.2 : AERMOD results 99.9 percentile 1hour CO GLCs (mg/m³) – FSRU liquid fuel (2016)

Table 6.2 : Grid point results 99.9 percentile 1hour CO GLCs (mg/m³) – FSRU liquid fuel

Statistic	2012	2013	2014	2015	2016
Maximum	1.55	1.57	1.56	1.53	1.50
90th Percentile	1.10	1.10	1.10	1.10	1.10
70th Percentile	1.08	1.08	1.08	1.08	1.08
Average	1.08	1.08	1.08	1.08	1.08
Median	1.07	1.07	1.07	1.07	1.07

SEPP(AQM) CO Design Criterion – 29 mg/m³ (no exceedences).

6.4 AERMOD results for NO_2 – Gas-fuelled FSRU

The AERMOD results for 99.9 percentile one-hour average NO_2 GLCs, for the gas-fuelled FSRU and liquid-fuelled LNG carrier scenario, are provided in Figure 6.3 (using 2016 meteorological data). A statistical summary of the results for the grid receptors is provided in Table 6.3. The results for the discrete receptors, for the meteorological case studies 2012-2016, are listed in Appendix D.

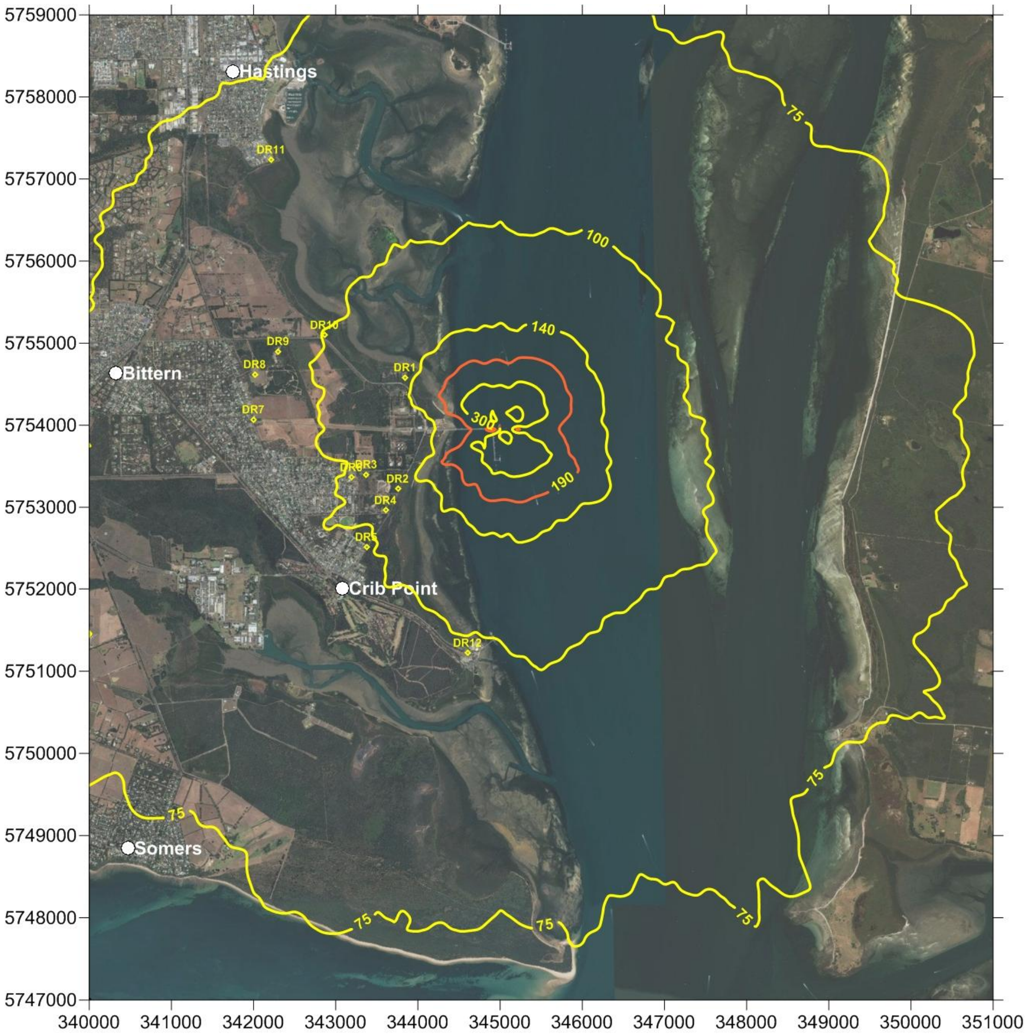

Figure 6.3 : AERMOD results 99.9 percentile 1 hour NO2 GLCs (µg/m^3) – FSRU gas fuel (2016)

Table 6.3 : Grid point results 99.9 percentile 1 hour NO_2 GLCs (µg/m^3) – FSRU gas fuel

Statistic	2012	2013	2014	2015	2016
Maximum	562	567	557	549	540
90th Percentile	101	102	102	102	101
70th Percentile	81	81	81	82	82
Average	83	83	83	84	84
Median	75	75	75	77	76

SEPP(AQM) NO_2 Design Criterion – 190 µg/m^3 (exceedences of the Design Criterion, but primarily off-shore, and around the site near the facility). No exceedences at discrete receptors.

6.5 AERMOD Results for NO_2 – Liquid-fuelled FSRU

The AERMOD results for 99.9 percentile one-hour average NO_2 GLCs, for the liquid-fuelled FSRU and liquid-fuelled LNG carrier scenario, are provided in Figure 6.4 (using 2016 meteorological data). A statistical summary of the results for the grid receptors is provided in Table 6.4. The results for the discrete receptors, for the meteorological case studies 2012-2016, are listed in Appendix D.

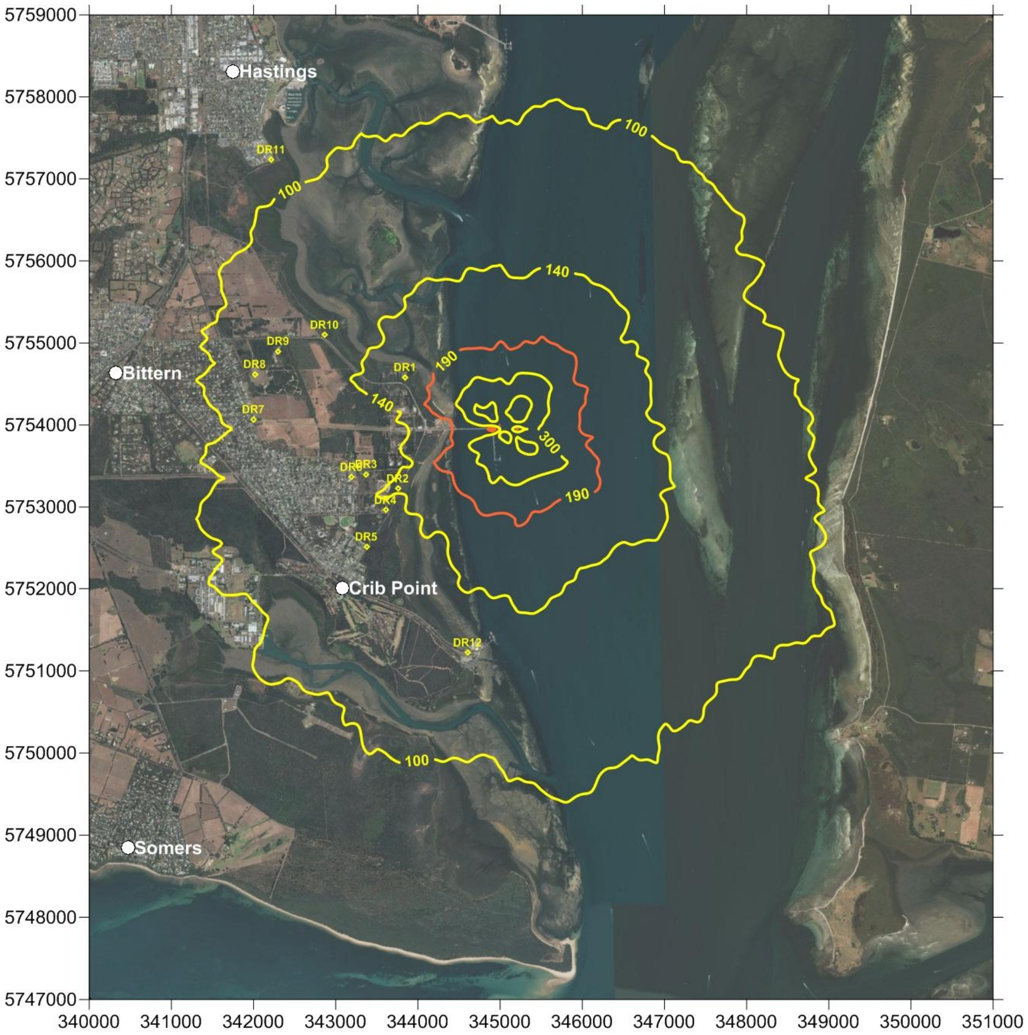

Figure 6.4 : AERMOD results 99.9 percentile 1 hour NO_2 GLCs (µg/m^3) – FSRU liquid fuel (2016)

Table 6.4 : Grid point results 99.9 percentile 1 hour NO_2 GLCs (µg/m^3) – FSRU liquid fuel

Statistic	2012	2013	2014	2015	2016
Maximum	634	640	642	640	618
90th Percentile	124	125	125	126	125
70th Percentile	97	97	97	99	98
Average	98	98	98	100	99
Median	88	88	88	90	89

SEPP(AQM) NO_2 Design Criterion – 190 µg/m^3 (exceedences of the Design Criterion, but primarily off-shore, and around the site near the facility). No exceedences at discrete receptors.

6.6 AERMOD Results for SO_2 – Liquid-fuelled FSRU (Only)

The AERMOD results for 99.9 percentile one-hour average SO_2 GLCs, for the liquid-fuelled FSRU scenario and liquid-fuelled LNG carrier scenarios, are provided in Figure 6.5 (using 2016 meteorological data). A statistical summary of the results for the grid receptors is provided in Table 6.5. The results for the discrete receptors, for the meteorological case studies 2012-2016, are listed in Appendix D.

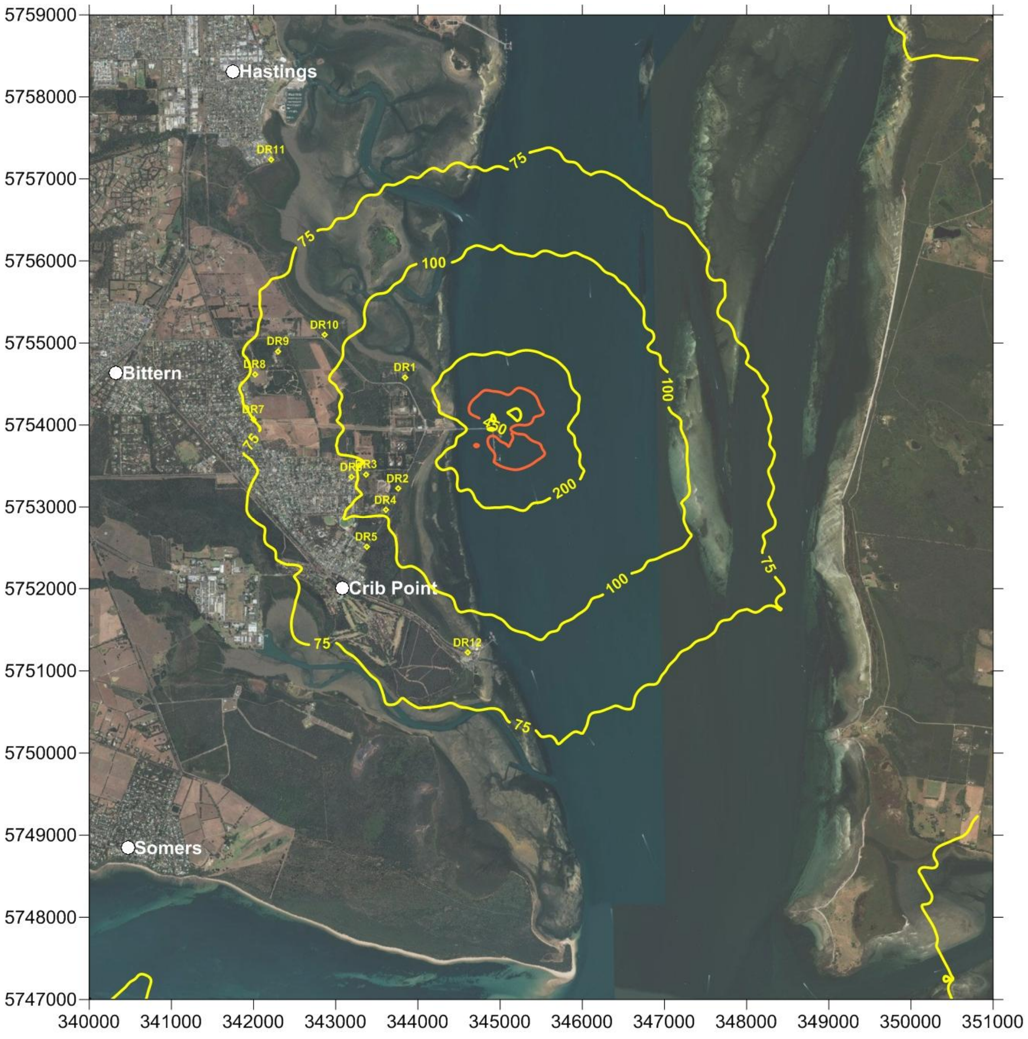

Figure 6.5 : AERMOD results 99.9 percentile 1 hour SO_2 GLCs (µg/m^3) – FSRU liquid fuel (2016)

Table 6.5 : Grid point results 99.9 percentile 1 hour SO_2 GLCs (µg/m^3) – FSRU liquid fuel

Statistic	2012	2013	2014	2015	2016
Maximum	773	778	768	759	741
90th Percentile	93	94	94	94	93
70th Percentile	65	65	65	67	66
Average	68	68	68	70	69
Median	57	57	57	59	58

SEPP(AQM) SO_2 Design Criterion – 450 µg/m^3 (exceedences of the Design Criterion, but all off-shore, around the site near the facility). No exceedences at discrete receptors.

6.7 AERMOD Results for PM_{10} – Liquid-fuelled FSRU (Only)

The AERMOD results for 99.9 percentile one-hour average PM_{10} GLCs, for the liquid-fuelled FSRU and liquid-fuelled LNG carrier scenario, are provided in Figure 6.6 (using 2016 meteorological data). A statistical summary of the results for the grid receptors is provided in Table 6.6. The results for the discrete receptors, for the meteorological case studies 2012-2016, are listed in Appendix D.

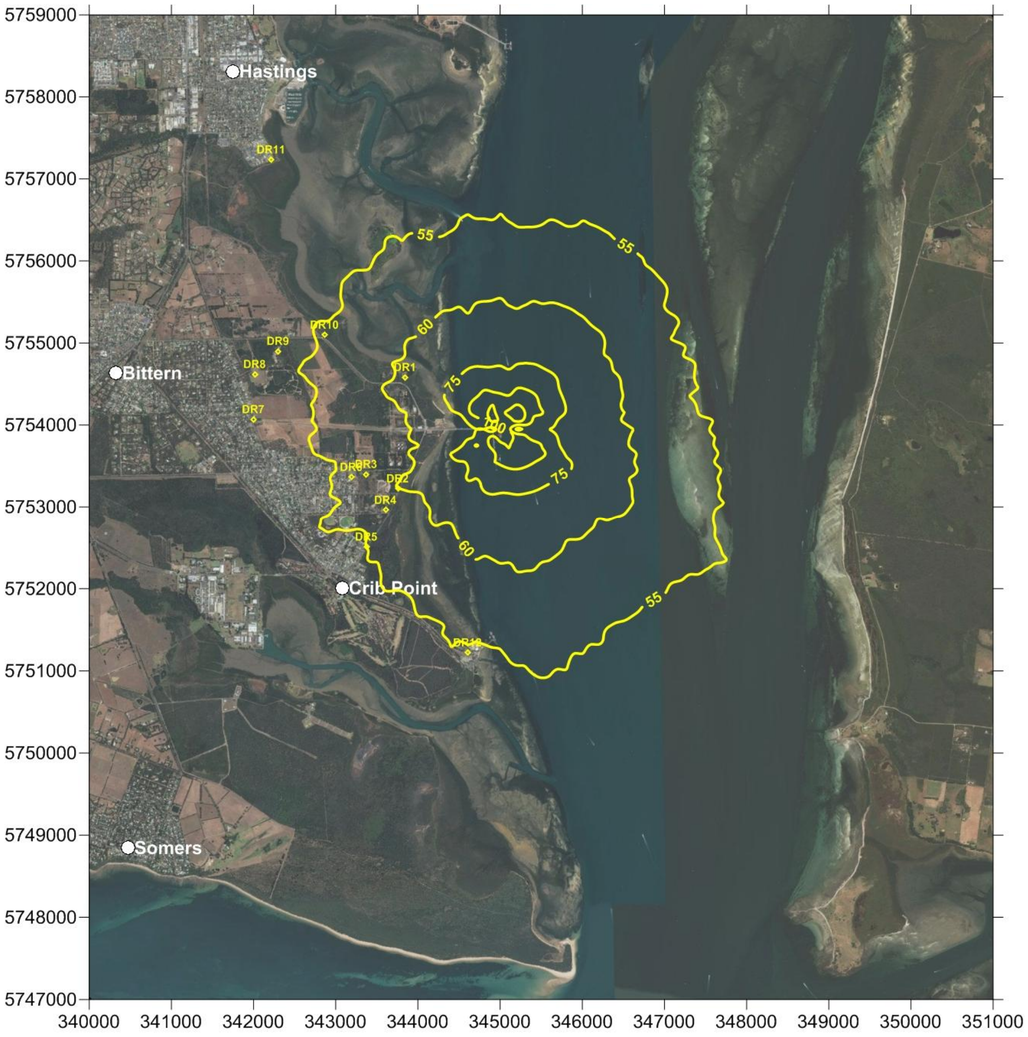

Figure 6.6 : AERMOD results 99.9 percentile 1 hour PM_{10} GLCs (µg/m^3) – FSRU liquid fuel (2016)

Table 6.6 : Grid point results 99.9 percentile 1 hour PM_{10} GLCs (µg/m^3) – FSRU liquid fuel

Statistic	2012	2013	2014	2015	2016
Maximum	139	140	137	136	135
90th Percentile	56	56	56	56	56
70th Percentile	52	52	52	52	52
Average	52	52	52	52	52
Median	51	51	51	51	51

SEPP(AQM) PM_{10} Design Criterion – 80 µg/m^3 (limited exceedences, around facility).

6.8 AERMOD Results for $PM_{2.5}$ – Liquid-fuelled FSRU (Only)

The AERMOD results for 99.9 percentile one-hour average $PM_{2.5}$ GLCs, for the liquid-fuelled FSRU and liquid-fuelled LNG carrier scenario, are provided in Figure 6.7 (using 2016 meteorological data). A statistical summary of the results for the grid receptors is provided in Table 6.7. The results for the discrete receptors, for the meteorological case studies 2012-2016, are listed in Appendix D.

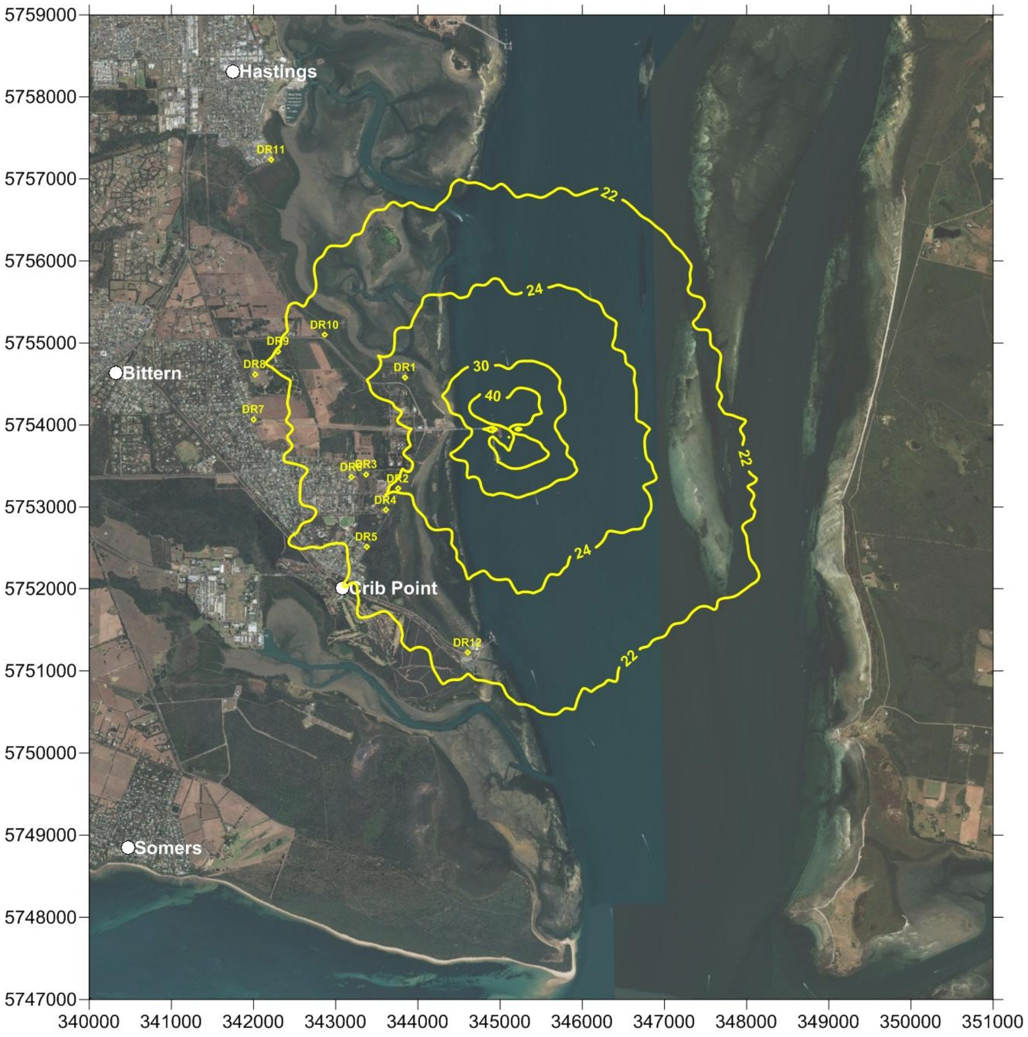

Figure 6.7 : AERMOD results 99.9 percentile 1 hour PM_{10} GLCs ($\mu g/m^3$) – FSRU liquid fuel (2016)

Table 6.7 : Grid point results 99.9 percentile 1 hour $PM_{2.5}$ GLCs ($\mu g/m^3$) – FSRU liquid fuel

Statistic	2012	2013	2014	2015	2016
Maximum	54	54	54	54	53
90th Percentile	23	23	23	23	23
70th Percentile	21	21	21	21	21
Average	21	21	21	21	21
Median	21	21	21	21	21

SEPP(AQM) $PM_{2.5}$ Design Criterion – 50 $\mu g/m^3$ (limited exceedences off-shore, near facility).

6.9 AERMOD Results for Benzene – Liquid-fuelled FSRU

The AERMOD results for 99.9 percentile 3-minute average benzene GLCs, for the liquid-fuelled FSRU and liquid-fuelled LNG carrier scenario, are provided in Figure 6-8 (using 2016 meteorological data). A statistical summary of the results for the grid receptors is provided in Table 6-8. The results for the discrete receptors, for the meteorological case studies 2012-2016, are listed Appendix D.

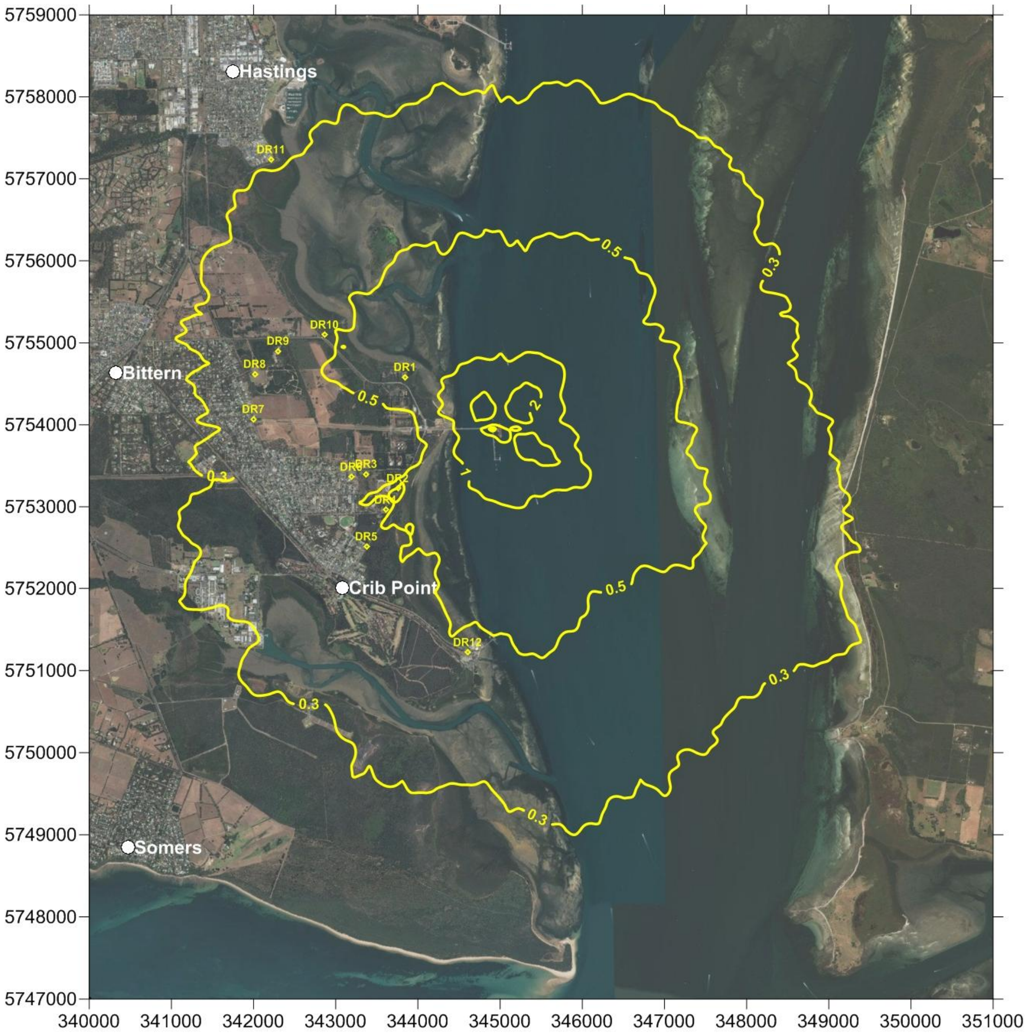

Figure 6-8 AERMOD results 99.9 percentile 3-minute Benzene GLCs (µg/m³) – FSRU liquid fuel (2016)

Table 6-8 Grid point results 99.9 percentile 3-minute Benzene GLCs (µg/m³) – FSRU liquid fuel

Statistic	2012	2013	2014	2015	2016
Maximum	4.0	4.0	4.0	3.8	3.7
90th Percentile	0.47	0.47	0.47	0.48	0.47
70th Percentile	0.30	0.30	0.30	0.31	0.30
Average	0.29	0.30	0.30	0.31	0.30
Median	0.23	0.24	0.24	0.25	0.24

SEPP(AQM) Benzene Design Criterion – 53 µg/m³ (no exceedences); background benzene not included in results, but would be approximately less than 1 µg/m³ based on EPA (2012).

6.10 AERMOD Results for Formaldehyde – Liquid-fuelled FSRU

The AERMOD results for 99.9 percentile 3-minute average formaldehyde GLCs, for the gas-fuelled FSRU and liquid-fuelled LNG carrier scenario, are provided in Figure 6.9 (using 2016 meteorological data). A statistical summary of the results for the grid receptors is provided in Table 6.9. The results for the discrete receptors, for the meteorological case studies 2012-2016, are listed in Appendix D.

