Port of Hastings
Aboriginal Cultural Heritage
Site Predictive Model Methodology
(Special Use Zone)

Sponsor: Port of Hastings Development Authority (ABN/ACN: 33 737 350 749)

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In May 2016 the Special Minister of State asked Infrastructure Victoria to provide advice on the future capacity of Victoria's commercial ports. Specifically, the Minister has asked for advice on when the need for a second container port is likely to arise and which variables may alter this timeline. The Minister has also asked for advice on where a second container port would ideally be located and under what conditions, including the suitability of, and barriers to investing in, sites at the Port of Hastings and the Bay West location.

In undertaking this task, Infrastructure Victoria reviewed work that was completed as part of the Port of Hastings development project before it was cancelled in 2014. This document forms part of the initial work undertaken for the proposed port development at Hastings. Infrastructure Victoria considers that much of the previous Hastings work, although preliminary in nature, is relevant and suitable for informing a strategic assessment. Therefore, Infrastructure Victoria has made the reports previously commissioned for the development project part of the evidence base on which Infrastructure Victoria will use in providing the Minister with advice.

The opinions, conclusions and any recommendations in this document are based on conditions encountered and information reviewed at the date of preparation of the document and for the purposes of the Port of Hastings Development Project.

Infrastructure Victoria and its consultants have used the information contained in these reports as an input but have not wholly relied on all the information presented in these reports.

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GLOSSARY AND REFERENCES

Burra Charter: Contains principles and procedures for best practice for cultural heritage management in Australia

DELWP: Department of Environment, Land, Water & Planning (former)

ICOMOS: International Council on Monument and Sites

Novák, David, 2014: *Local Relief Model (LRM) Toolbox for ArcGIS*. Institute of Archaeology, Czech Academy of Science, Prague.

1

RATIONALE FOR THE SITE PREDICTIVE MODEL

An assessment of the likely impact to cultural heritage across the study area requires the creation of site predictive models regarding the distribution of various Aboriginal places within the study area.

Seven site predictive models were developed for the purposes of better understanding patterns of occupation and use of the landscape by Aboriginal people across the Project area. The models also provide the Project with a greater level of comparability to guide the systematic comparison of study area across all environmental, social and community issues.

To determine the impact of the Project on registered and potential Victorian Aboriginal Heritage Register (VAHR) places, the following seven site types were modelled:

1. Artefact scatters (major)
2. Ancestral remains
3. Earth features
4. Quarries
5. Scarred trees
6. Shell middens
7. Stone features

This assessment has specifically excluded minor artefact scatters (commonly registered as Low Density Artefact Scatters, LDADs), including isolated artefacts as these have the potential to occur across the study area landscape as a whole without necessarily displaying any readily identifiable patterning in association with environmental factors.[1]

The site predictive models considered various existing spatial datasets including the VAHR data (registered cultural heritage places), geomorphological data, EVC data, hydrological data, ecological data, ethnohistory (observations of Aboriginal lifestyles and activities) and a review of relevant archaeological reports.

The following datasets were used as the base layers in constructing the predictive model for the study area:

- Modelled 1750s Ecological Vegetation Classes
- Geological units
- Distance from freshwater
- Distance from (meso-)saline water
- Local relief

[1] See Bird and Rhoads 2011 for a potential refutation of this position.

The datasets were selected on the basis that their attributes were considered to have had a modifying influence on the Aboriginal occupation and use of the geographic region and therefore the study area. This influence is expected to be detectable in variations in the distribution and density of different types of Aboriginal cultural heritage places in the geographic region.

The specific datasets used and the relevant attributes are listed in **Table 1**.

Dataset	Origin/custodian	Attribute
Modelled 1750s Ecological Vegetation Classes with transitions	Derived, from NV1750_EVC (DELWP)	X_EVCNAME
Geological units	Derived, from Westernport and Cranbourne 1:63,360 geology map sheets (Geological Survey of Victoria 1967) and GeolUnit_250k_py (seamless; DELWP)	Map legend/FORMATTED_
Distance form freshwater	Derived, from HY_WATER_AREA_POLYGON, HY_WATERCOURSE, wetland_current, wetland_pre_european (DELWP) and Plan of the Agricultural Area of Tyabb, 1865 (Lands and Survey Office, Melbourne)	Distance
Distance from (meso-)saline water	Derived, from HY_WATER_AREA_POLYGON, Wetland_current and VICMAP_BOUNDARY (DELWP)	Distance
Local relief	Derived, from client-supplied 0.5 m contours	ELEVATION

Table 1: Datasets used in the construction of the predictive model.

As can be seen from **Table 1**, all of the datasets used in the modelling are derivative of existing datasets. See Figure 1 to Figure 5 for the graphical representation of these.

2

MODEL RATINGS

2.1 Introduction

In preparation for the predictive modelling, summary data were collected with regard to the occurrence of attributes from the above-described datasets within the geographic region and within the proposed road reserve, as well as the prevalence of previously registered Aboriginal cultural heritage places associated with these attributes. Together with the desktop research, this information informed the expert panel in rating the various attributes for their expected influence on the occurrence, distribution and density of Aboriginal cultural heritage places of varying types.

The conversion of the five spatial datasets for input into the seven models (excluding the non-archaeological places model) involved the selection for each of the datasets, of the attribute class(es) to be rated for the actual assignment of ratings to these classes. The ratings range from 1 to 999 in set intervals, with 10 being neutral with respect to the likely presence of Aboriginal places (see **Table 2**). Although the attribute class(es) selected for rating were the same for each of the seven models, the actual ratings vary substantially between the models for the different site types (see below).

Rating	Interpretation
1	Strongly positively correlated with places of the relevant type
5	Weakly positively correlated with places of the relevant type
10	Neutral with regard to places of the relevant type
20	Weakly negatively correlated with places of the relevant type
40	Strongly negatively correlated with places of the relevant type
999	No data / disturbed

Table 2: Rating interpretations used for correlation of each attribute with relevant site type

The strength and type of correlation between places and particular spatial data classes was established through assessment in workshops with a team of archaeological and geomorphological specialists and was informed by tabulated information regarding the association of known heritage places and environmental variables.

The ratings convey the likelihood that Aboriginal activities resulting in the formation of particular site types were associated with specific attribute classes. In other words, the predictive model is concerned with site formation, not with site preservation. Once the ratings for the first modelling iteration were agreed upon amongst the consulted specialists, rated layers were derived through the reclassification of the input datasets. Rated vector datasets (geology, EVCs and distance from

primary and secondary water) were then rasterised in correspondence with the elevation and slope rasters[2].

The ratings were applied in the construction of the seven models and are presented in **Table 3** to **Table 8**).

2.2 Modelled 1750s Ecological Vegetation Classes with Transitional Zones

The 1750s Ecological Vegetation Classes (EVCs) dataset was modified to include 100m-wide transitional zones between different Ecological Vegetation Classes. These transitional zones were rated separately for their likelihood to contain Aboriginal cultural heritage places. **Table 3** shows the ratings for the non-transitional areas in the 1750s EVCs dataset. **Table 4** shows the ratings for the transitional areas in the 1750s EVCs dataset.

[2] a raster consists of a matrix of cells (or pixels) generally organised into rows and columns (or a grid) where each cell contains a value representing information.

Group name