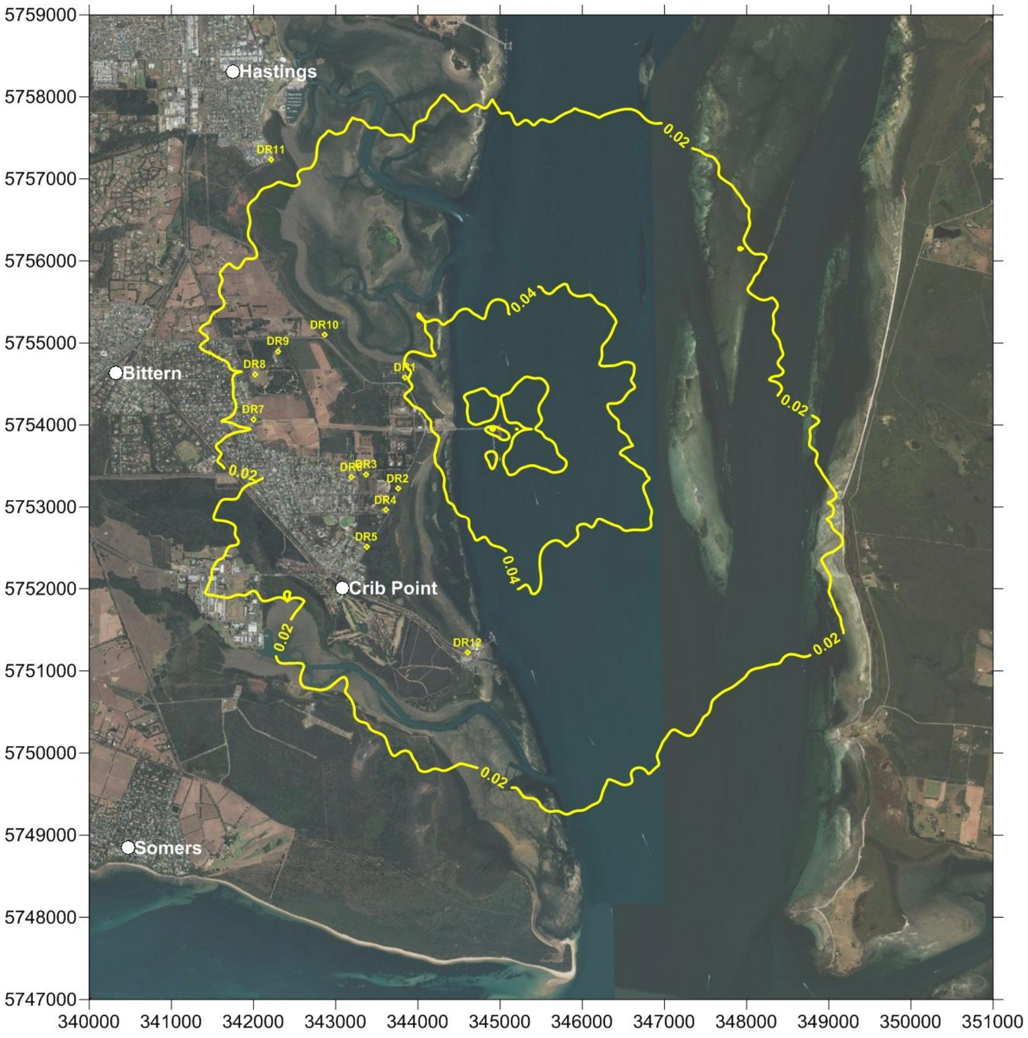

Figure 6.9 : AERMOD results 99.9 percentile 3-minute CH_2O GLCs (µg/m^3) – FSRU liquid fuel (2016)

Table 6.9 : Grid point results 99.9 percentile 3-minute formaldehyde GLCs (µg/m^3) – FSRU liquid fuel

Statistic	2012	2013	2014	2015	2016
Maximum	0.36	0.37	0.36	0.34	0.32
90th Percentile	0.041	0.042	0.041	0.043	0.042
70th Percentile	0.027	0.027	0.027	0.028	0.027
Average	0.026	0.027	0.026	0.027	0.027
Median	0.021	0.021	0.021	0.022	0.022

SEPP(AQM) Formaldehyde Design Criterion – 40 µg/m^3 (no exceedences); background CH_2O not included in results, but would be approximately less than 10 µg/m^3 based on EPA (2012).

6.11 AERMOD Results for PAH – Liquid-fuelled FSRU

The AERMOD results for 99.9 percentile 3-minute average PAH GLCs, for the gas-fuelled FSRU and liquid-fuelled LNG carrier scenario, are provided in Figure 6.10 (using 2016 meteorological data). A statistical summary of the results for the grid receptors is provided in Table 6.10. The results for the discrete receptors, for the meteorological case studies 2012-2016, are listed in Appendix D.

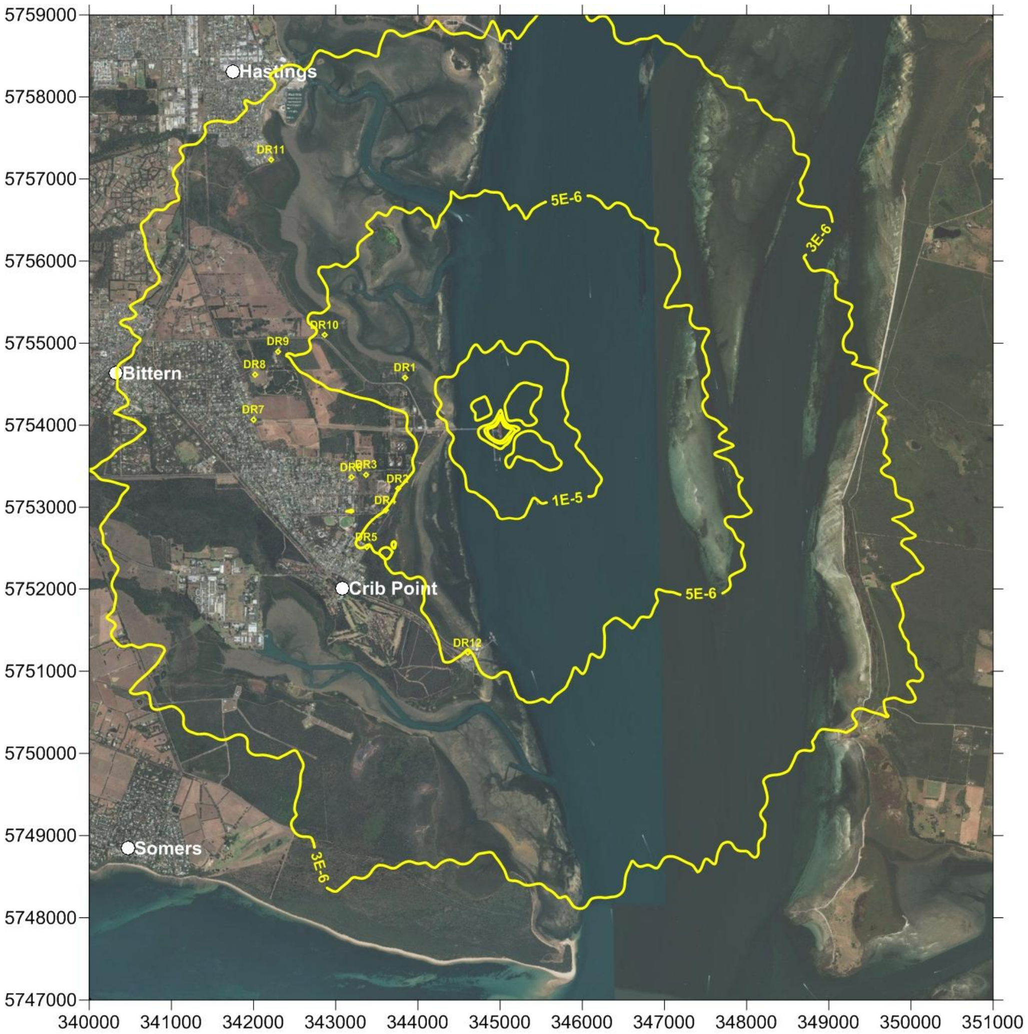

Figure 6.10 : AERMOD results 99.9 percentile 3-minute PAH GLCs (µg/m³) – FSRU liquid fuel (2016)

Table 6.10 : Grid point results 99.9 percentile 3-minute PAH GLCs (µg/m³) – FSRU liquid fuel

Statistic	2012	2013	2014	2015	2016
Maximum	4.8E-05	5.0E-05	4.8E-05	4.4E-05	4.1E-05
90th Percentile	5.3E-06	5.3E-06	5.3E-06	5.4E-06	5.3E-06
70th Percentile	3.4E-06	3.5E-06	3.5E-06	3.6E-06	3.5E-06
Average	3.4E-06	3.4E-06	3.4E-06	3.5E-06	3.5E-06
Median	2.7E-06	2.8E-06	2.8E-06	2.9E-06	2.9E-06

SEPP(AQM) PAH as B(a)P Design Criterion – 0.73 µg/m³ (no exceedences); background PAHs not included in results, but would be approximately less than 1 ng/m³ based on Reisen et al. (2016).

7. Management and Mitigation

Key recommendations around management and mitigation of the operating FSRU are provided in the following points:

- Implementation of best practice and emissions controls; e.g., see
  - VG (2001) – SEPP(AQM)
  - EPA (2017) – Demonstrating Best Practice
- Australian Standard-compliant air quality monitoring; e.g.
  - Air quality monitoring data linked to site emissions controls for real-time environmental management by the FSRU operator.
  - Pollutants that may be monitored include $PM_{10}/PM_{2.5}$ and NOx (NO/NO_2); the monitored substances and methods will be confirmed after EPA's review of an Air Quality Monitoring Plan.
  - Contribute air quality monitoring data to the EPA's network
- High quality Australian Standard-compliant meteorological monitoring linked to open communications and site emissions management systems and controls
- Environmental complaints register; e.g., odours, visible smoke, dust.

8. Conclusion

An air quality impact assessment was undertaken for the AGL Gas Import Jetty Project, in accordance with the SEPP(AQM) and EPA guidelines for the use of the regulatory model, AERMOD (EPA, 2014a; EPA, 2014b). The application of best practice was considered in the assessment (EPA, 2013).

Key components of the AERMOD modelling assessment methods were:

1) Use of AERMOD in accordance with EPA (2014b); and
2) Creation of AERMOD meteorological data in accordance with EPA (2014a) including the use of a five-year, dataset of hourly meteorological parameters. Conservative measures taken in the assessment included adoption of a 'low wind' algorithm for calculating air pollutant dispersion specifically for lower wind speeds, inclusion of wake and downwash effects around the FSRU and carrier hulls and superstructures, and high estimates for the ratios: NO_2/NOx (30%) and $PM_{2.5}$/PM_{10} (84%).

Higher risk air pollutants identified from a review of the proposed FSRU and LNG carrier operations were: CO, NO_2, SO_2, PM_{10}, $PM_{2.5}$, and the VOCs: benzene, formaldehyde and PAHs as B(a)P.

Pollutants judged as having a low risk of air quality impact for the gas-fuelled FSRU scenario due to very small emission rates, therefore not assessed for that scenario, were; SO_2, PM_{10} and $PM_{2.5}$.

The AERMOD results for the gas-fuelled and liquid (diesel)-fuelled FSRU scenarios demonstrated there were no exceedences of SEPP(AQM) Design Criteria at any of the discrete receptors, for any of the pollutants.

The AERMOD modelling assessment of the FSRU scenarios demonstrated there were no exceedences of SEPP(AQM) Design Criteria for nearly all grid points over land, with most exceedences occurring around the FSRU, and off-shore. These results for 'low risk', primarily off-shore exceedences were obtained for the pollutants: NO_2 (for which conservative measures were taken in the assessment), SO_2, PM_{10}, and $PM_{2.5}$.

There were no exceedences for any of the grid receptors for any of the higher risk VOCs tested by modelling; benzene, formaldehyde, and PAHs.

The general conclusion of the air quality modelling assessment is that there is a low risk of air quality impact from the Project's FSRU and LNG carrier operations for on-shore sensitive receptors near Crib Point. Air pollutant emissions from the Project are unlikely to have regionally or State significant effects on the air environment.

Schedule 1 of the Environment Protection (Scheduled Premises) Regulation 2017 sets out a list of activities that require a Licence and/or a Works Approval. Relevantly, premises which exceed air emissions thresholds are included in the list of Scheduled premises. Assessment of the emissions from the FSRU, which is intended to be operated on LNG boil-off gas as the primary fuel, has shown that emissions of NOx, CO and VOCs exceed the thresholds prescribed for scheduled premises (Type L01 – general emissions to air). As such the expectation is the FSRU will require a Works Approval and a Licence for these air emissions. The EPA assessment process for these approvals will involve close consideration of the design of the FSRU, and in general this would result in approvals with conditions regarding the design and operations of the FSRU.

EPA requirements for best practice emissions controls that will be adopted for the FSRU are discussed in the main part of the report. With respect to the application of best practice technology and operations for the Project, emissions information was sought from a number of candidate FSRU providers. Data were received from two suppliers confirming the emissions performance of the engines meet U.S. EPA Tier 3 emission standards as is generally required to comply with ECA emission requirements. This is considered industry best practice for FSRUs.

The EPA's Guidelines Recommended separation distances for industrial residual air emissions, apply to industrial land uses and are not clearly applicable to the Project and/or the FSRU. Moreover, the Project does not meet any of the industry descriptions for Industrial Residual Air Emissions (IRAE), but the most similar industrial activities with separation distances are:

- ‘Other hydrocarbon production and refining’ – 500 metres
- ‘Petroleum refining (including liquefying gas)’ – 2000 metres.

The nearest off-site sensitive receiver (resident) to the main FSRU gas processing area at Berth 2 is located at 103 The Esplanade Crib Point, which is located approximately 1.5 kilometres from the Project. This is more than the 500 metre buffer set for "other hydrocarbon production and refining", and less than the 2 kilometre buffer set for "petroleum refining". However, the Project has fewer emissions of IRAEs than would be associated with a traditional petroleum refinery where a 2 kilometre buffer zone may be needed. As such the existing buffer is considered adequate for management of any IRAE, and this would be quantified further as part of Project HAZOP studies during the Project design phase.

Recommended management and mitigation measures include air quality monitoring during operations; preparation of an Air Quality Monitoring Plan is recommended. These measures would be included in the conditions of any EPA approvals for the Project.

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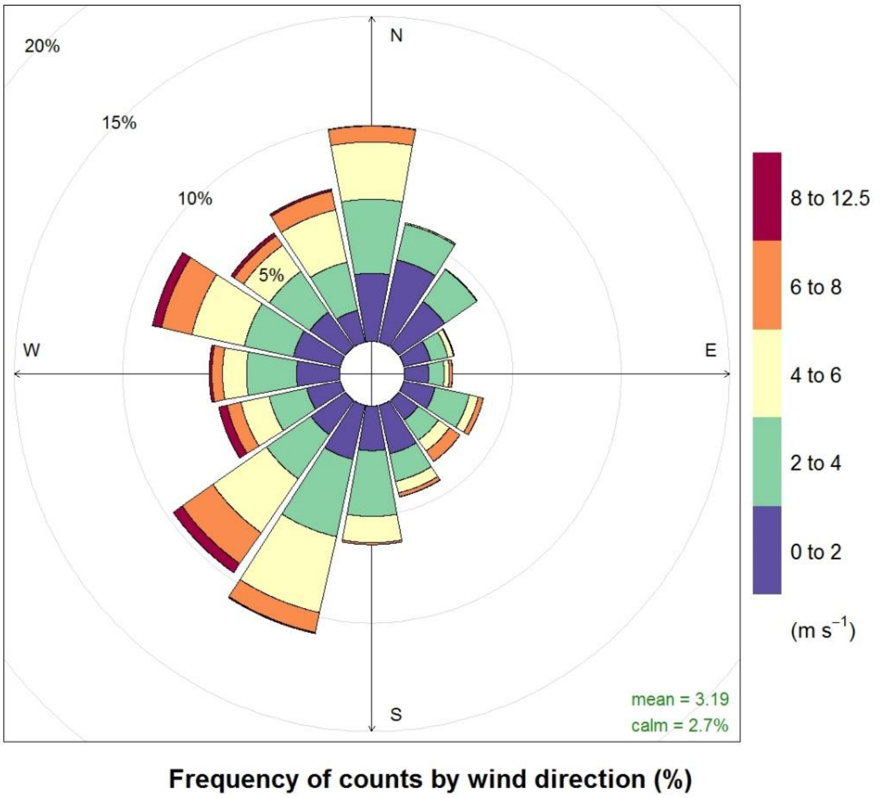
Appendix A. Annual wind roses

Annual Wind Rose BoM Cerberus (086361) - 2012



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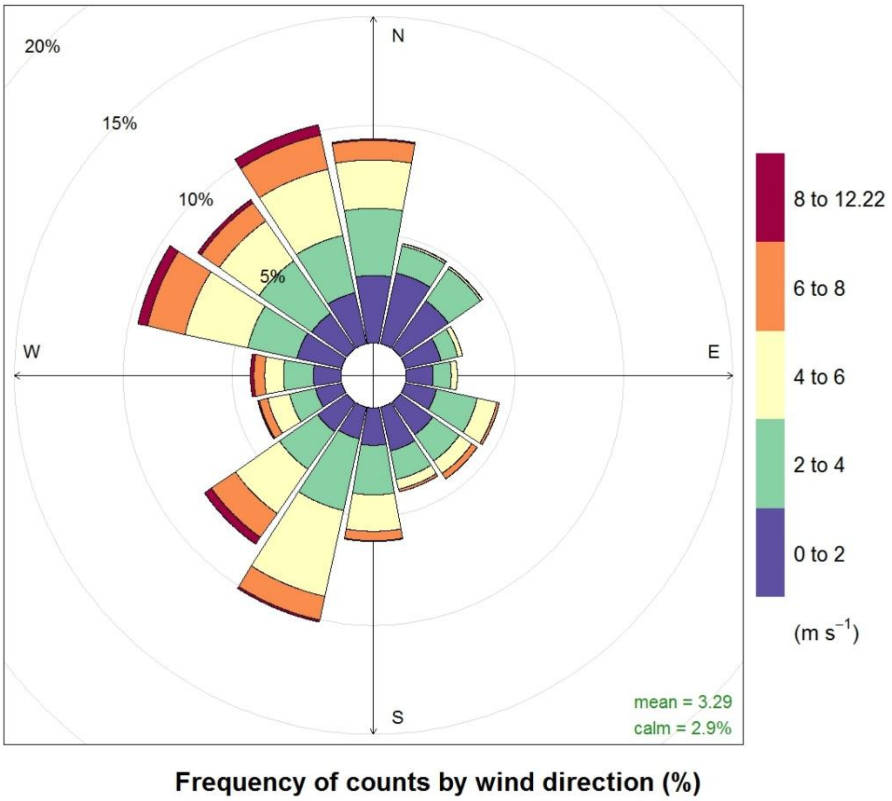

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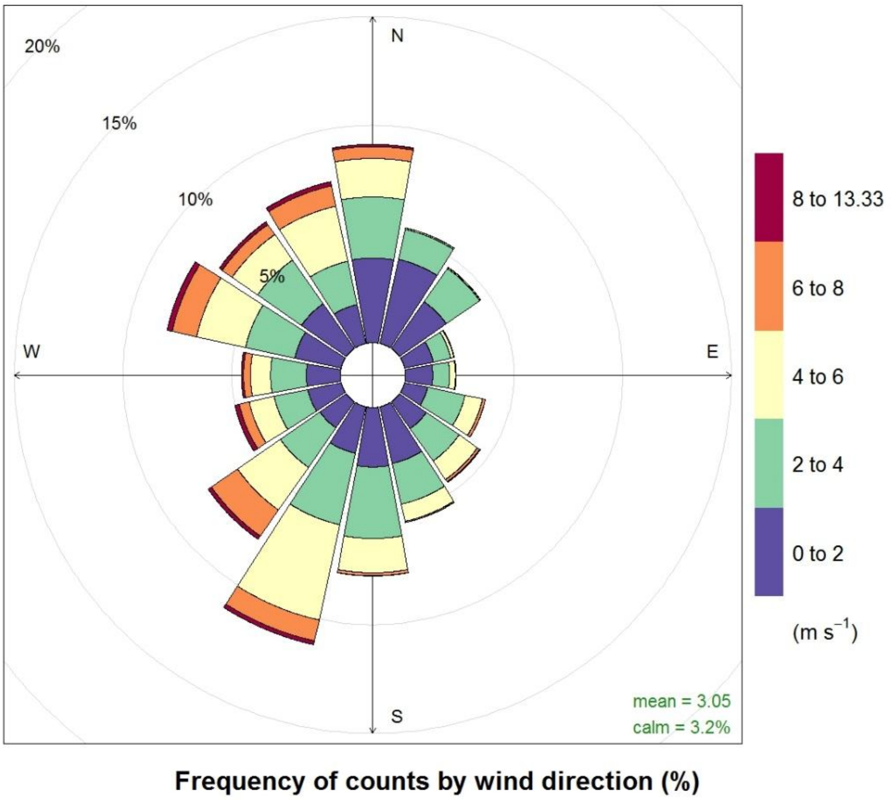

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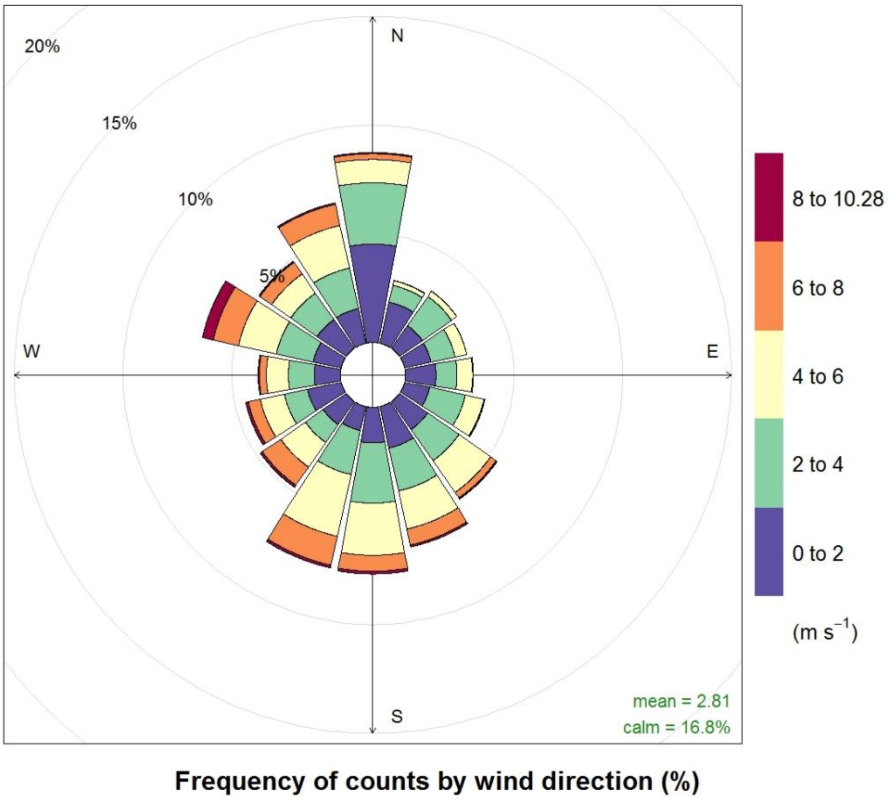

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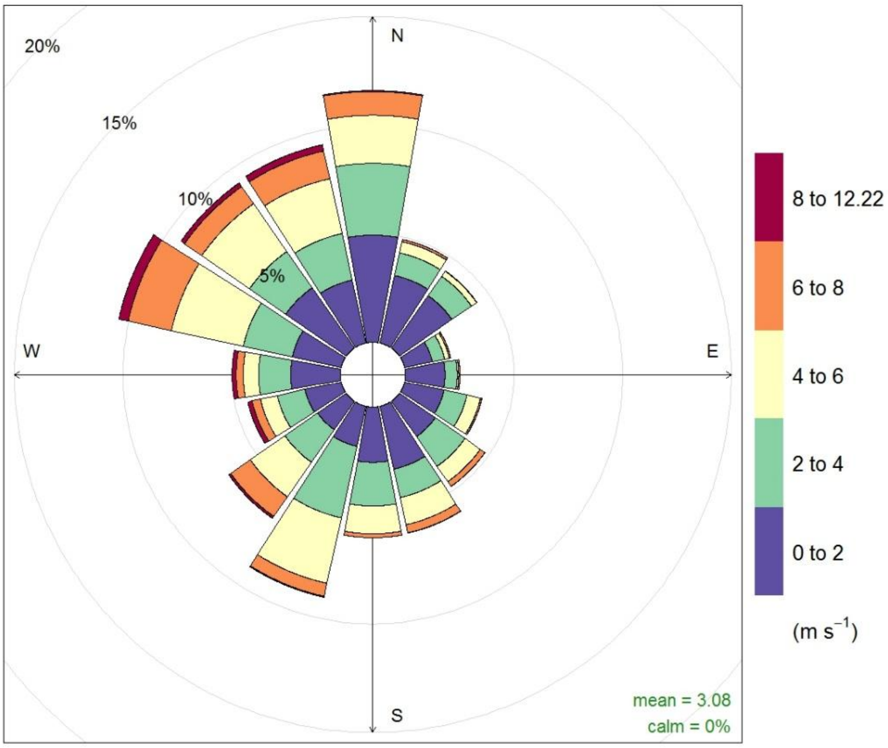
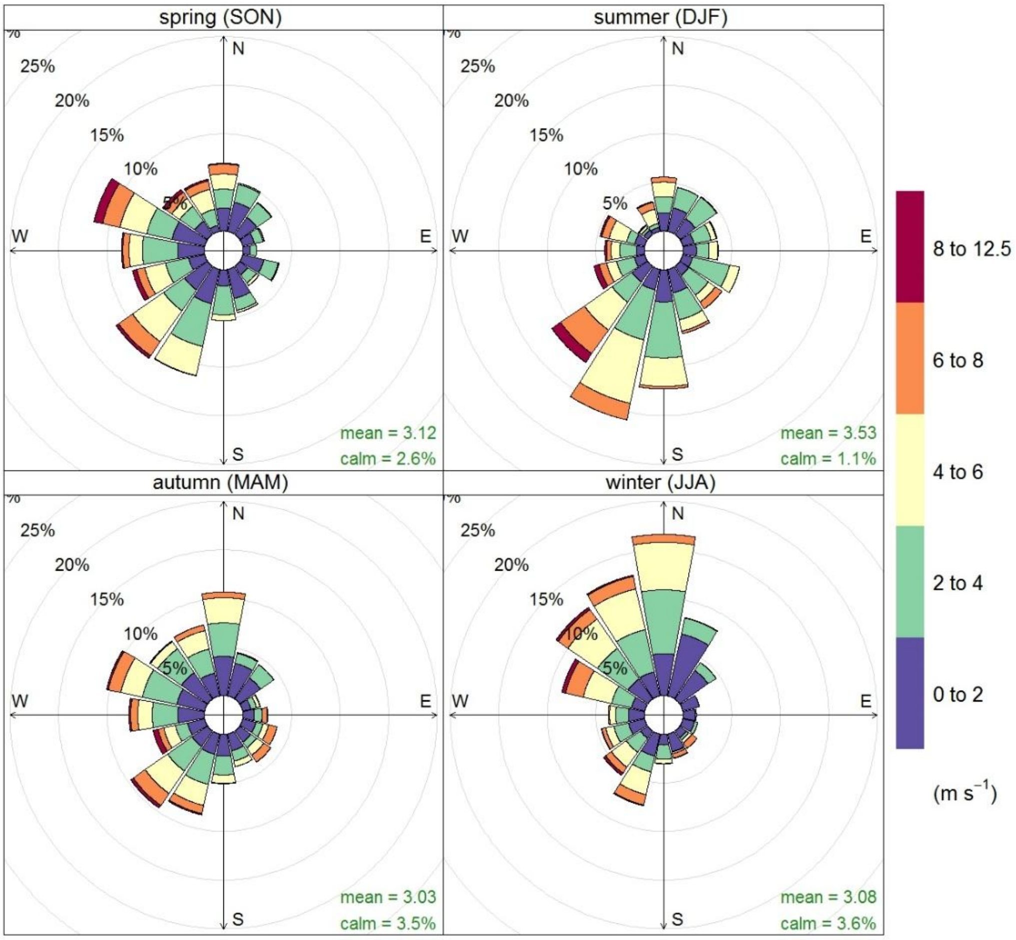


Frequency of counts by wind direction (%)

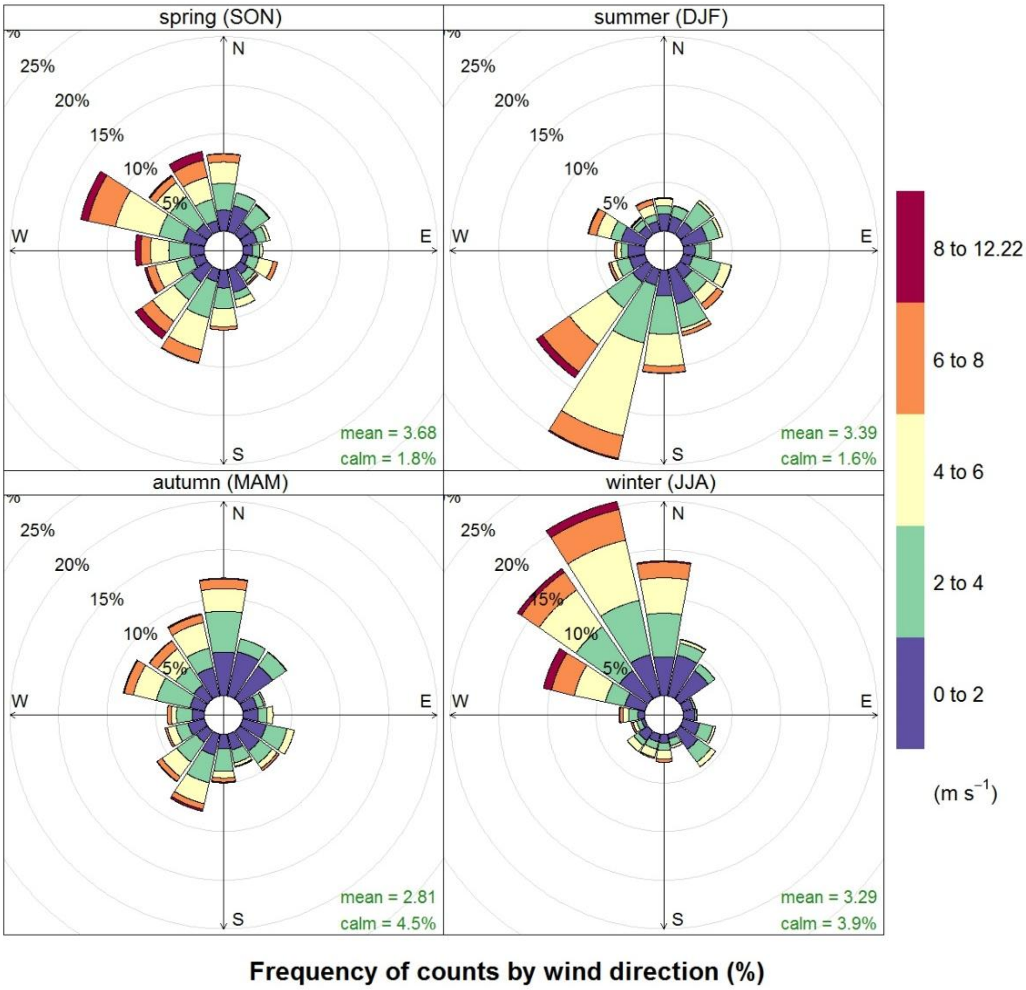
Appendix B. Seasonal wind roses

Seasonal Wind Rose BoM Cerberus (086361) – 2012



Frequency of counts by wind direction (%)

Seasonal Wind Rose BoM Cerberus (086361) – 2013



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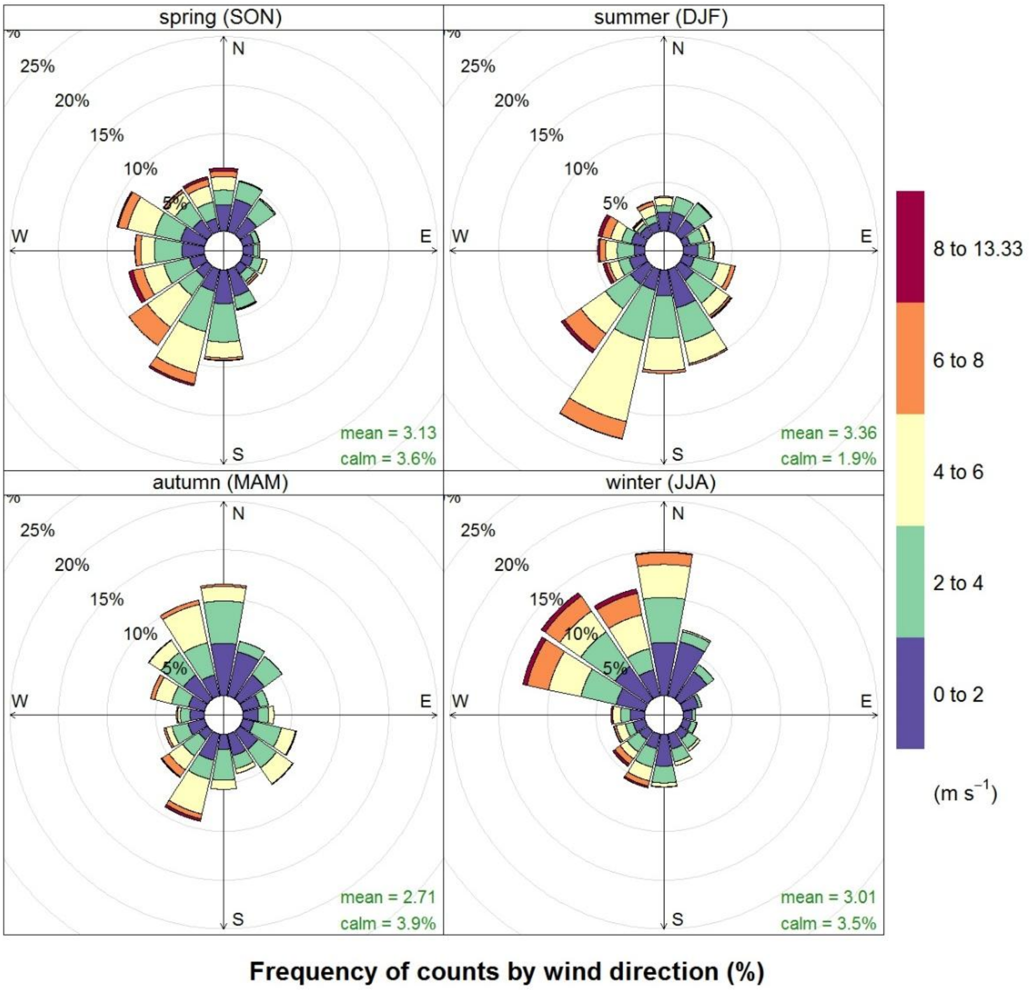

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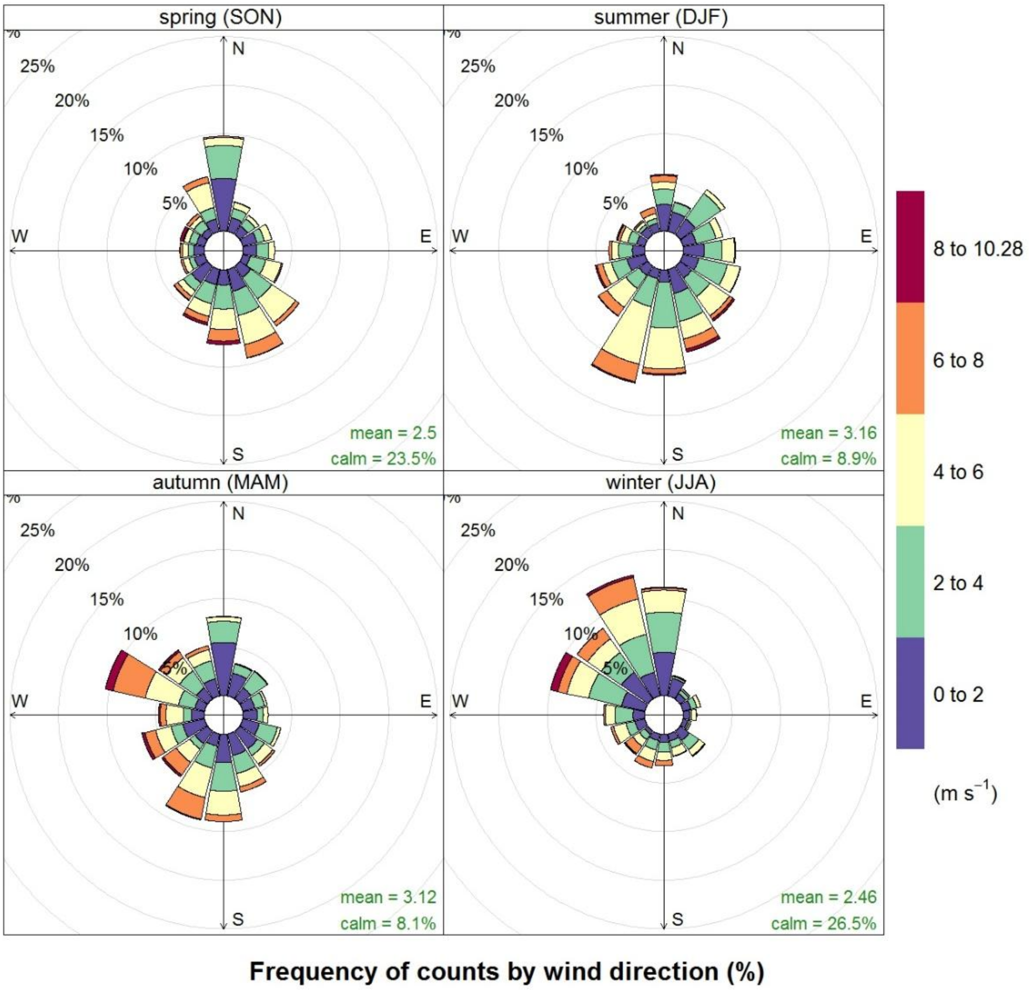

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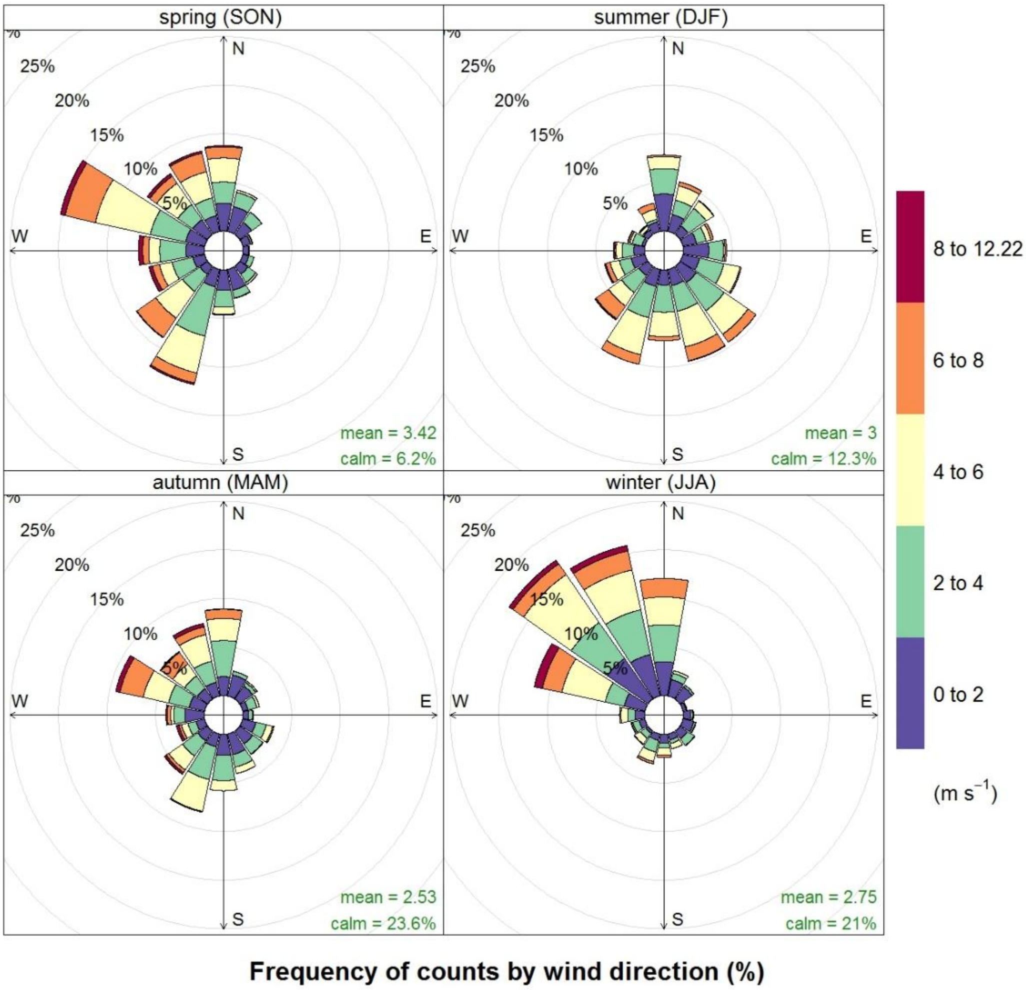
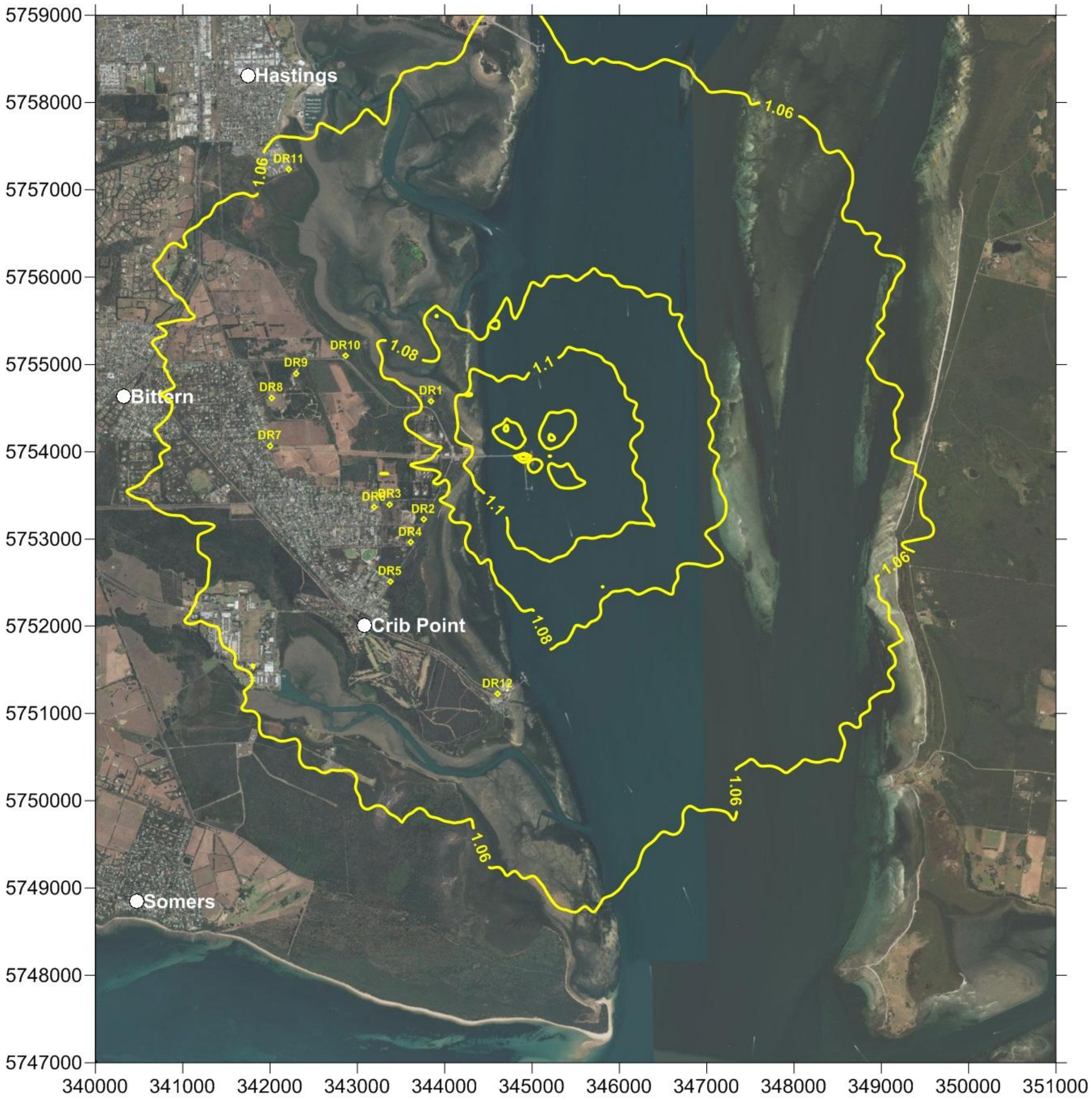


Appendix C. AERMOD results: 2012-2015 Met. Data

AERMOD Results 99.9 Percentile 1 Hour CO GLCs (mg/m^3) – FSRU Gas Fuel – 2012



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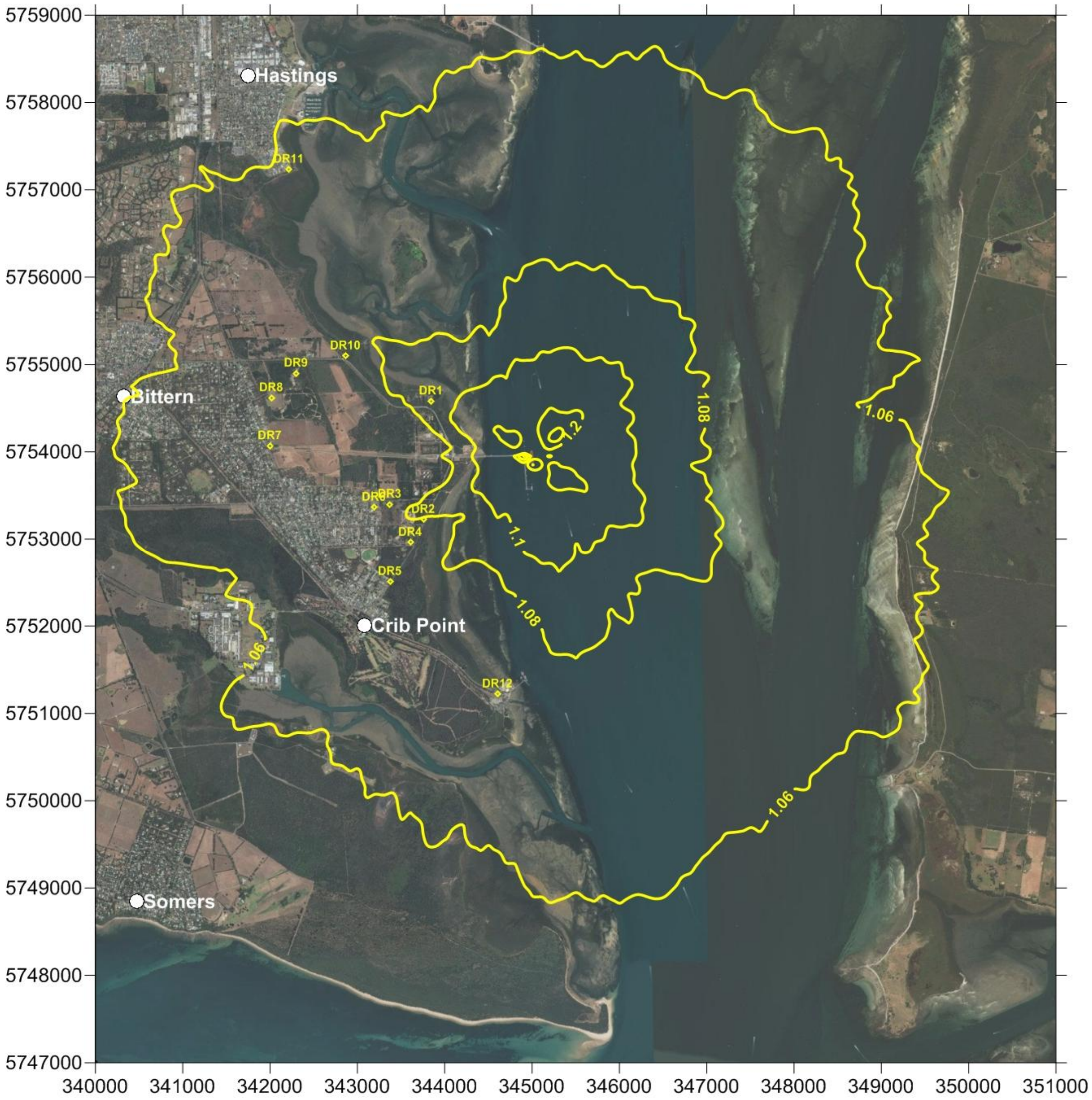

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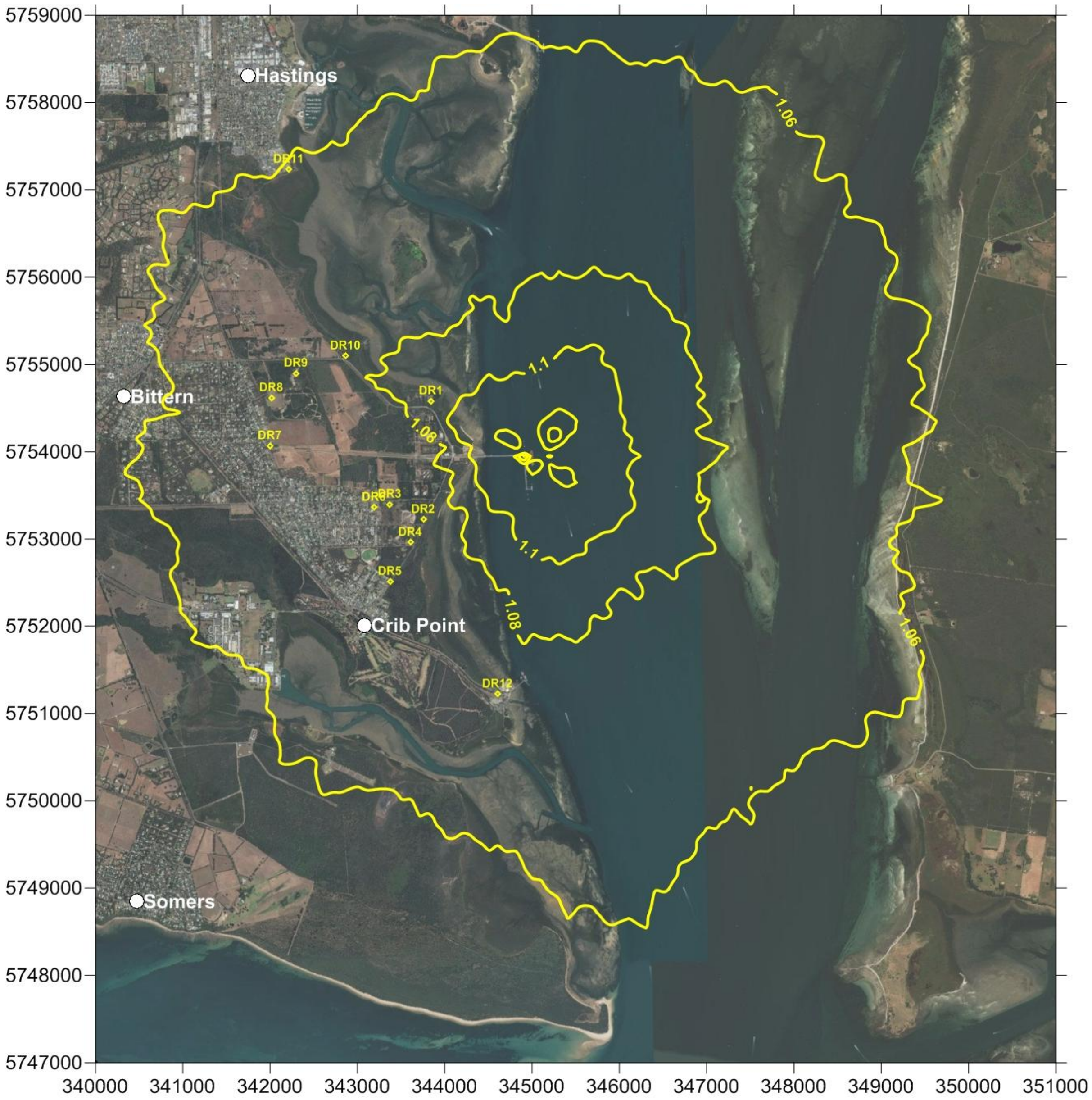

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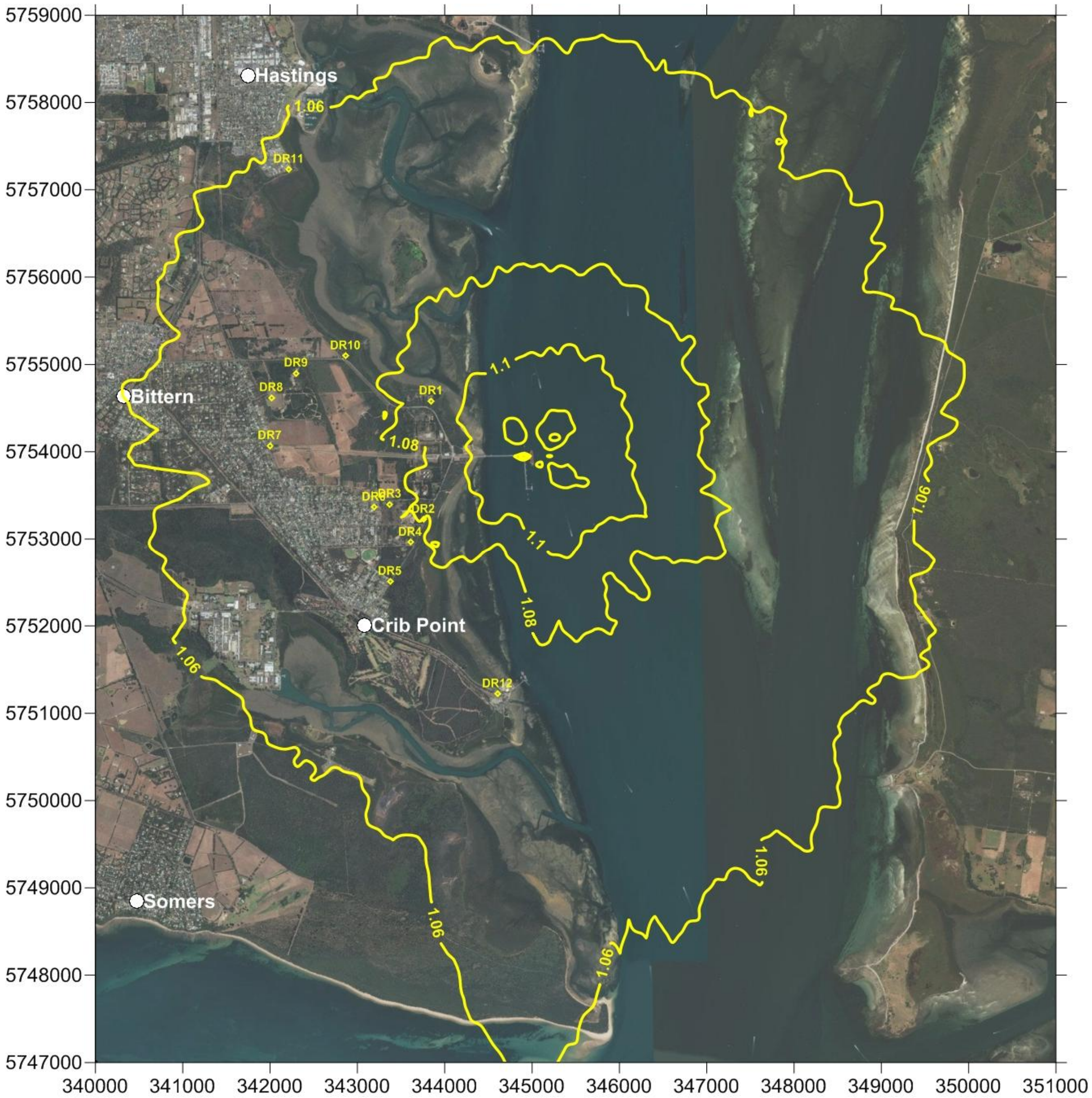
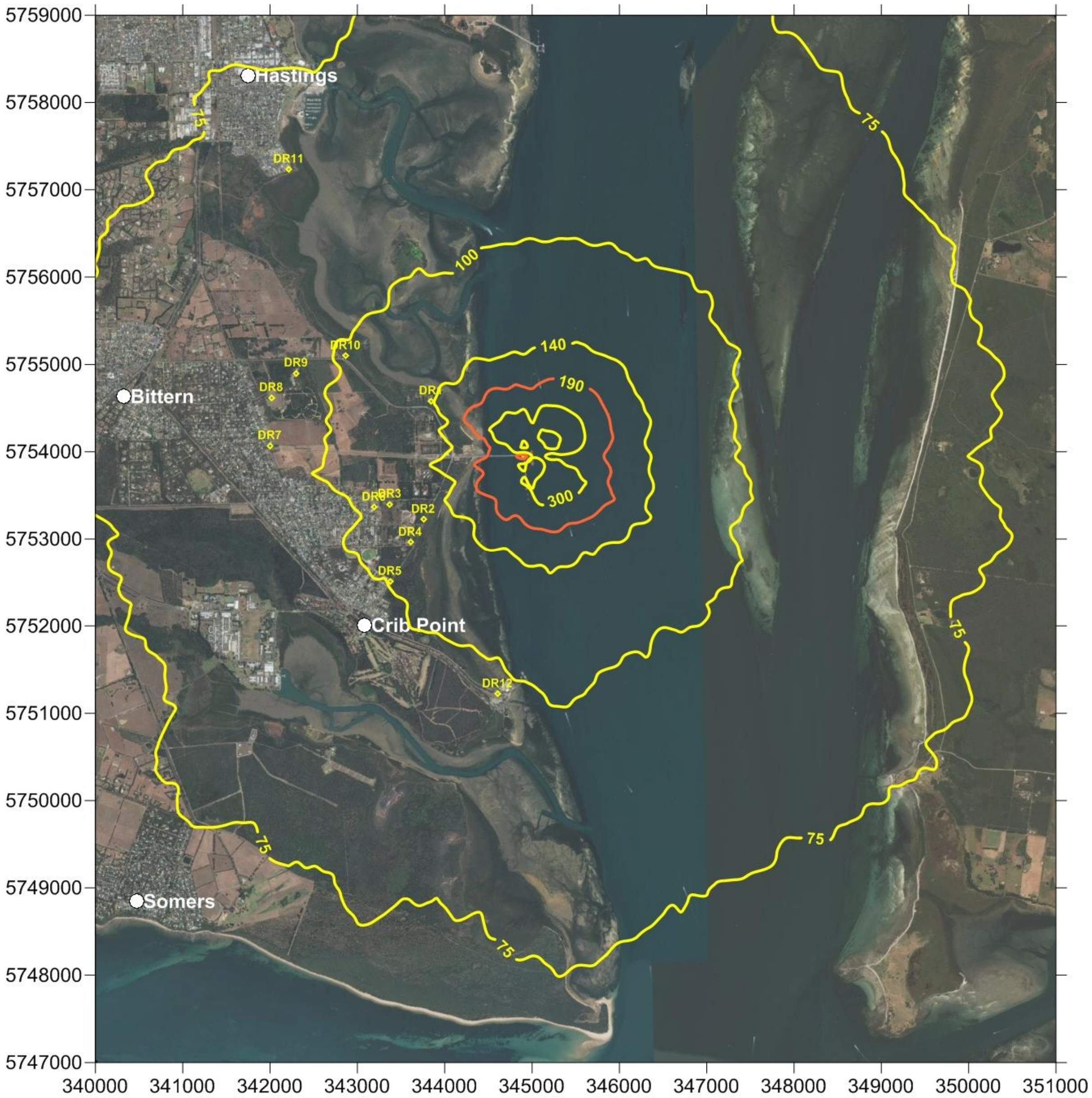


AERMOD Results 99.9 Percentile 1 Hour NO_2 GLCs (µg/m^3) – FSRU Gas Fuel – 2012



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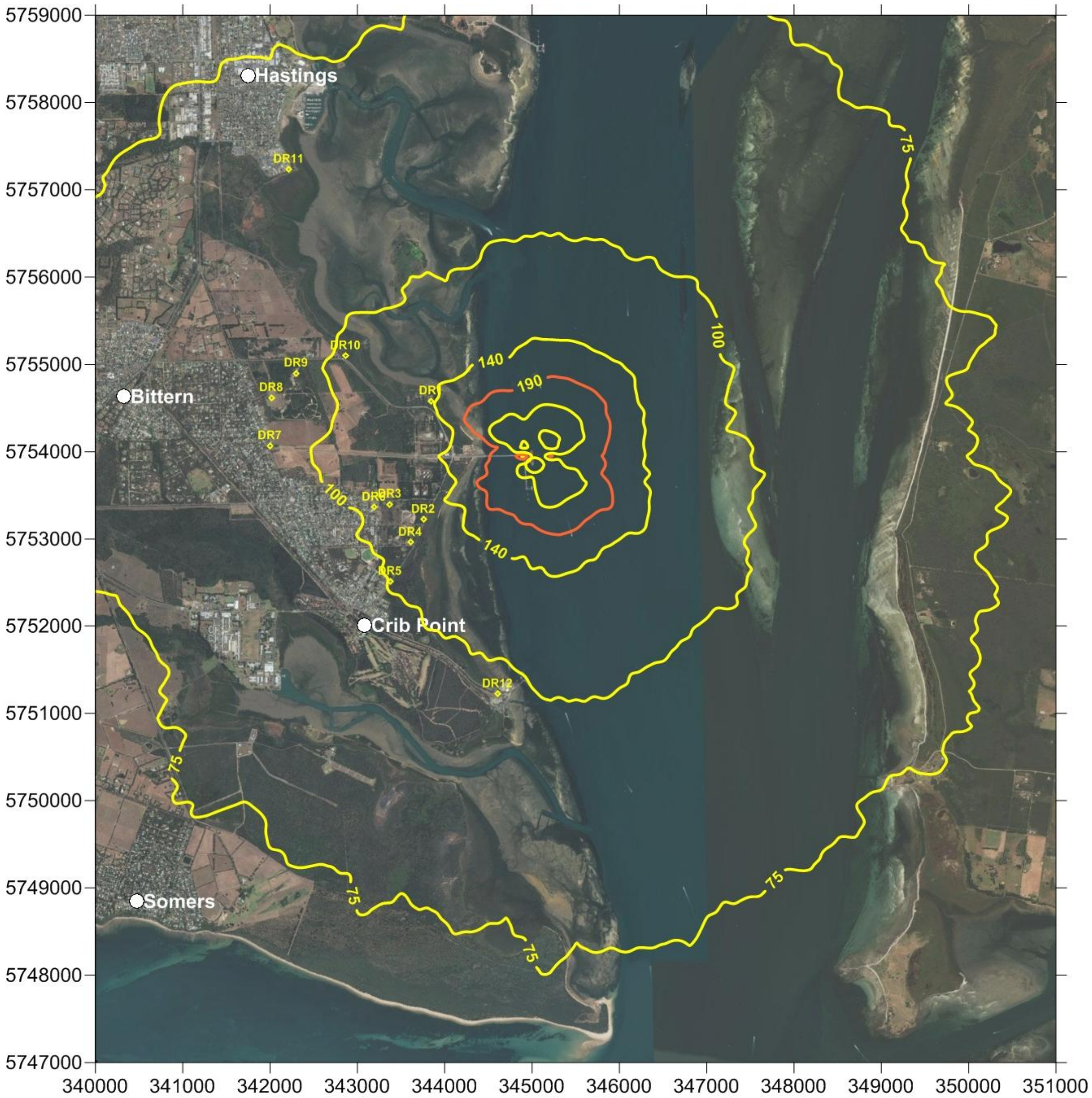

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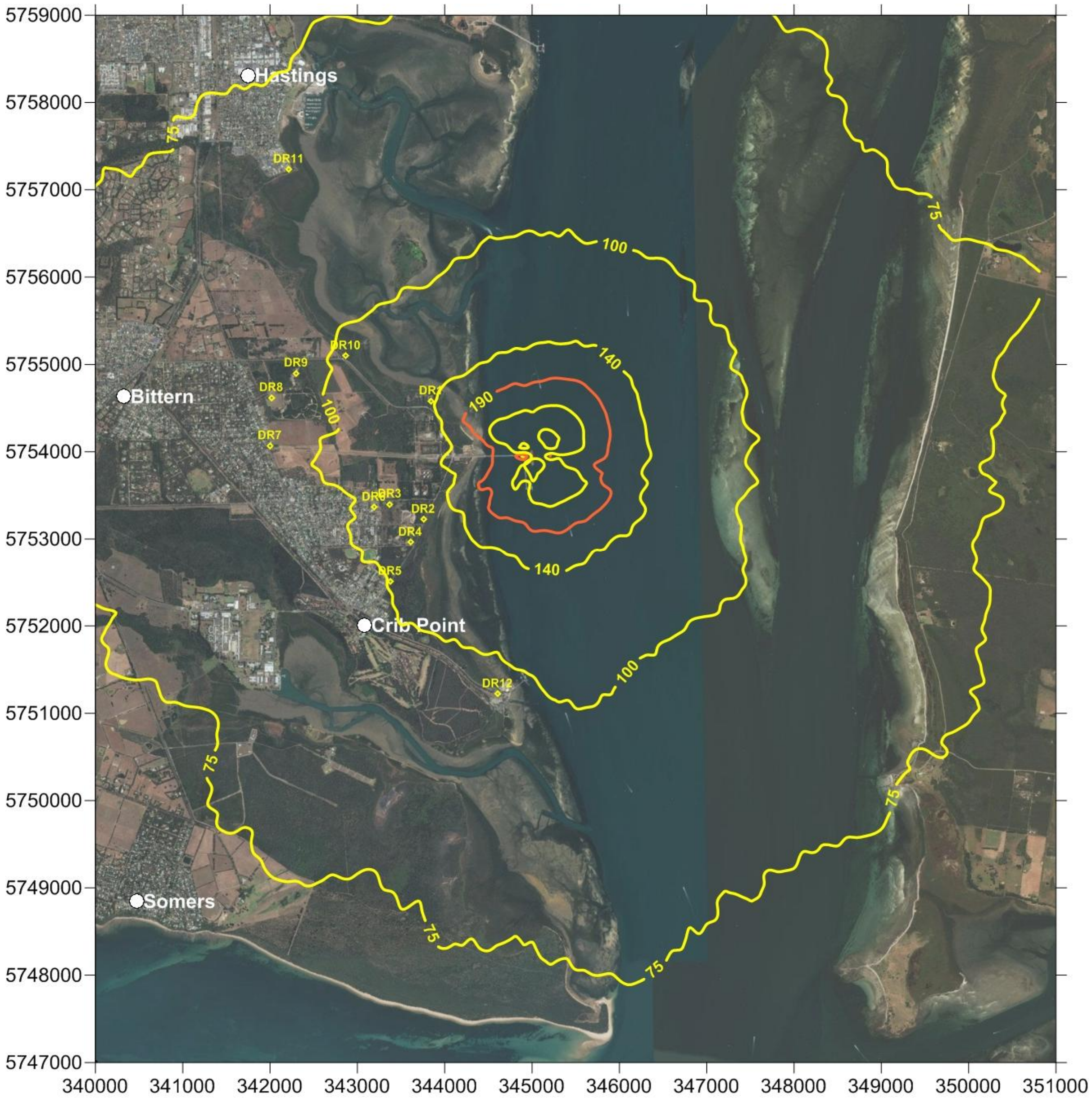

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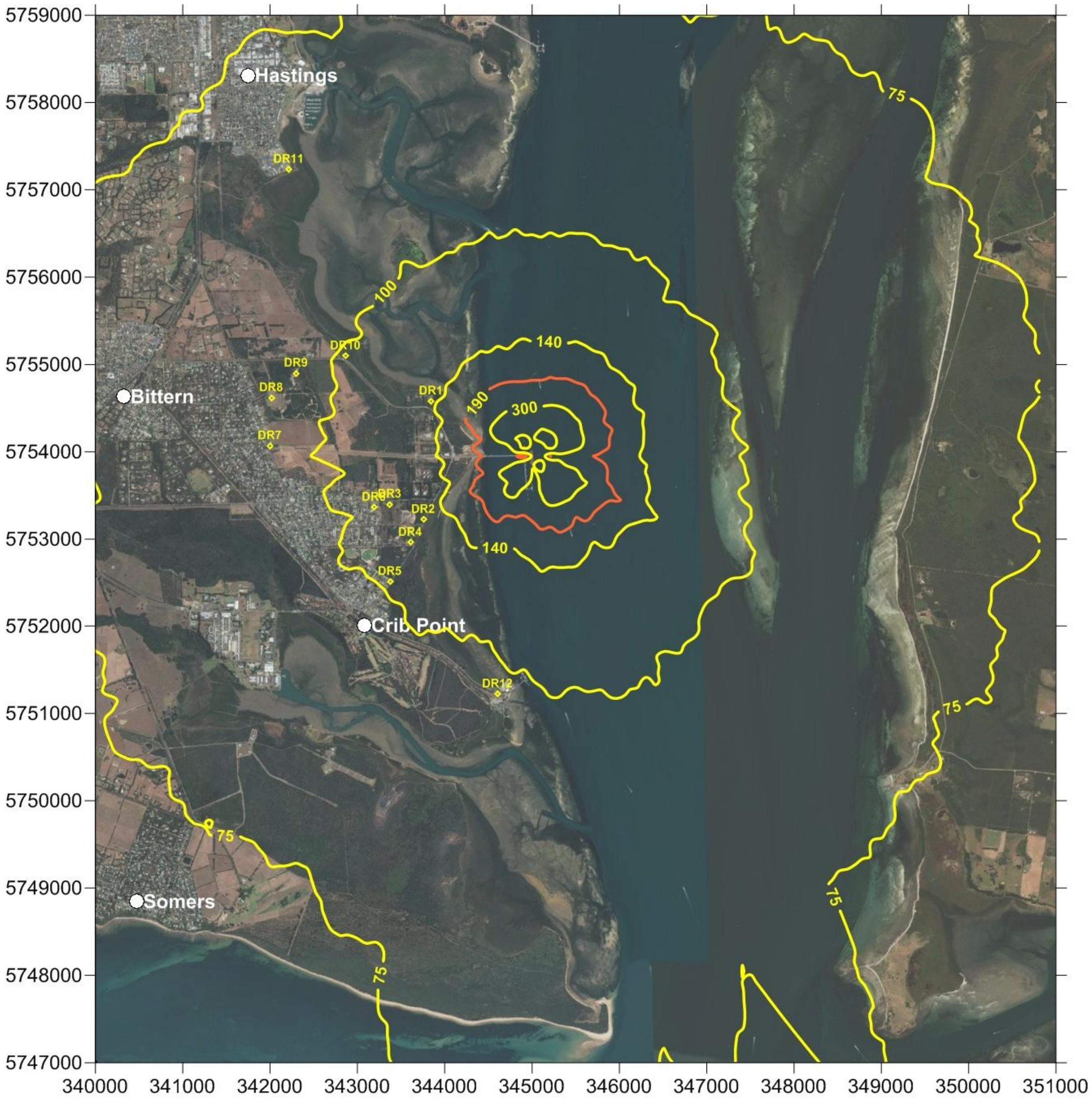

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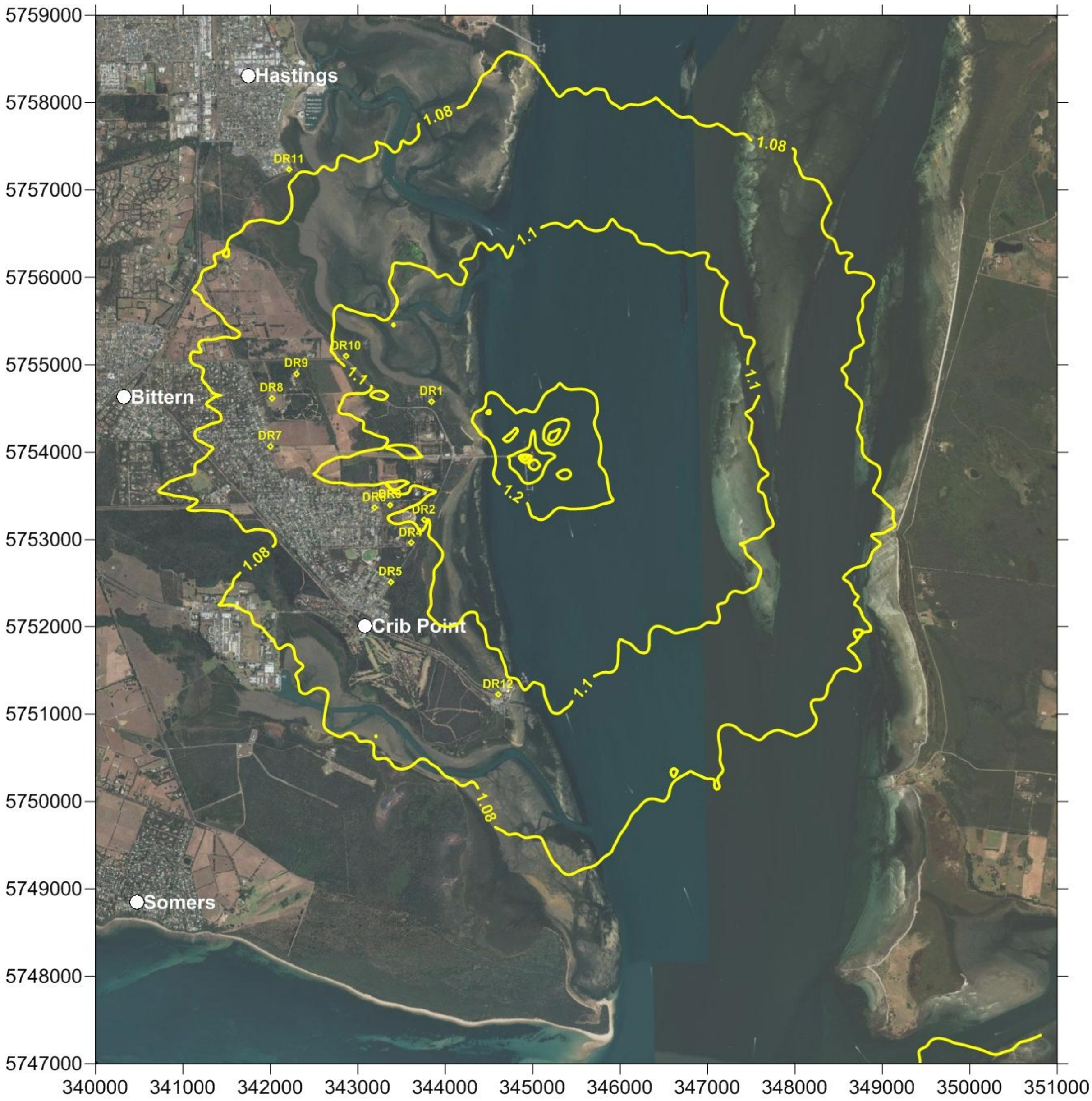

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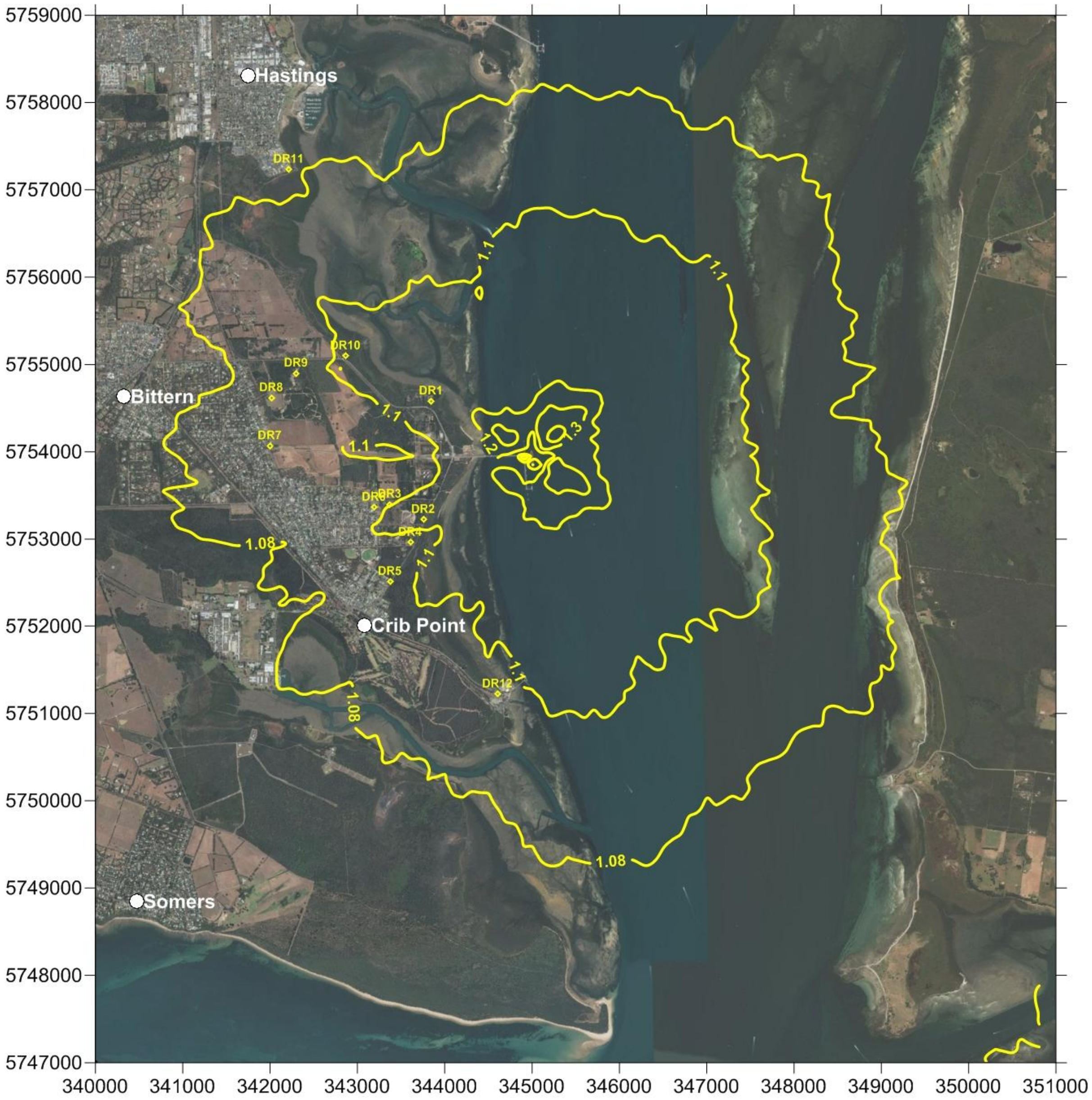

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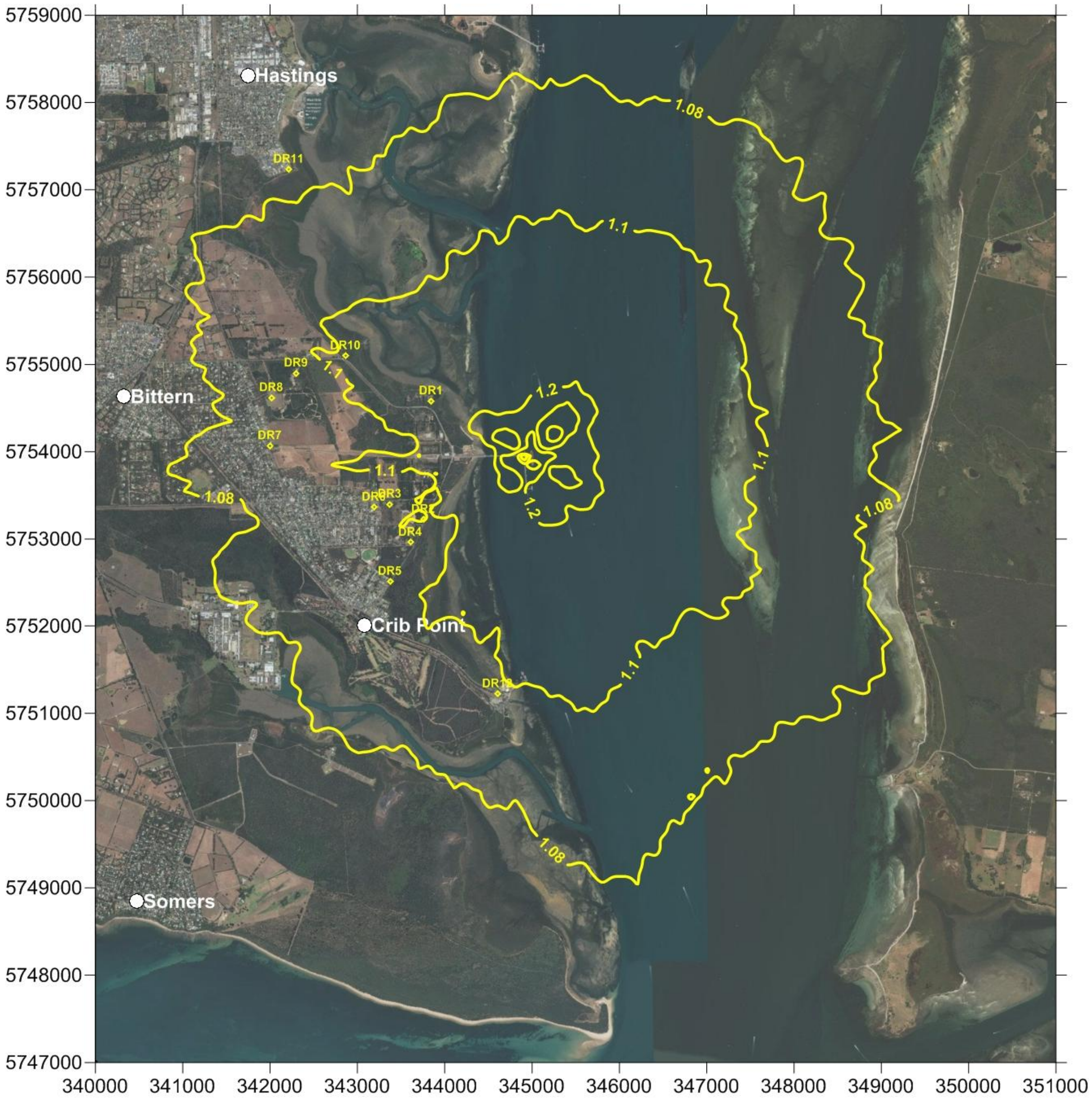

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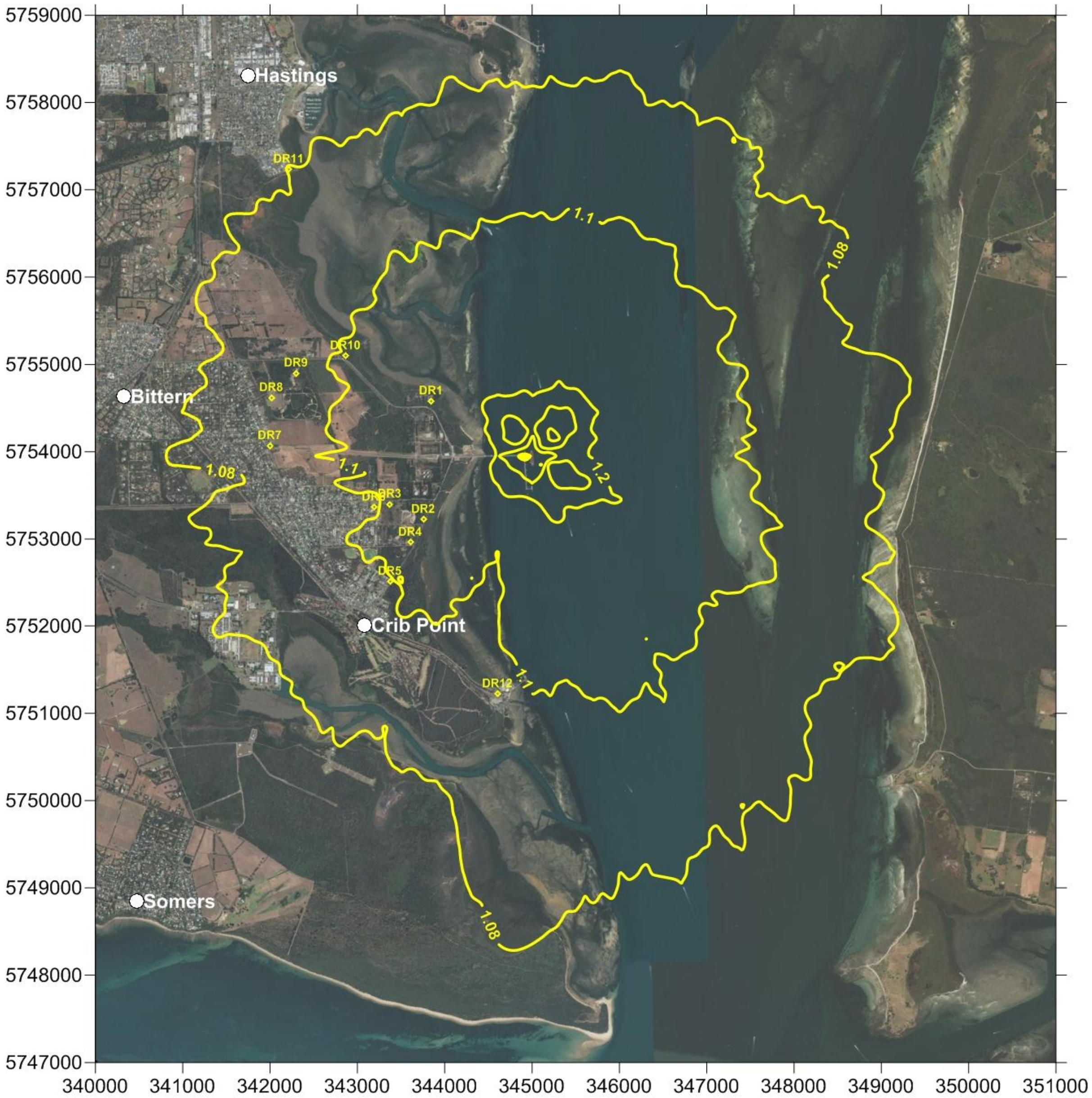

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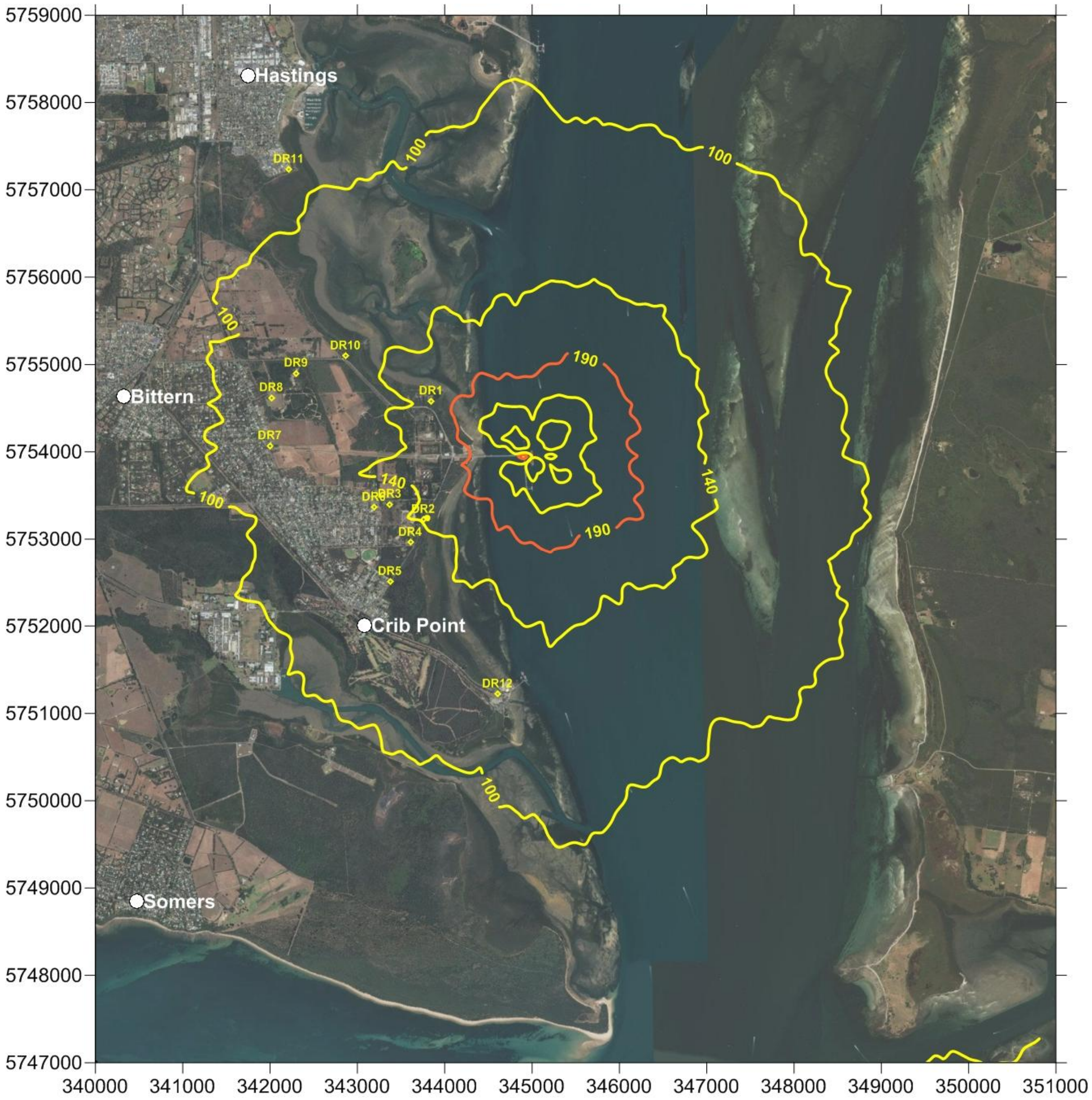

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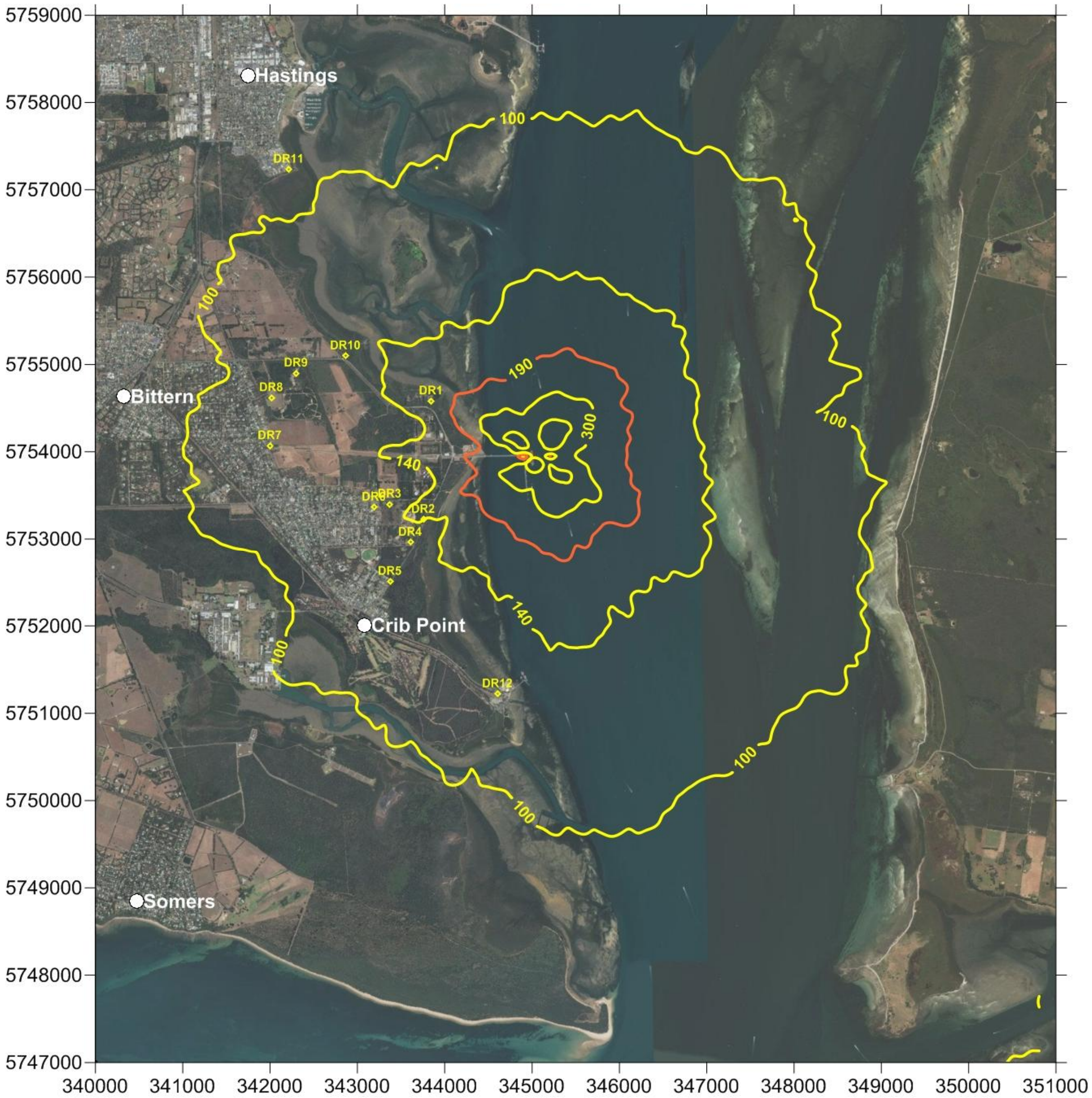

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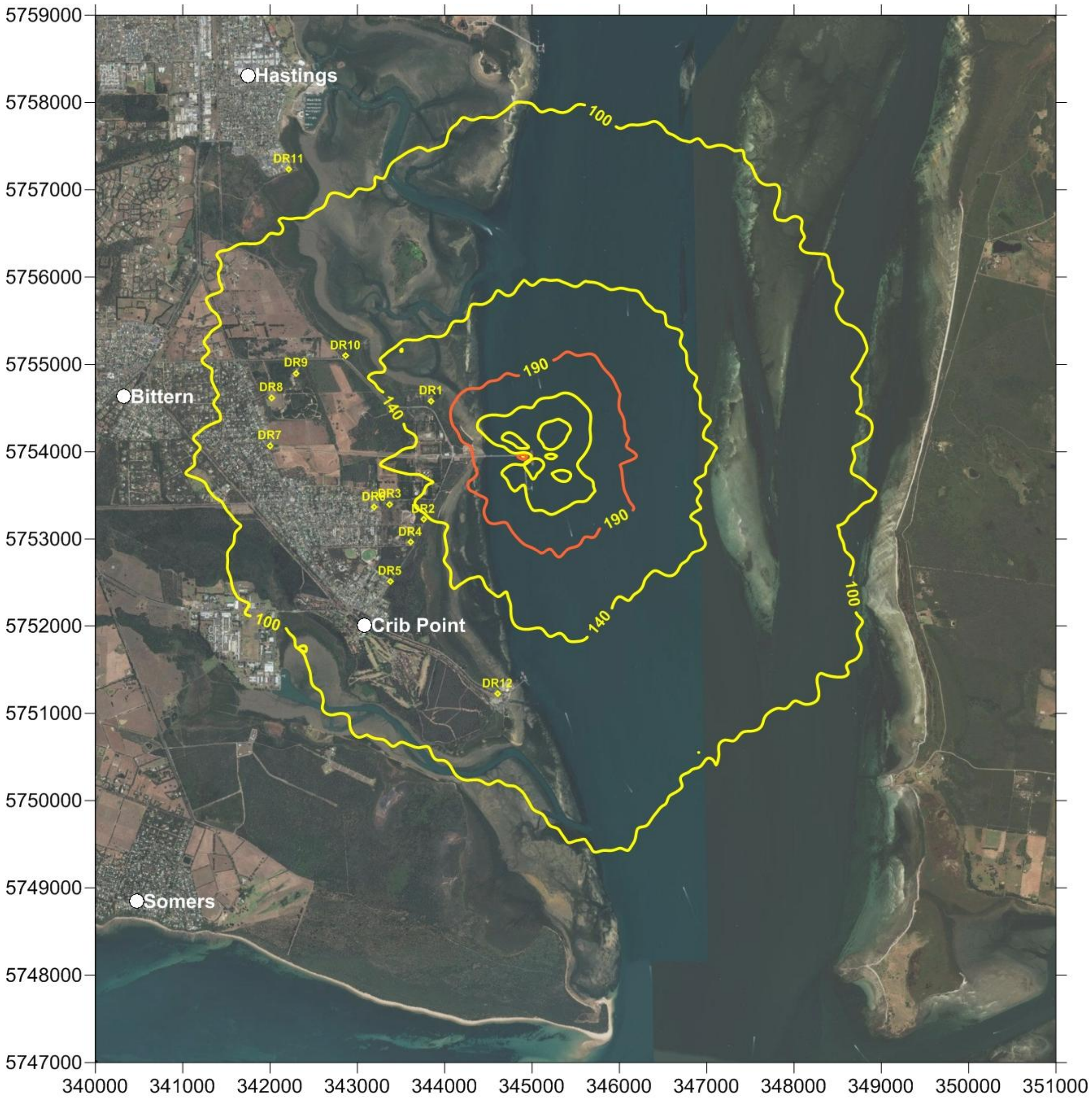

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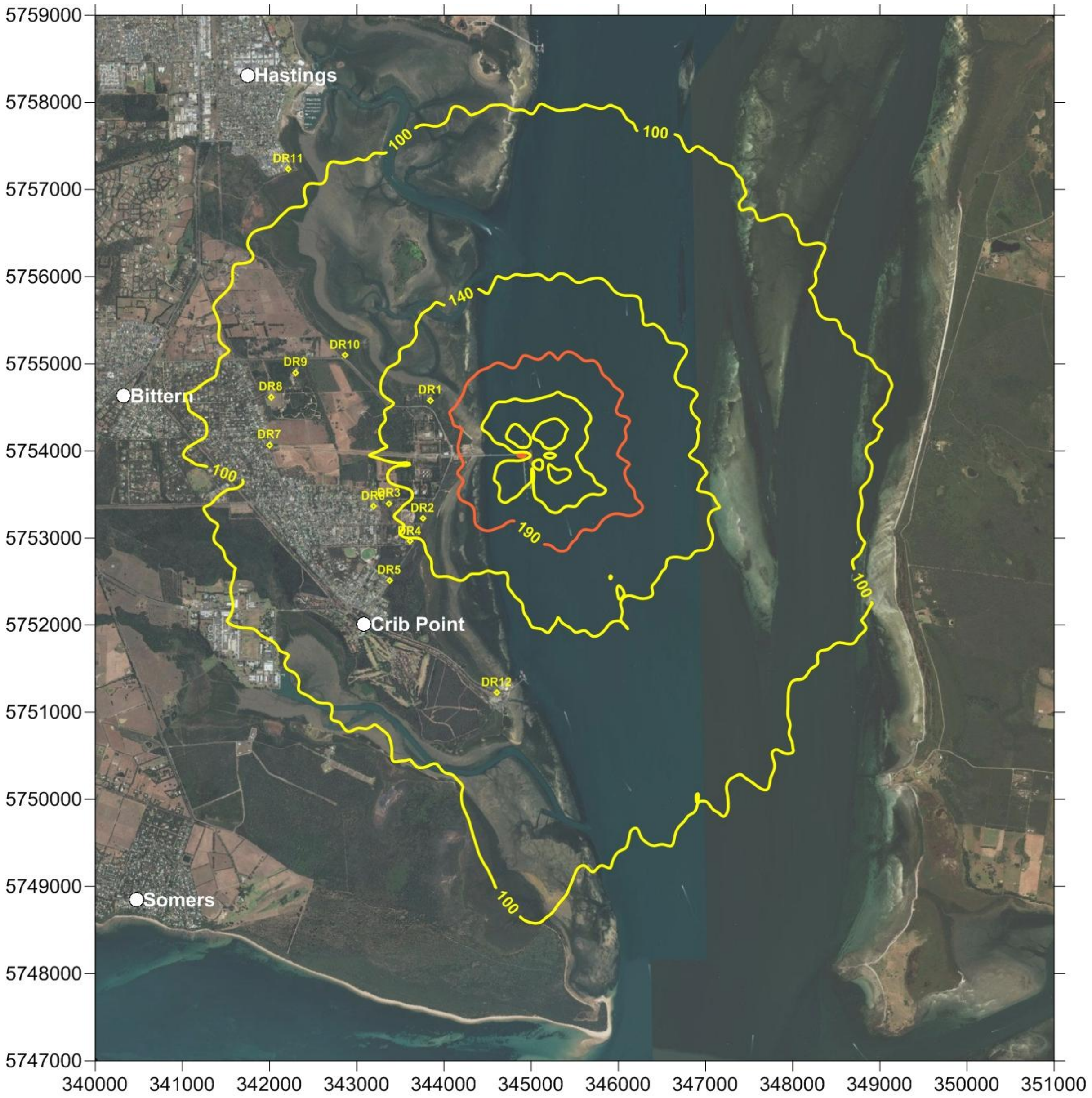

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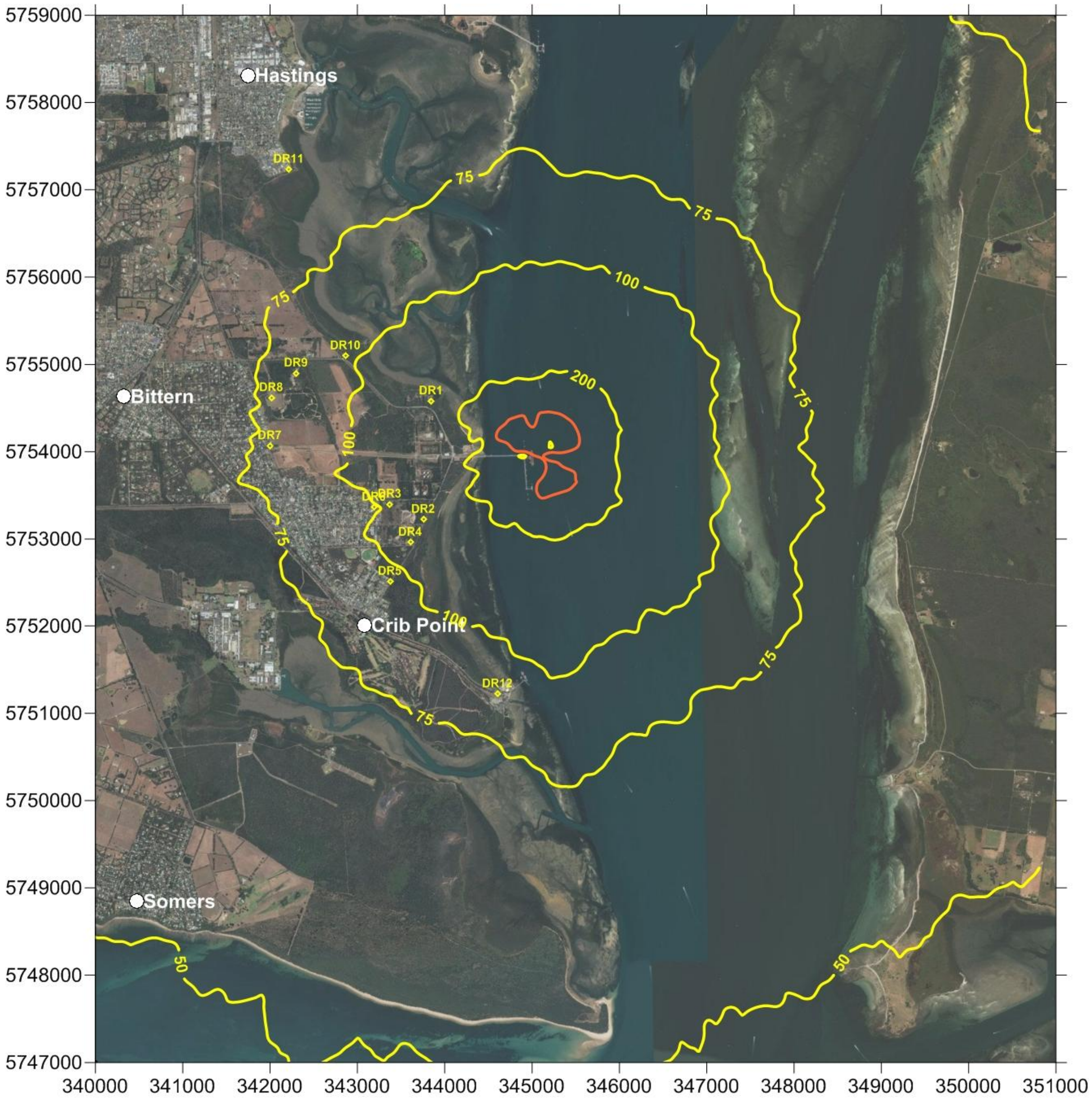

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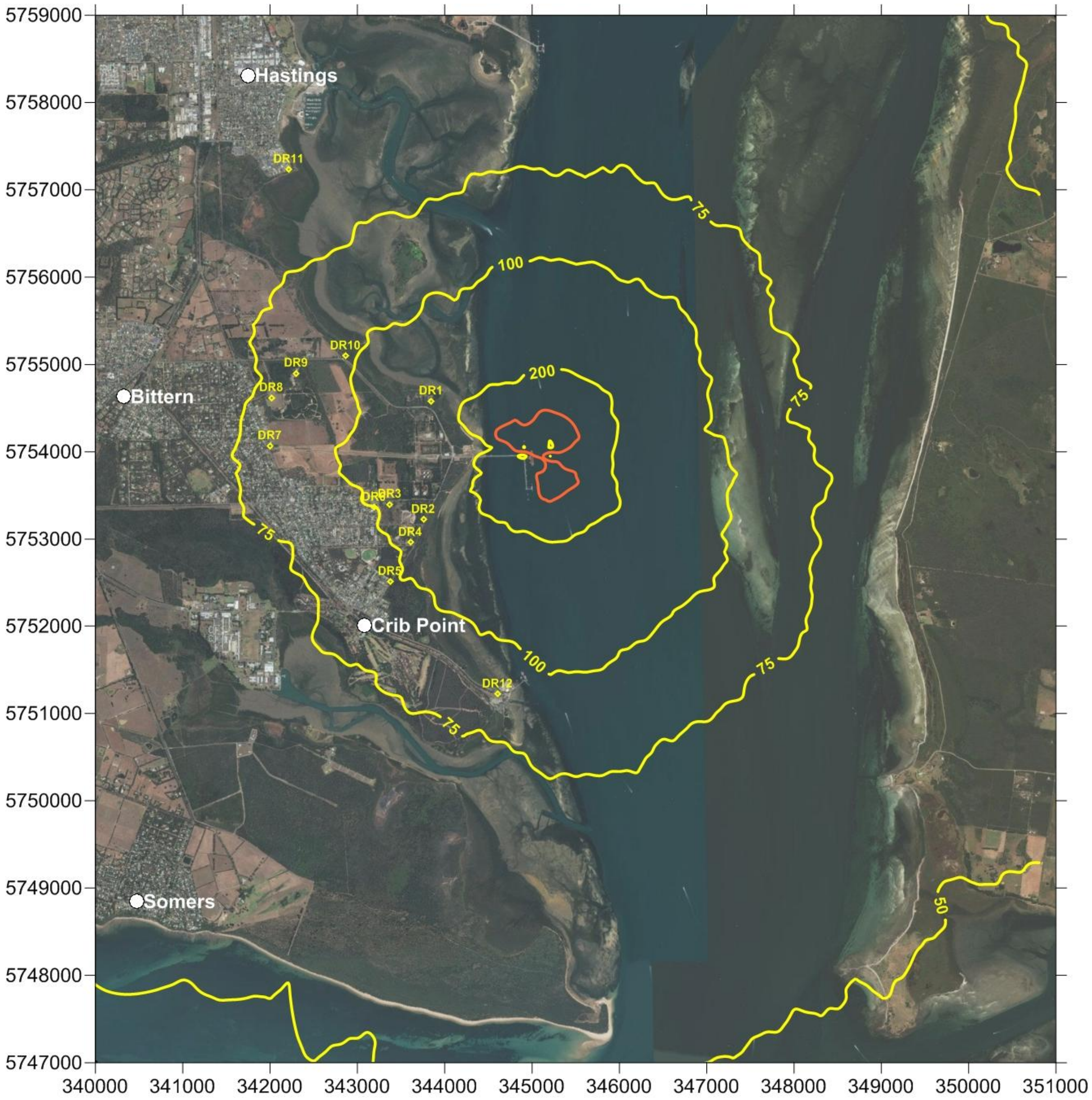

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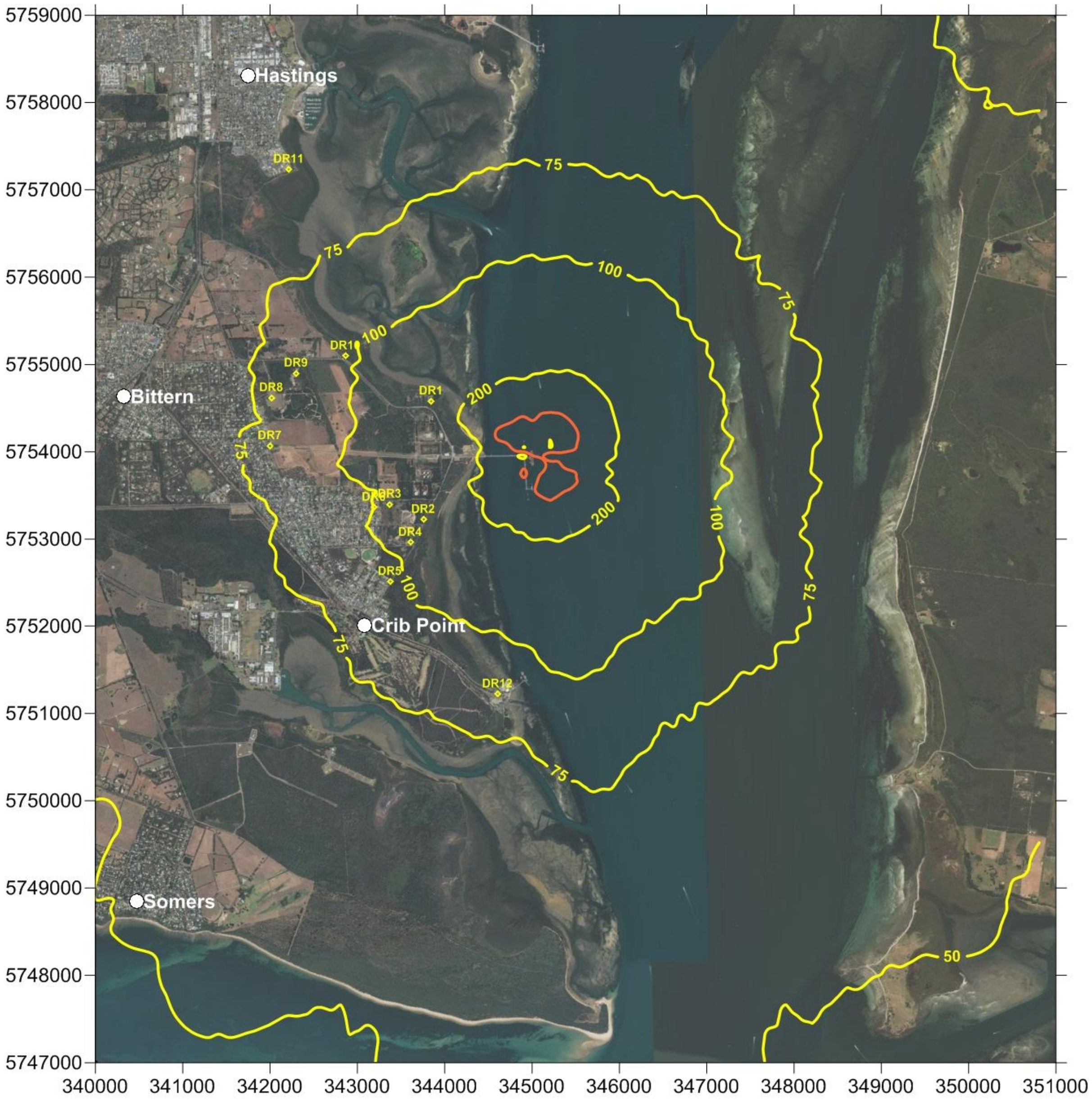

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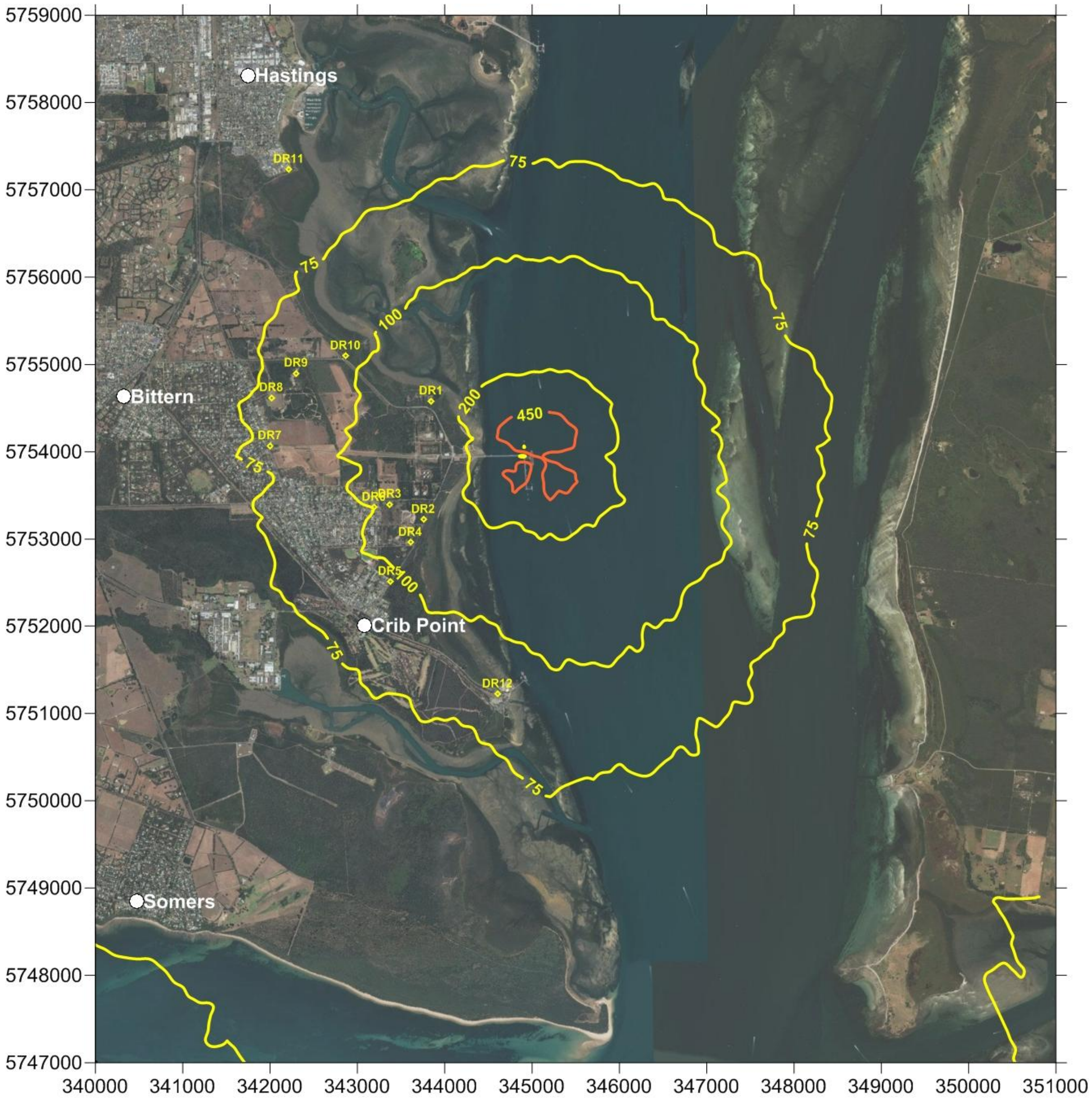

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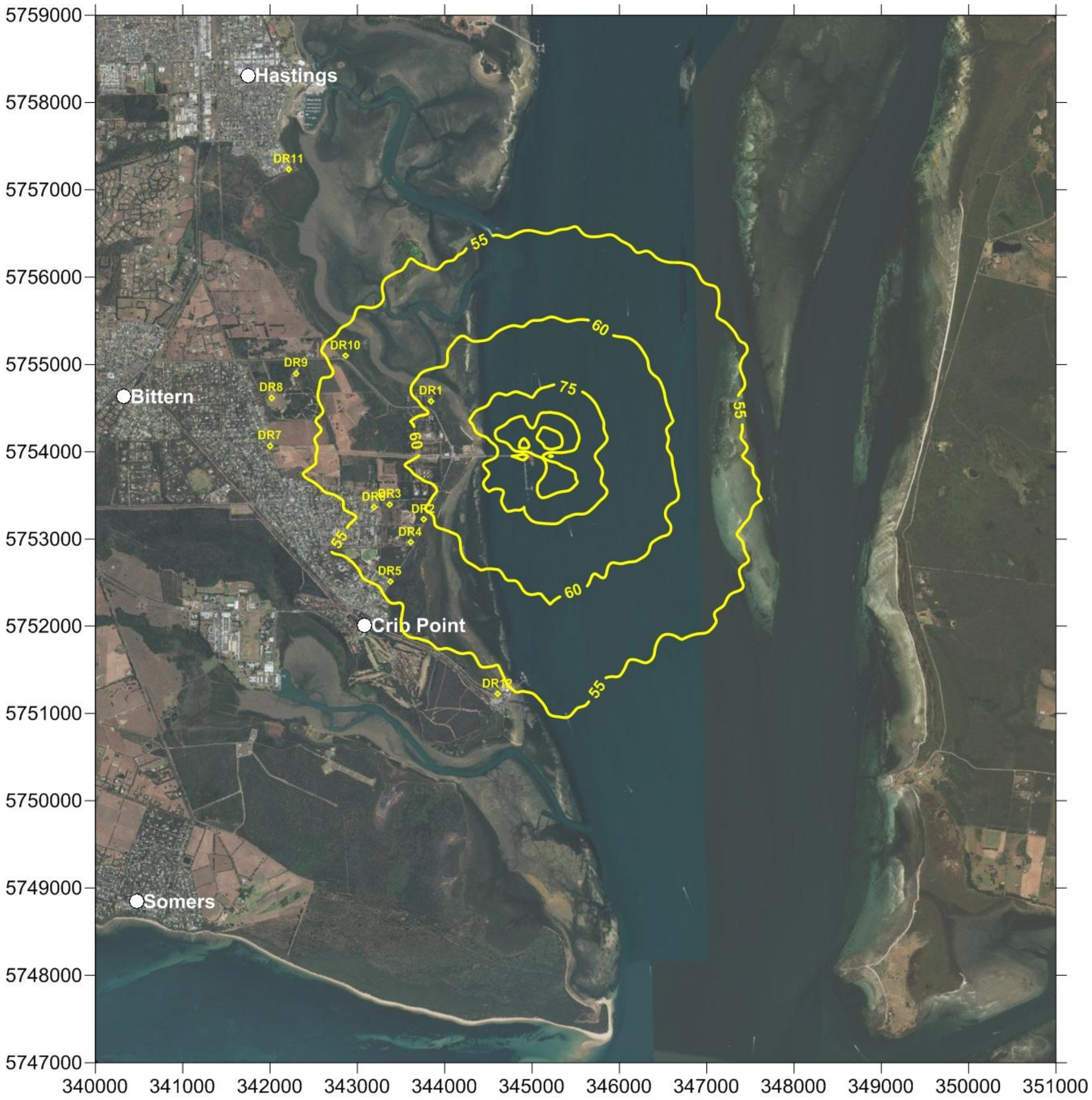

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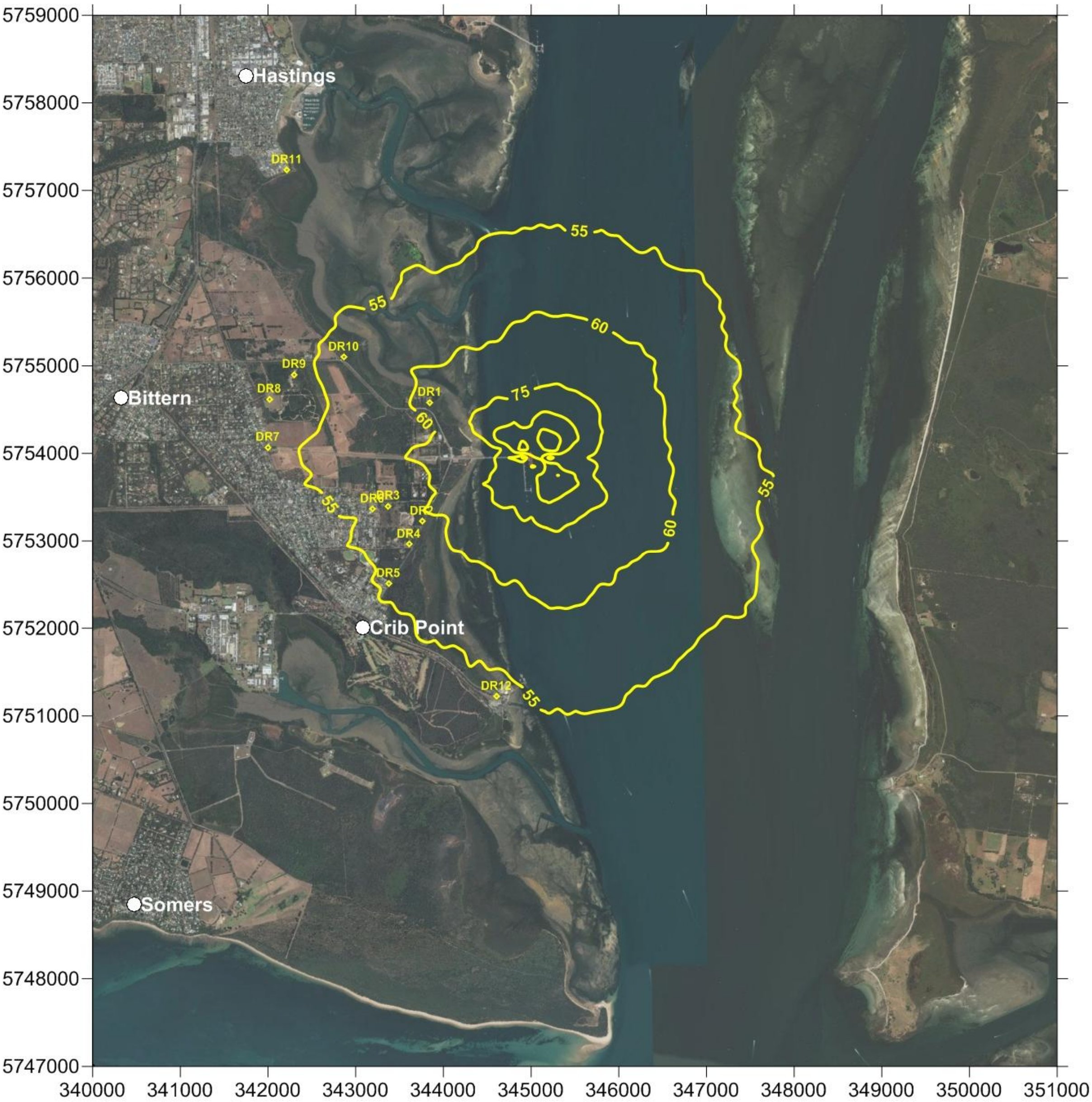

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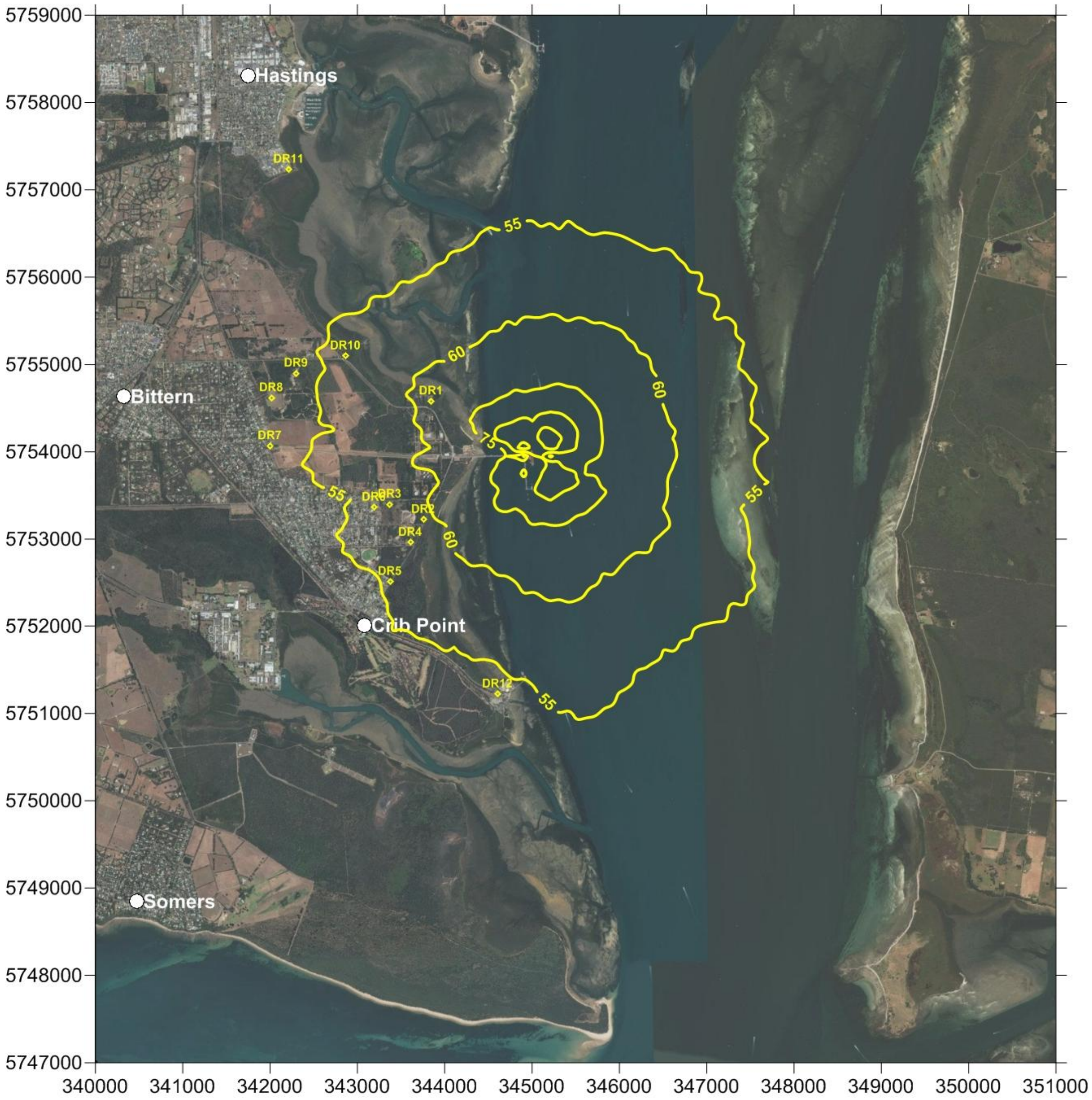

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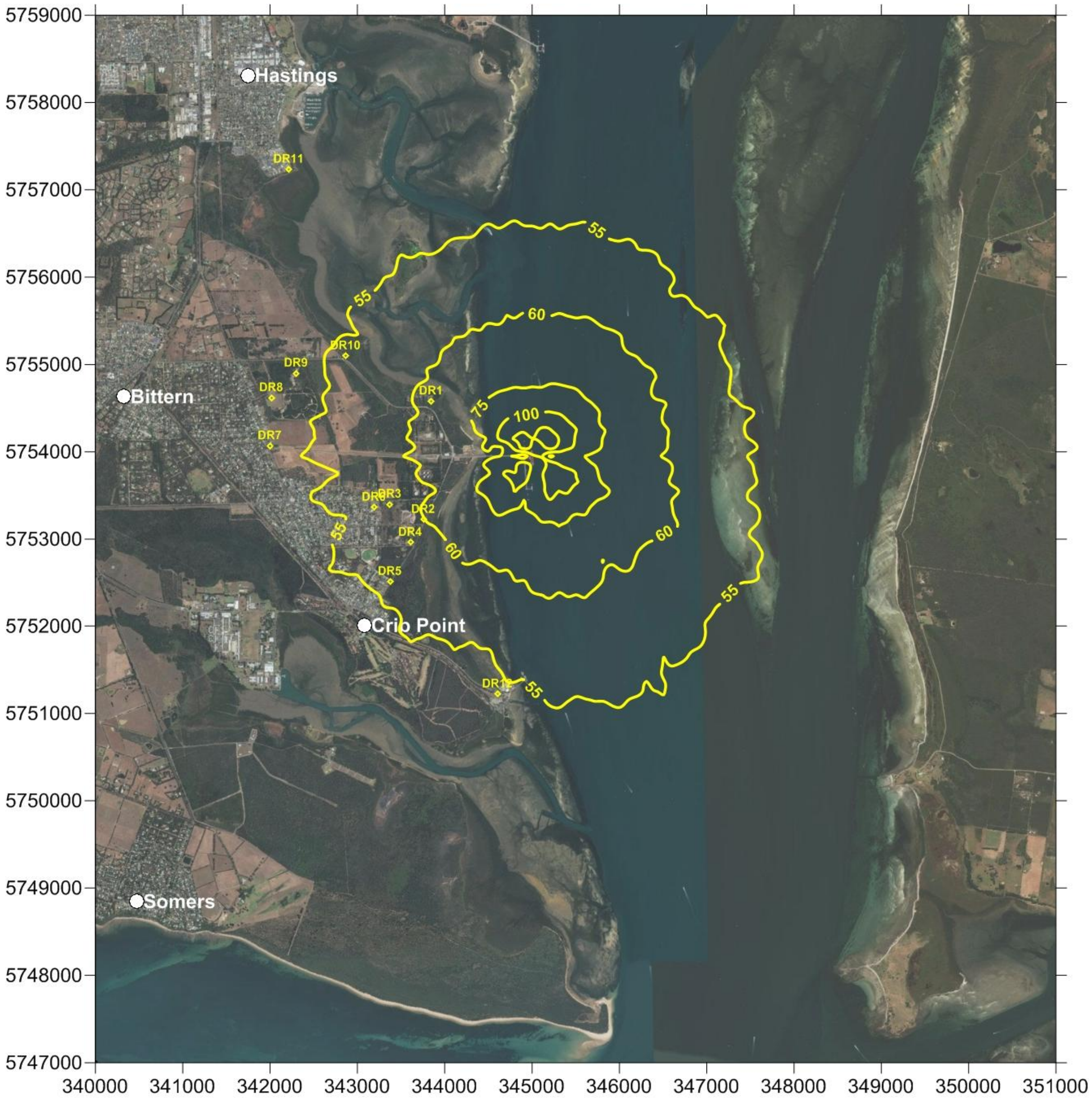

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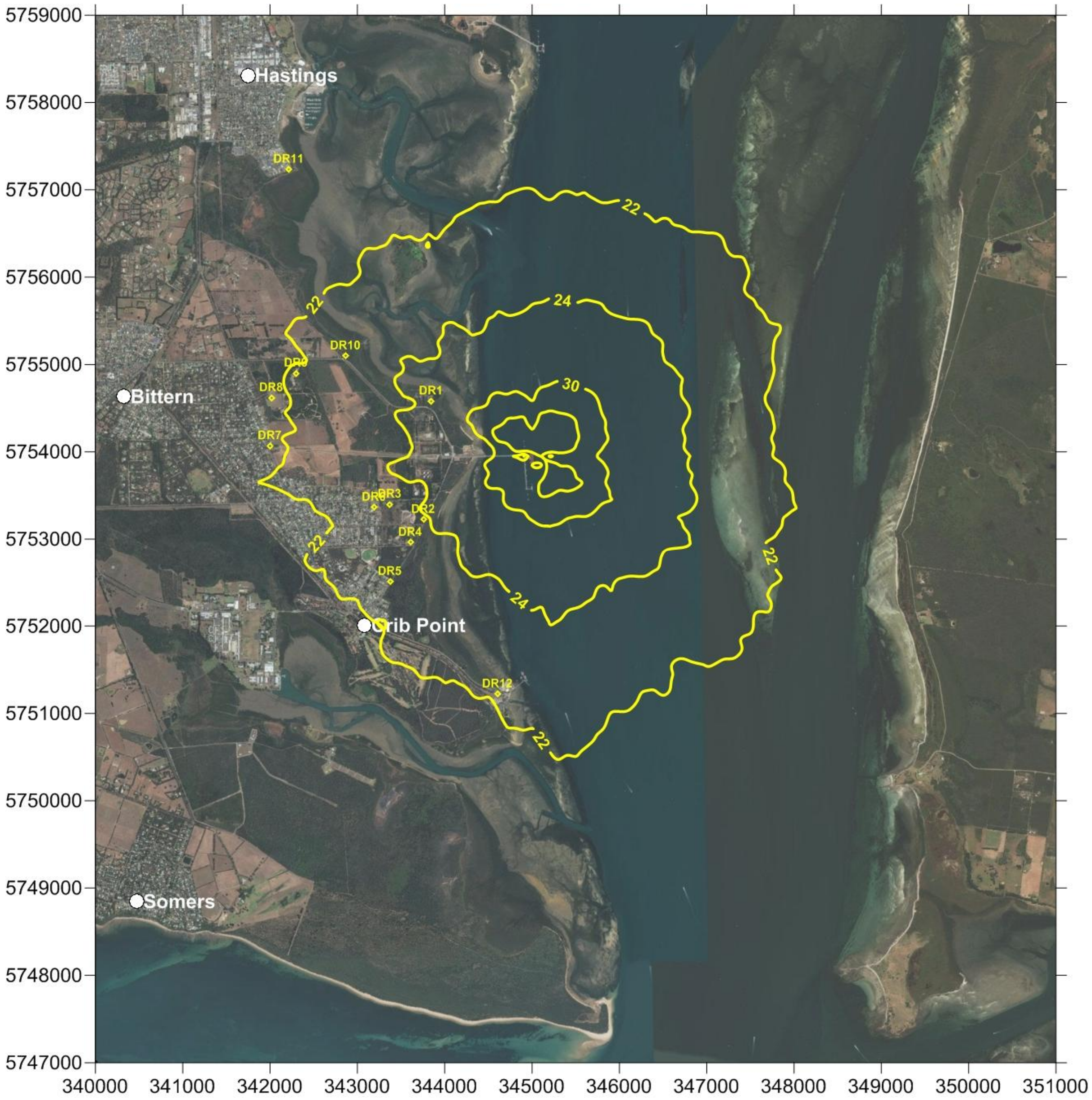

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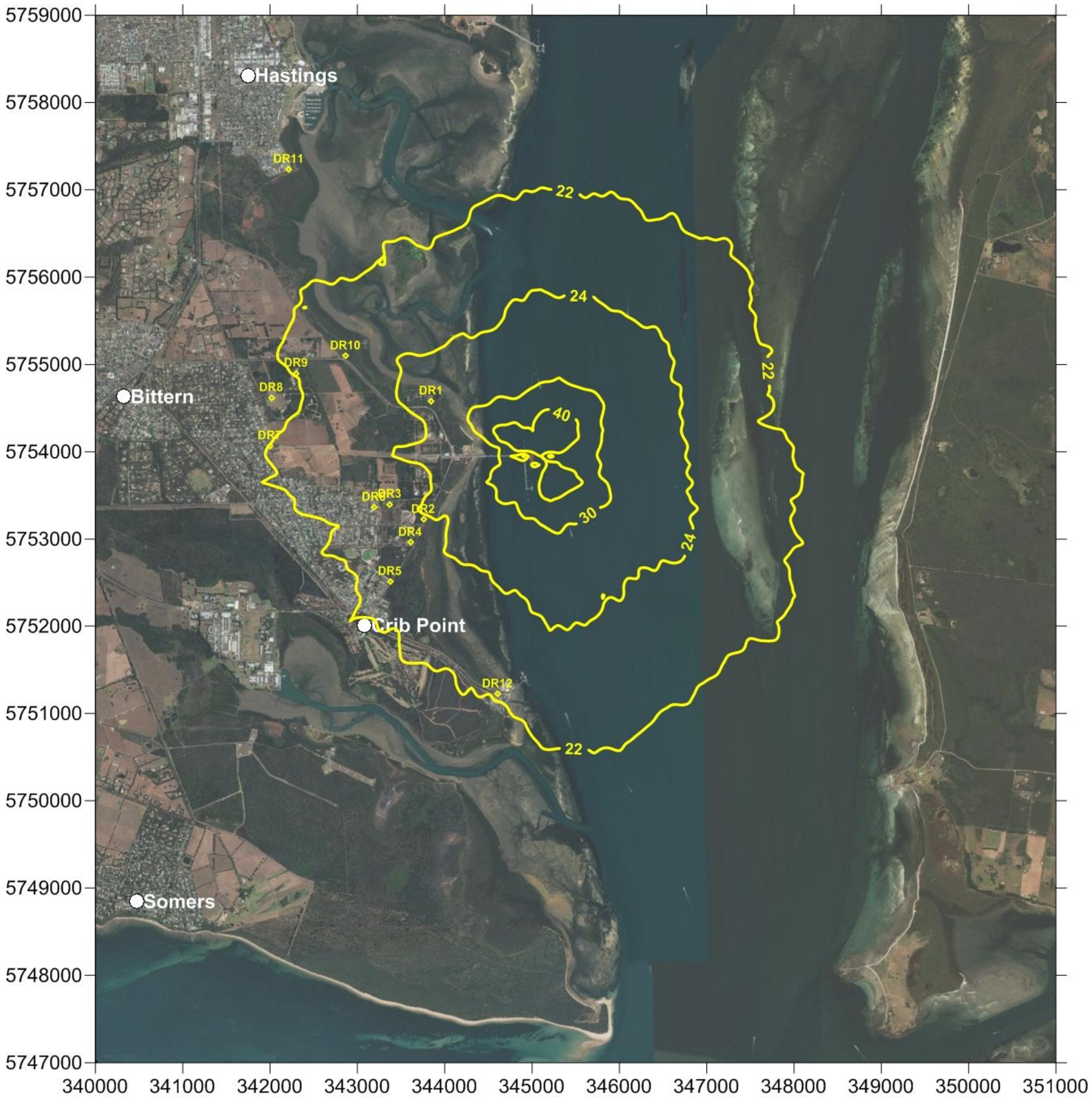

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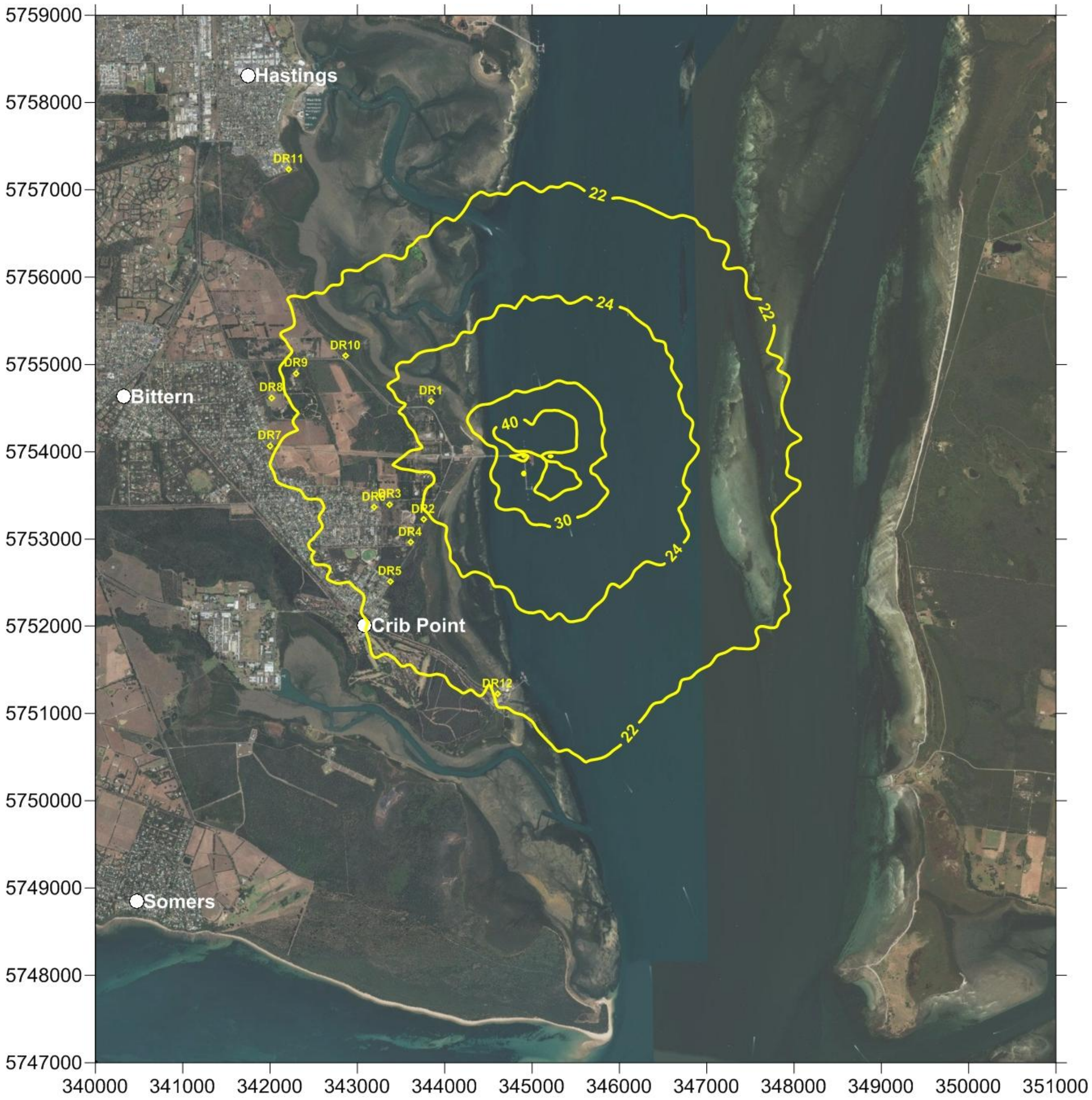

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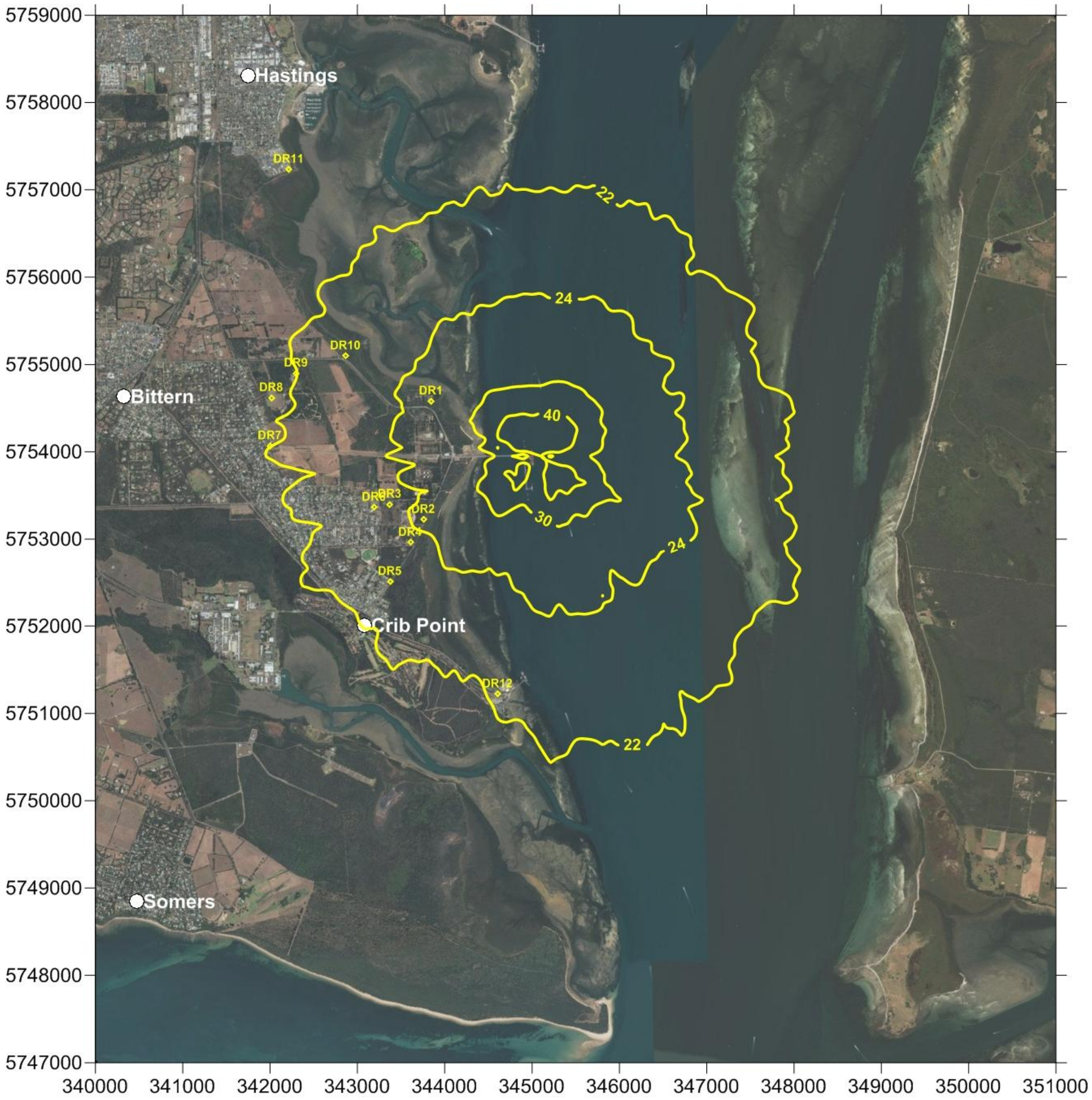
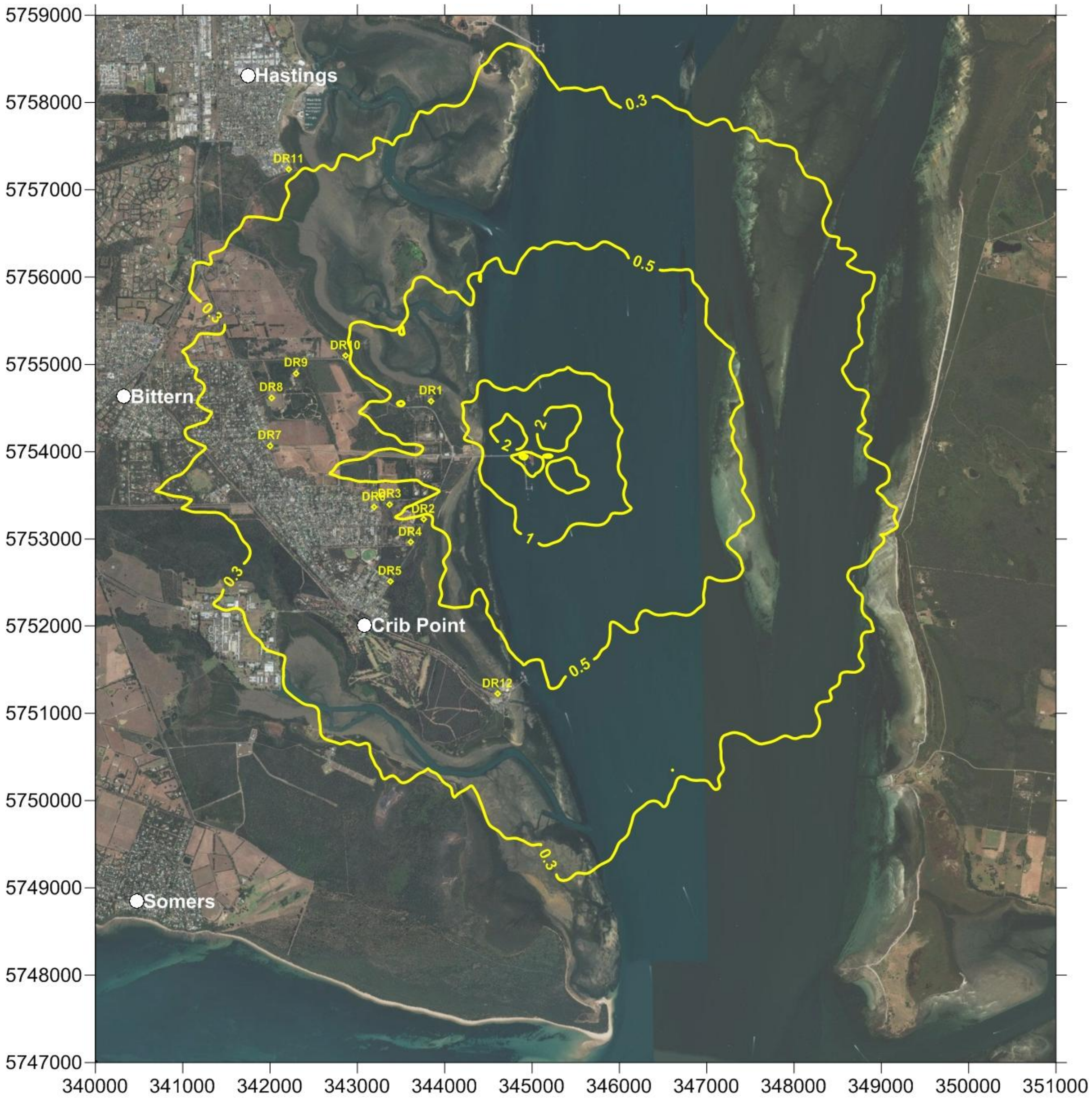


AERMOD Results 99.9 Percentile 3 Minute Benzene GLCs (µg/m^3) – FSRU Liquid Fuel – 2012



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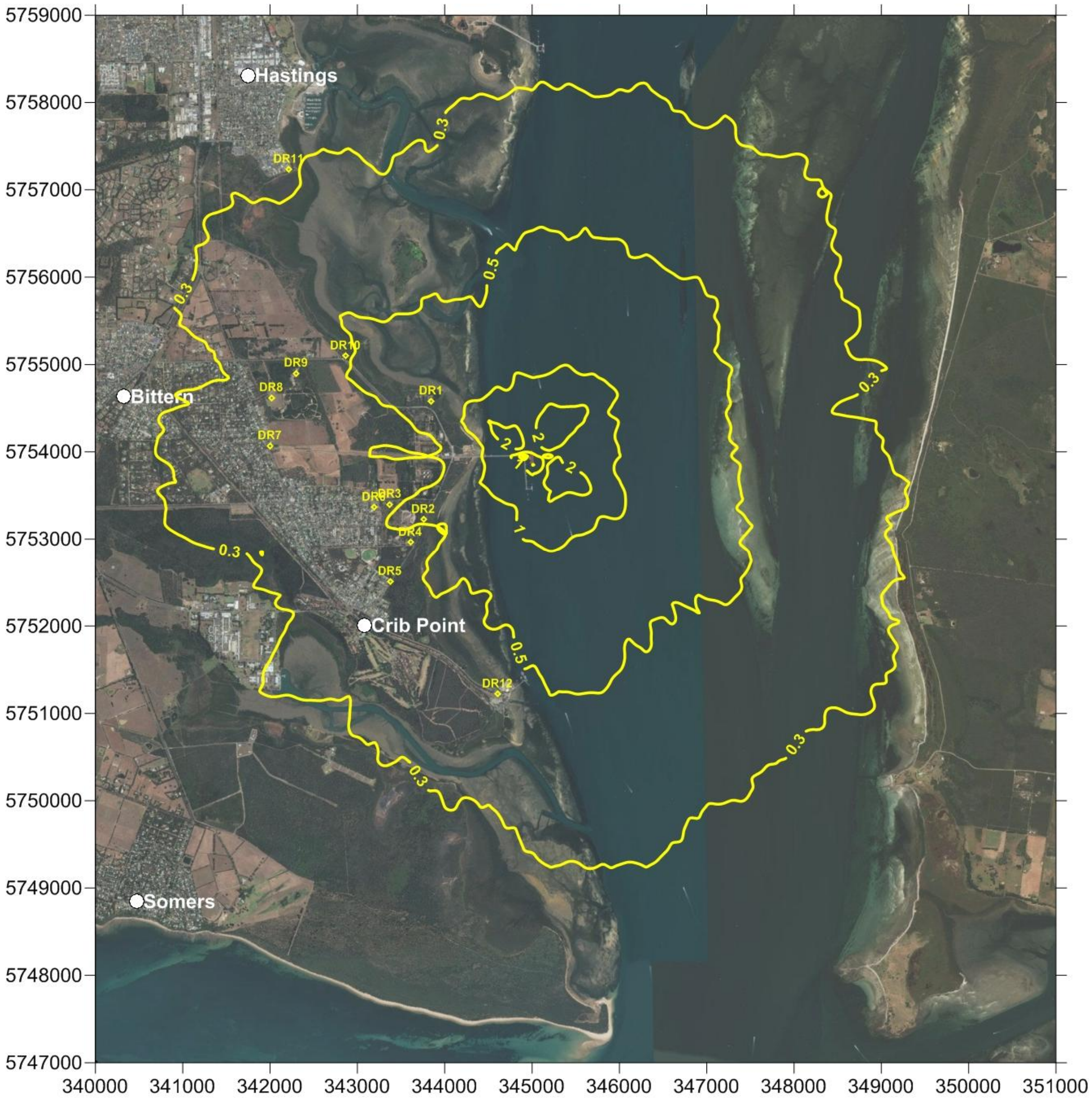

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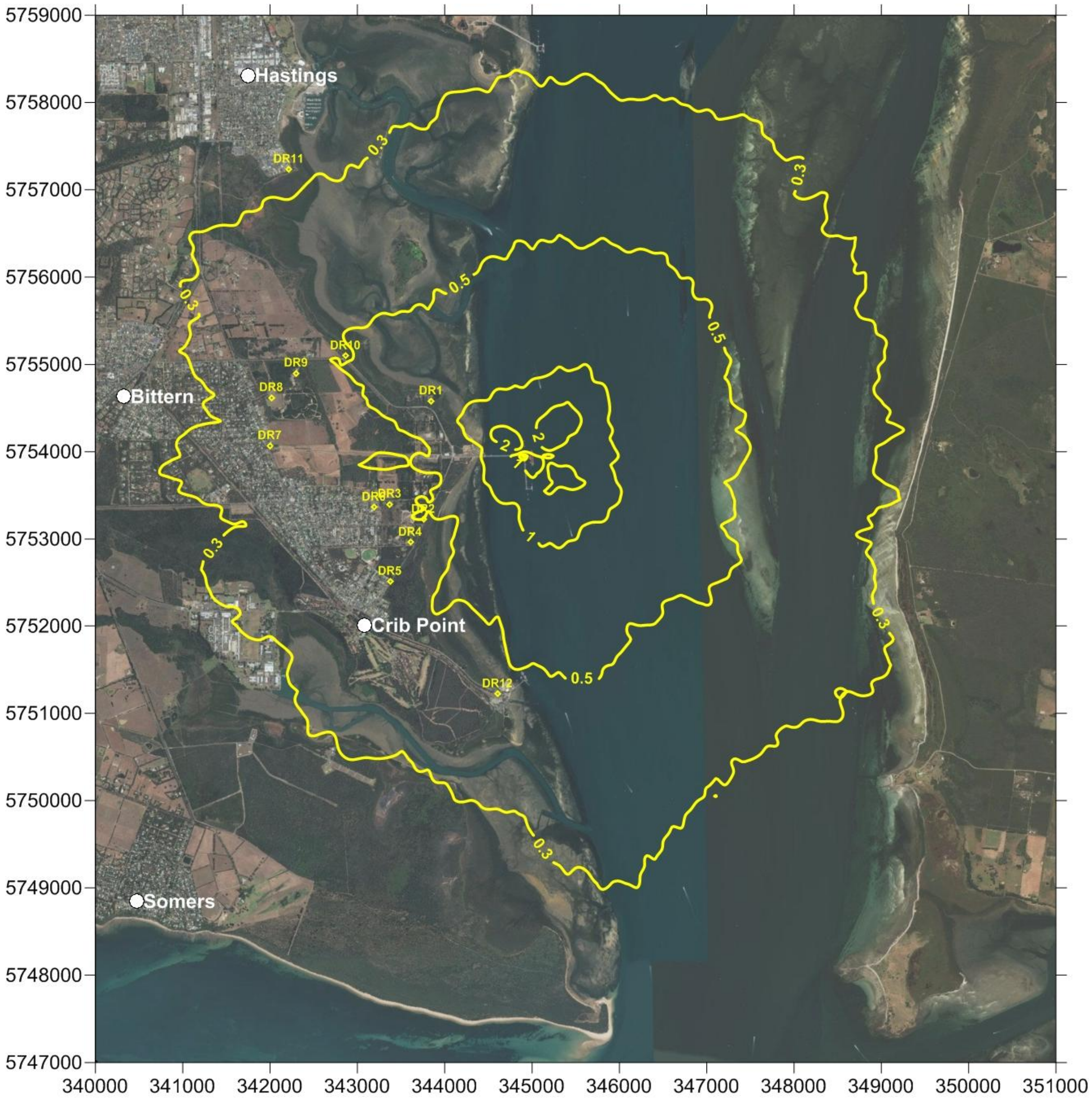

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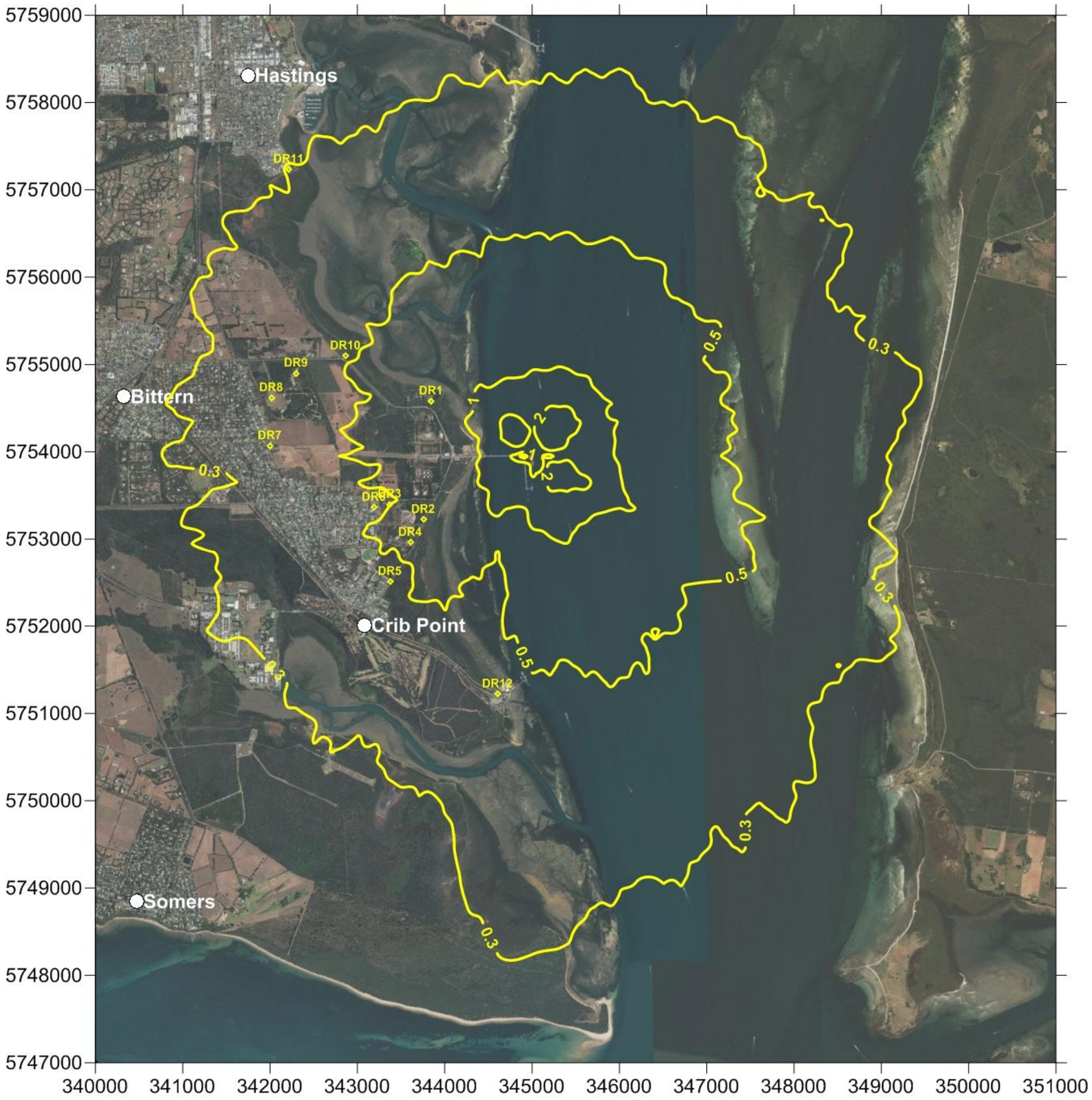
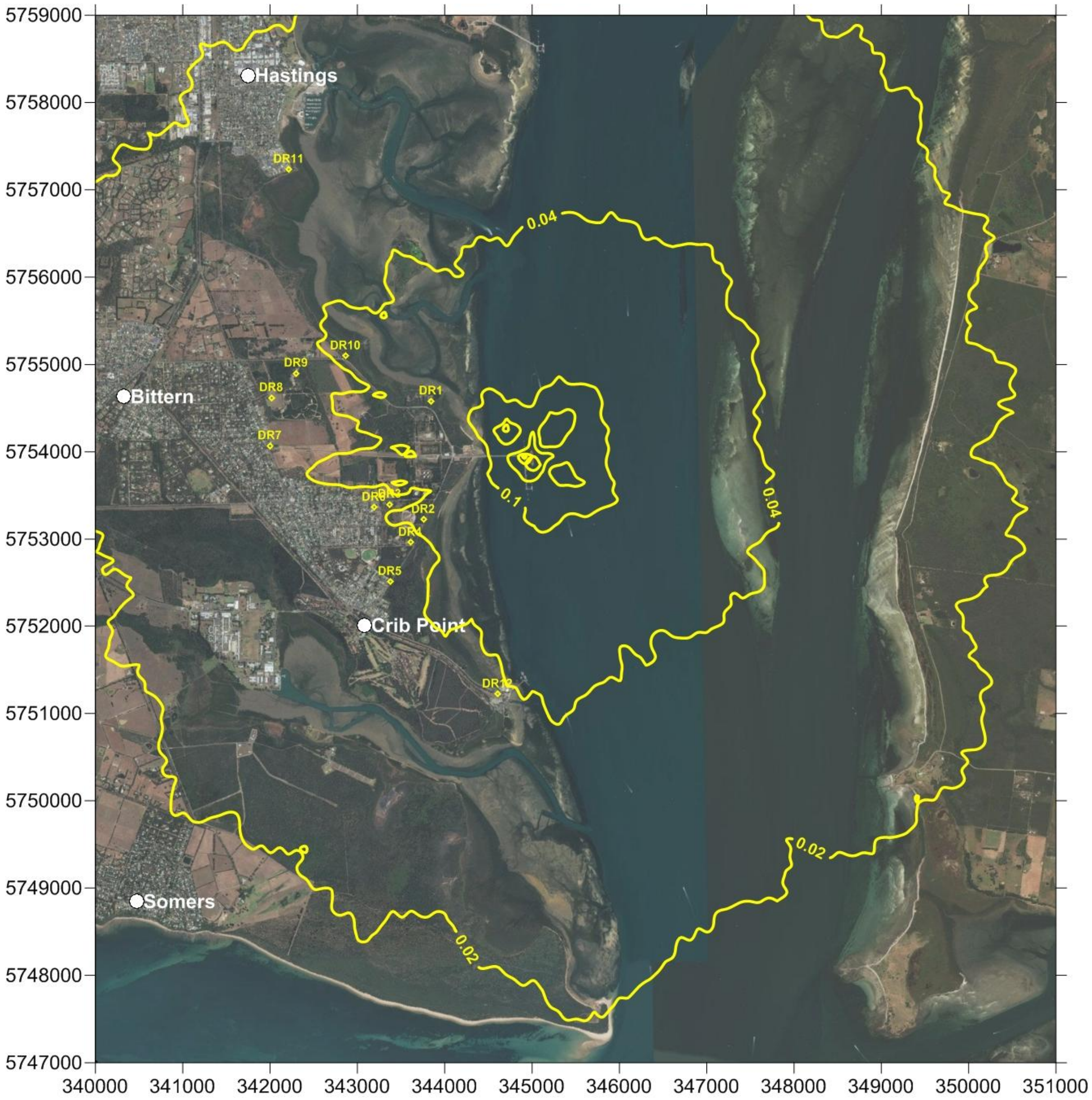
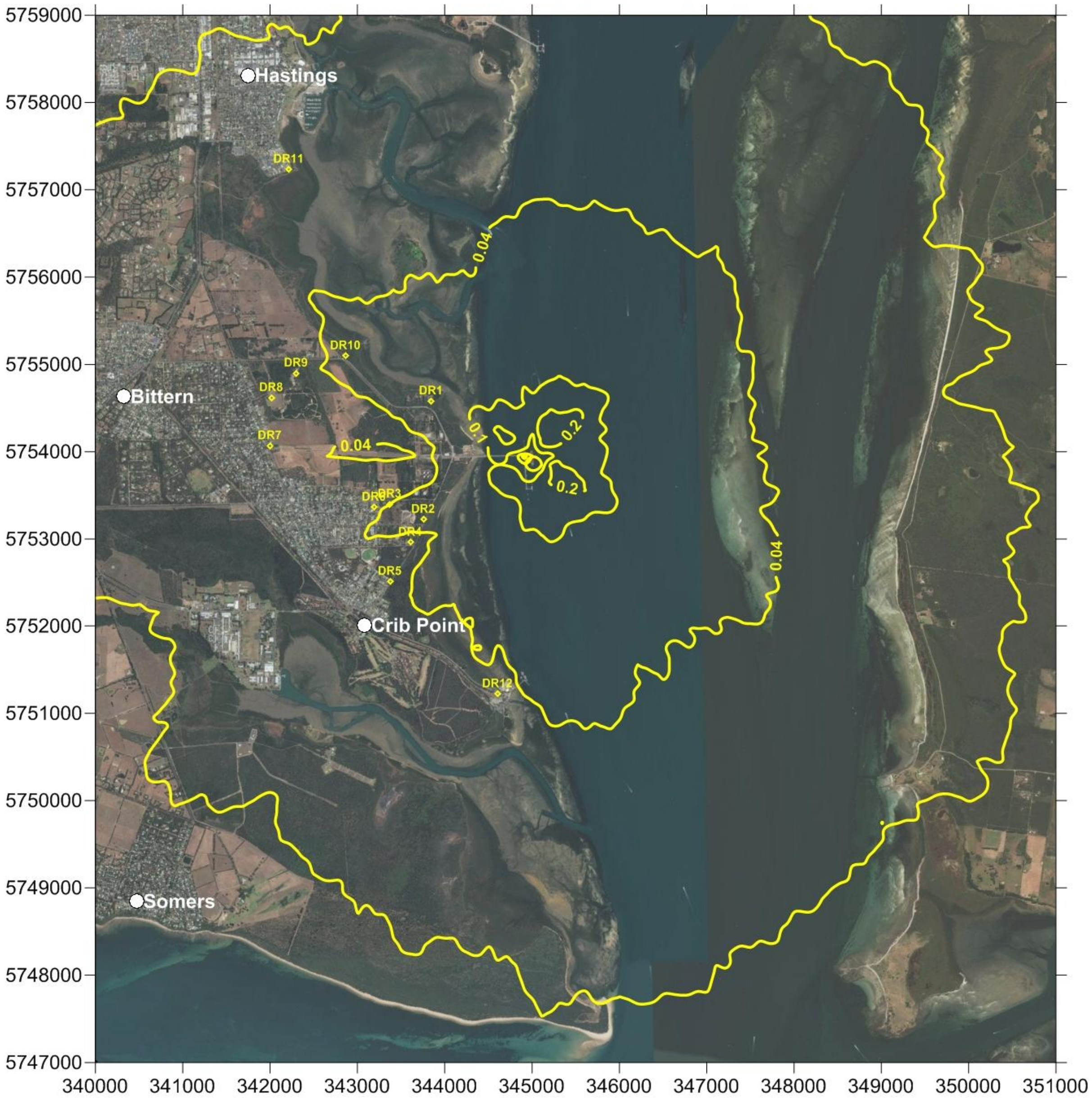


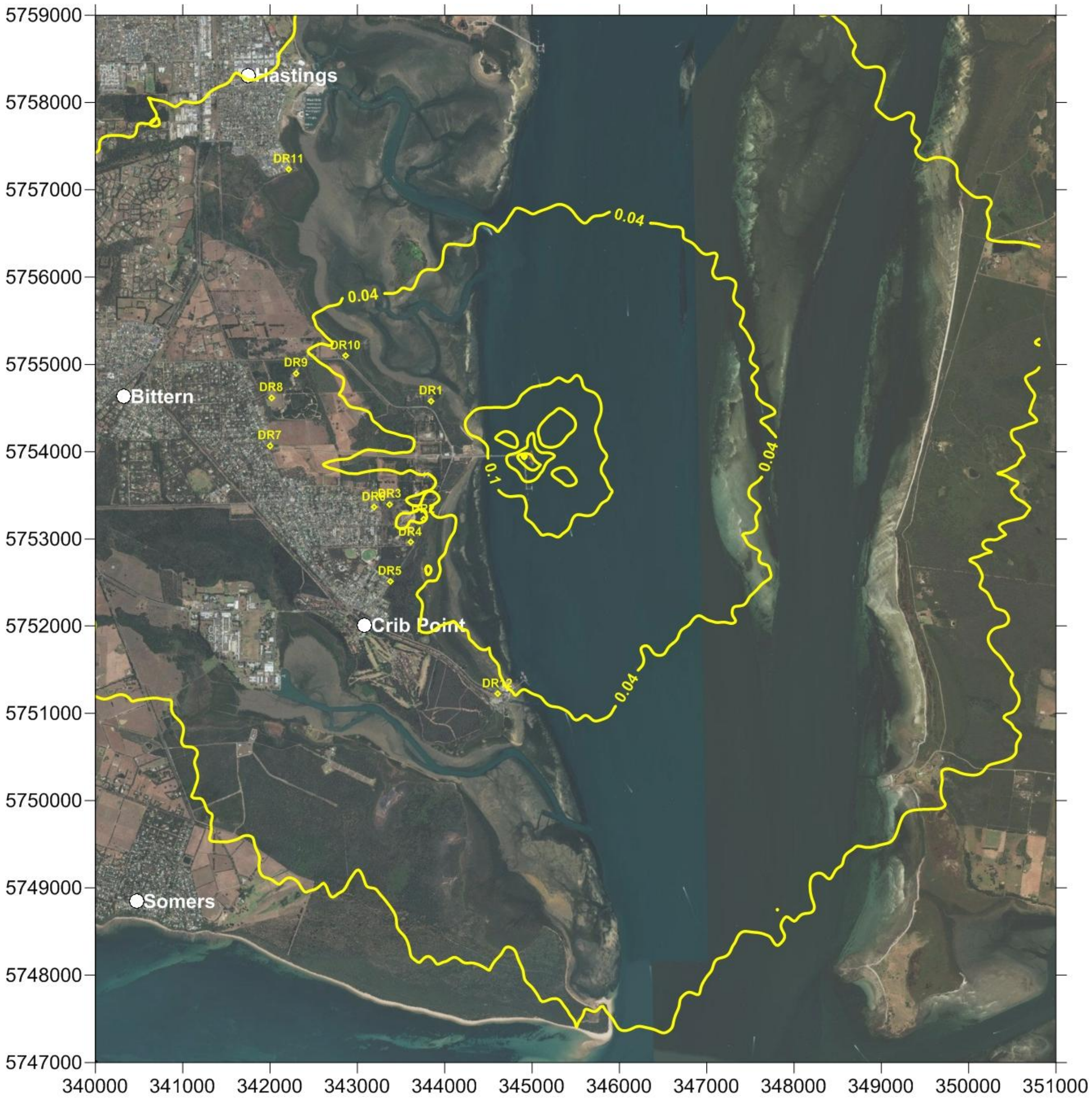
AERMOD Results 99.9 Percentile 3 Minute Formaldehyde GLCs (µg/m^3) – FSRU Liquid Fuel – 2012



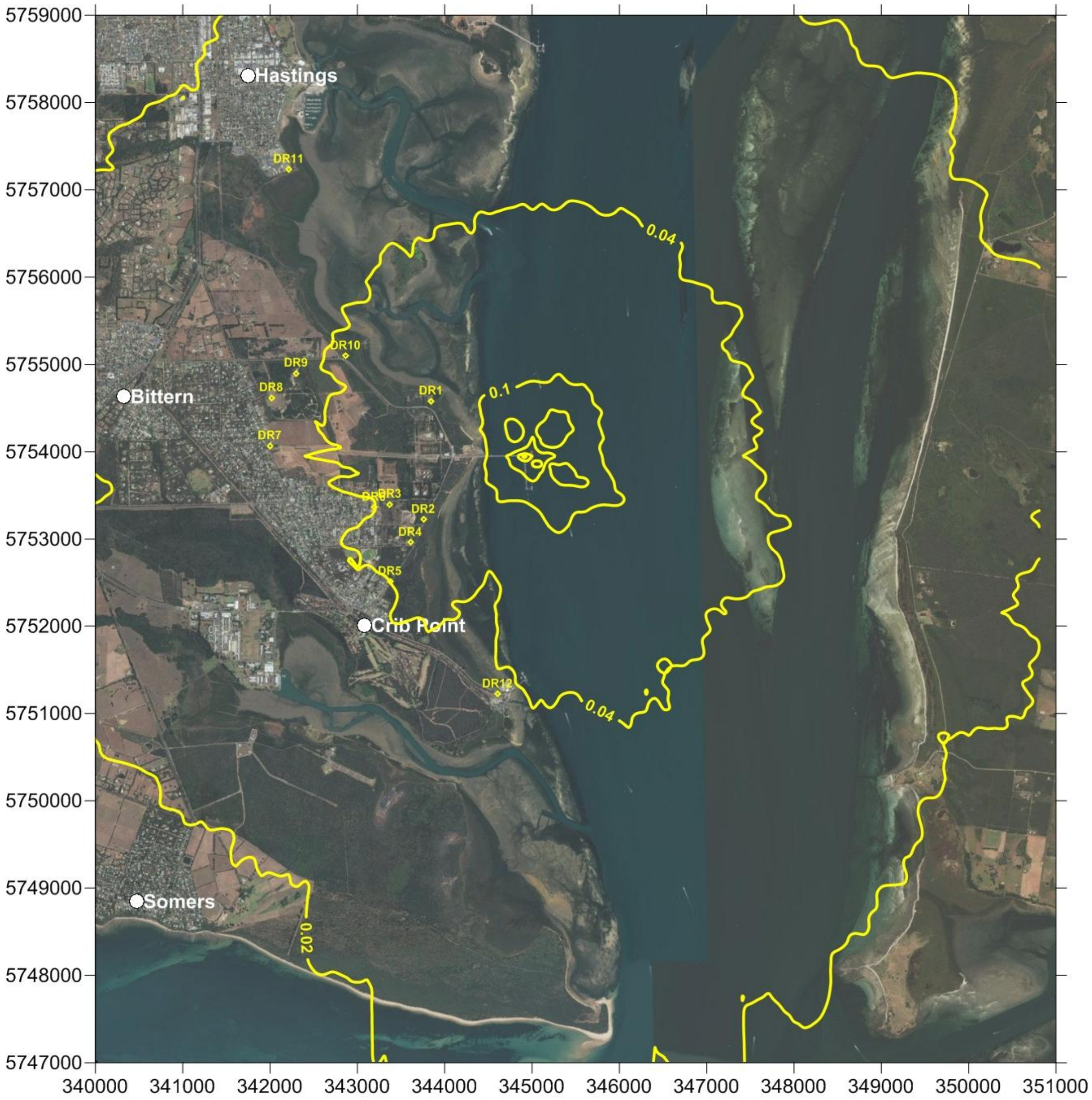
AERMOD Results 99.9 Percentile 3 Minute Formaldehyde GLCs ($\mu g/m^3$) – FSRU Liquid Fuel – 2013



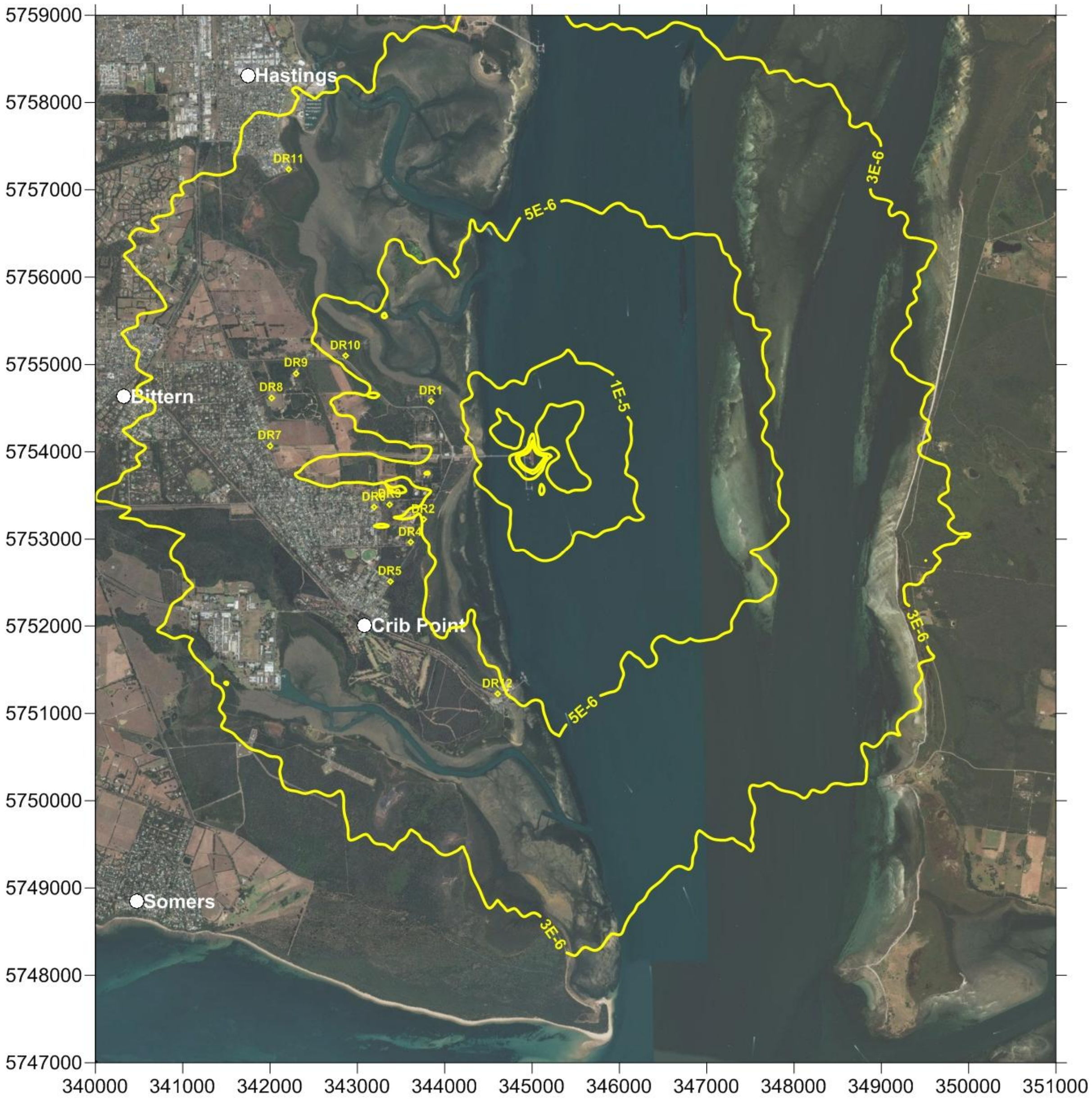
AERMOD Results 99.9 Percentile 3 Minute Formaldehyde GLCs (µg/m^3) – FSRU Liquid Fuel – 2014



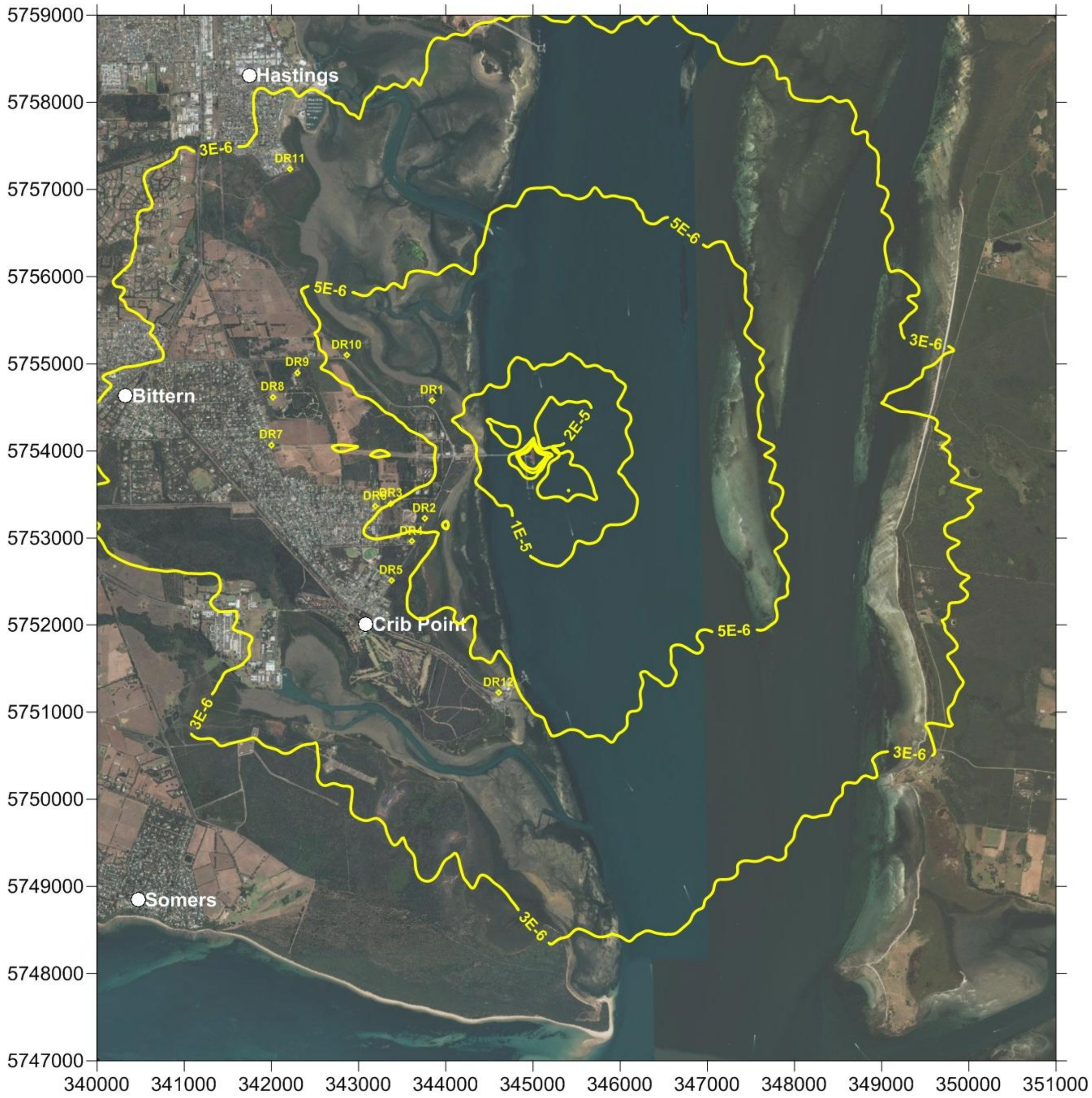
AERMOD Results 99.9 Percentile 3 Minute Formaldehyde GLCs ($\mu g/m^3$) – FSRU Liquid Fuel – 2015



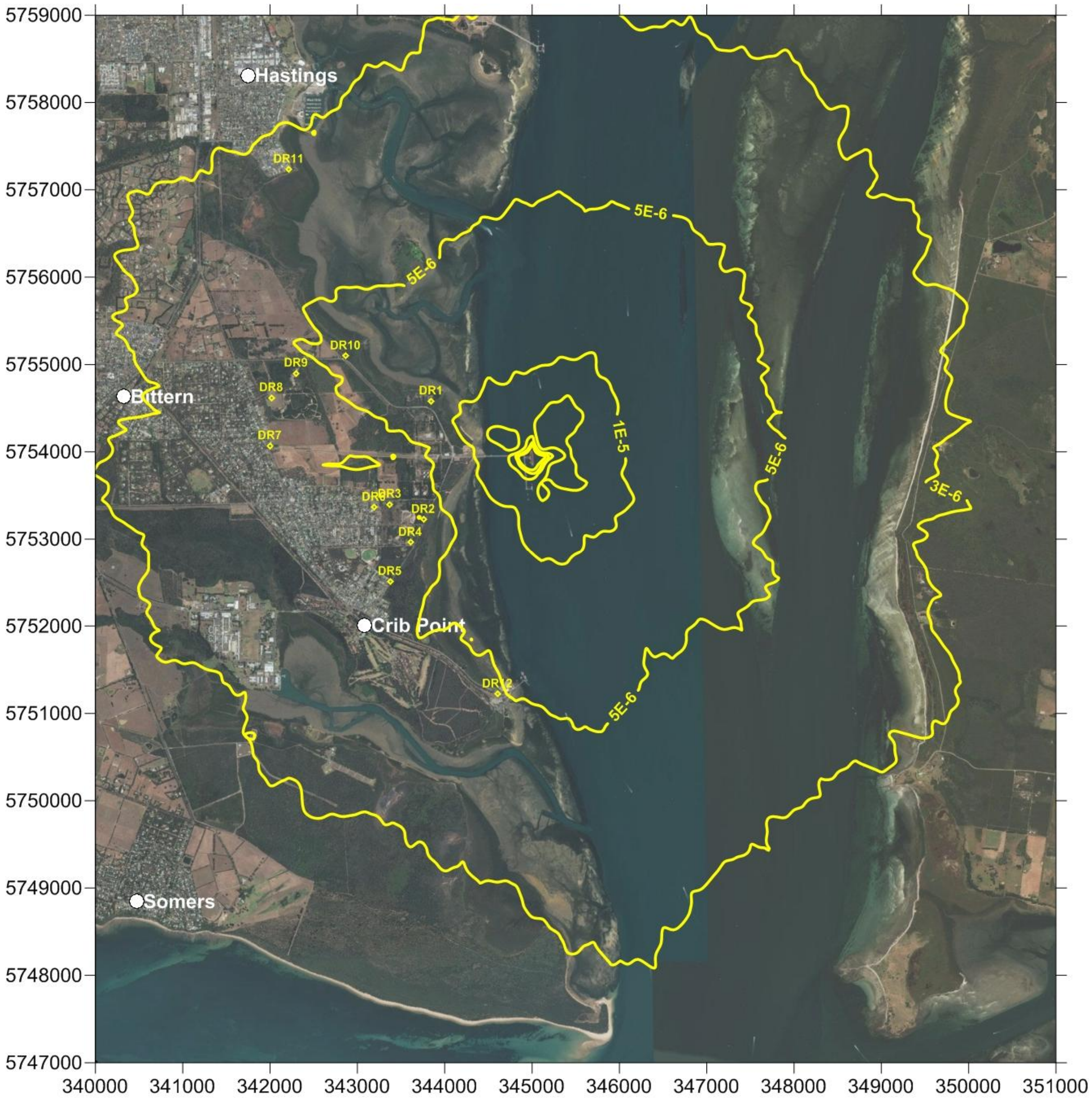
AERMOD Results 99.9 Percentile 3 Minute PAH GLCs (µg/m^3) – FSRU Liquid Fuel – 2012



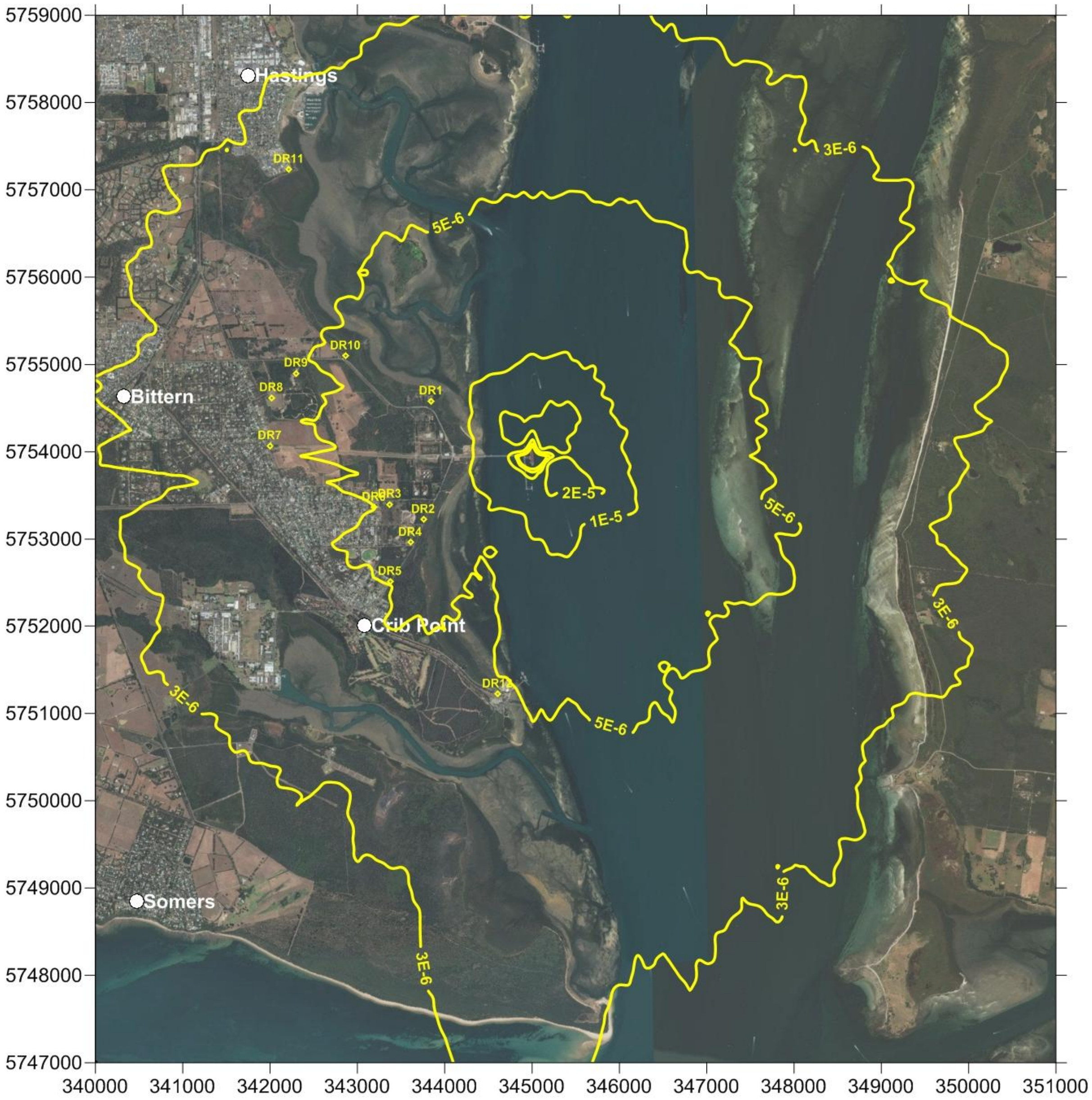
AERMOD Results 99.9 Percentile 3 Minute PAH GLCs (µg/m^3) – FSRU Liquid Fuel – 2013



AERMOD Results 99.9 Percentile 3 Minute PAH GLCs (µg/m^3) – FSRU Liquid Fuel – 2014



AERMOD Results 99.9 Percentile 3 Minute PAH GLCs (µg/m^3) – FSRU Liquid Fuel – 2015



Appendix D. AERMOD results: Discrete receptors

The first set of tables in this appendix provide the AERMOD discrete receptor results for the ‘criteria pollutants’; i.e., CO, NO_2, SO_2, PM_{10} and $PM_{2.5}$; see the Results Section 6.1 for more details.

Table D.1 : AERMOD discrete receptor results 99.9 percentile 1hour CO GLCs (mg/m^3) – FSRU gas fuel

Statistic	2012	2013	2014	2015	2016
DR01	1.08	1.09	1.09	1.09	1.08
DR02	1.07	1.08	1.08	1.08	1.08
DR03	1.07	1.07	1.07	1.07	1.07
DR04	1.07	1.07	1.07	1.08	1.07
DR05	1.07	1.07	1.07	1.07	1.07
DR06	1.07	1.07	1.07	1.07	1.07
DR07	1.07	1.07	1.07	1.07	1.07
DR08	1.07	1.06	1.07	1.07	1.06
DR09	1.07	1.07	1.07	1.07	1.07
DR10	1.08	1.08	1.07	1.07	1.07
DR11	1.06	1.06	1.06	1.06	1.06
DR12	1.07	1.07	1.07	1.07	1.07

SEPP(AQM) CO Design Criterion – 29 mg/m^3 (no exceedences)

Table D.2 : AERMOD discrete receptor results 99.9 percentile 1hour CO GLCs (mg/m^3) – FSRU liquid fuel

Statistic	2012	2013	2014	2015	2016
DR01	1.12	1.13	1.13	1.12	1.12
DR02	1.10	1.11	1.10	1.11	1.10
DR03	1.09	1.10	1.10	1.10	1.09
DR04	1.10	1.09	1.09	1.11	1.10
DR05	1.09	1.09	1.09	1.10	1.10
DR06	1.09	1.09	1.10	1.10	1.09
DR07	1.09	1.09	1.09	1.09	1.09
DR08	1.09	1.08	1.09	1.09	1.08
DR09	1.09	1.09	1.09	1.09	1.09
DR10	1.10	1.10	1.10	1.10	1.10
DR11	1.08	1.08	1.08	1.08	1.08
DR12	1.09	1.09	1.09	1.09	1.10

SEPP(AQM) CO Design Criterion – 29 mg/m^3 (no exceedences).

Table D.3 : AERMOD discrete receptor results 99.9 percentile 1hour NO_2 GLCs (µg/m^3) – FSRU gas fuel

Statistic	2012	2013	2014	2015	2016
DR01	138	137	137	136	134
DR02	121	117	119	126	127
DR03	107	107	110	108	108
DR04	113	108	110	114	109
DR05	101	100	101	102	98
DR06	103	104	105	104	102
DR07	90	93	92	92	88
DR08	90	90	91	90	89
DR09	94	94	95	93	93
DR10	103	104	102	102	100
DR11	81	81	80	81	79
DR12	94	94	93	95	97

SEPP(AQM) NO_2 Design Criterion – 190 µg/m^3 (no exceedences)

Table D.4 : AERMOD discrete receptor results 99.9 percentile 1hour NO_2 GLCs (µg/m^3) – FSRU liquid fuel

Statistic	2012	2013	2014	2015	2016
DR01	161	163	162	163	161
DR02	138	140	136	151	148
DR03	127	124	131	128	127
DR04	134	123	128	136	131
DR05	120	122	120	124	118
DR06	122	121	124	123	120
DR07	109	113	111	112	106
DR08	110	106	109	108	105
DR09	114	113	116	111	116
DR10	128	127	127	126	122
DR11	97	96	94	97	95
DR12	115	114	114	116	119

SEPP(AQM) NO_2 Design Criterion – 190 µg/m^3 (no exceedences).

Table D.5 : AERMOD discrete receptor results 99.9 percentile 1hour SO_2 GLCs (µg/m^3) – FSRU liquid fuel (only)

Statistic	2012	2013	2014	2015	2016
DR01	161	160	161	159	156
DR02	124	119	121	130	131
DR03	104	104	108	106	104
DR04	112	105	108	113	106
DR05	94	93	94	96	90
DR06	98	100	100	100	95
DR07	78	82	81	80	75
DR08	78	78	79	78	76
DR09	83	83	84	82	82
DR10	96	97	95	95	92
DR11	64	65	63	65	63
DR12	85	85	83	84	86

SEPP(AQM) 1h SO_2 Design Criterion – 450 µg/m^3 (no exceedences).

Table D.6 : AERMOD discrete receptor results 99.9 percentile 1hour PM_{10} GLCs (µg/m^3) – FSRU liquid fuel (Only)

Statistic	2012	2013	2014	2015	2016
DR01	64	64	64	64	63
DR02	59	58	59	60	60
DR03	56	57	57	57	57
DR04	58	57	57	58	57
DR05	55	55	55	56	55
DR06	56	56	56	56	56
DR07	54	54	54	54	53
DR08	53	53	54	54	53
DR09	54	54	54	54	54
DR10	56	56	56	56	55
DR11	52	52	52	52	51
DR12	54	54	54	54	55

SEPP(AQM) 1h PM_{10} Design Criterion – 80 µg/m^3 (no exceedences).

Table D.7 : AERMOD discrete receptor results 99.9 percentile 1hour $PM_{2.5}$ GLCs (µg/m^3) – FSRU liquid fuel (only)

Statistic	2012	2013	2014	2015	2016
DR01	26	26	26	26	26
DR02	24	24	24	24	24
DR03	23	23	23	23	23
DR04	23	23	23	23	23
DR05	23	23	23	23	22
DR06	23	23	23	23	23
DR07	22	22	22	22	22
DR08	22	22	22	22	22
DR09	22	22	22	22	22
DR10	23	23	23	23	23
DR11	21	21	21	21	21
DR12	22	22	22	22	22

SEPP(AQM) 1h $PM_{2.5}$ Design Criterion – 50 µg/m^3 (no exceedences).

The remaining tables in this appendix provide the AERMOD discrete receptor results for the higher risk VOCs; i.e., benzene, formaldehyde (CH_2O), and PAHs; see the Results Section 6.1 for more details.

Table D.8 : AERMOD discrete receptor results 99.9 percentile 3-minute Benzene GLCs (µg/m^3) – FSRU liquid fuel

Discrete Rec.	2012	2013	2014	2015	2016
DR01	0.63	0.71	0.68	0.68	0.64
DR02	0.48	0.54	0.49	0.56	0.50
DR03	0.45	0.46	0.46	0.49	0.40
DR04	0.47	0.41	0.42	0.52	0.48
DR05	0.40	0.42	0.41	0.46	0.44
DR06	0.43	0.41	0.44	0.44	0.41
DR07	0.36	0.40	0.37	0.39	0.35
DR08	0.37	0.34	0.36	0.38	0.34
DR09	0.40	0.40	0.41	0.38	0.42
DR10	0.50	0.50	0.49	0.48	0.46
DR11	0.29	0.29	0.28	0.31	0.29
DR12	0.41	0.40	0.40	0.42	0.44

SEPP(AQM) 3-Minute Benzene Design Criterion – 53 µg/m^3 (no exceedences).

Table D.9 : AERMOD discrete receptor results 99.9 percentile 3-minute CH_2O GLCs (µg/m^3) – FSRU liquid fuel

Discrete Rec.	2012	2013	2014	2015	2016
DR01	0.054	0.062	0.058	0.057	0.055
DR02	0.040	0.047	0.040	0.045	0.041
DR03	0.036	0.039	0.038	0.042	0.033
DR04	0.038	0.034	0.035	0.045	0.040
DR05	0.035	0.037	0.035	0.041	0.039
DR06	0.037	0.036	0.038	0.040	0.033
DR07	0.032	0.035	0.032	0.034	0.031
DR08	0.032	0.030	0.032	0.034	0.029
DR09	0.035	0.035	0.036	0.034	0.038
DR10	0.043	0.043	0.043	0.043	0.040
DR11	0.026	0.026	0.025	0.028	0.026
DR12	0.036	0.035	0.036	0.037	0.038

SEPP(AQM) 3-Minute CH_2O Design Criterion – 40 µg/m^3 (no exceedences).

Table D.10 : AERMOD discrete receptor results 99.9 percentile 3-minute PAH GLCs (µg/m^3) – FSRU liquid fuel

Discrete Rec.	2012	2013	2014	2015	2016
DR01	6.6E-06	7.8E-06	7.5E-06	7.1E-06	7.0E-06
DR02	5.0E-06	6.2E-06	4.5E-06	5.6E-06	5.0E-06
DR03	4.2E-06	5.1E-06	4.6E-06	5.4E-06	4.0E-06
DR04	4.7E-06	4.5E-06	4.6E-06	5.7E-06	5.0E-06
DR05	4.4E-06	4.5E-06	4.4E-06	5.0E-06	4.9E-06
DR06	4.3E-06	4.6E-06	4.5E-06	5.0E-06	4.0E-06
DR07	4.0E-06	4.4E-06	4.0E-06	4.3E-06	3.9E-06
DR08	4.1E-06	3.8E-06	4.0E-06	4.3E-06	3.8E-06
DR09	4.4E-06	4.4E-06	4.5E-06	4.3E-06	4.8E-06
DR10	5.3E-06	5.6E-06	5.4E-06	5.4E-06	5.1E-06
DR11	3.4E-06	3.4E-06	3.3E-06	3.6E-06	3.3E-06
DR12	4.7E-06	4.5E-06	4.6E-06	4.8E-06	4.9E-06

SEPP(AQM) 3-Minute PAH Design Criterion – 0.73 µg/m^3 (no exceedences).

– End of Report –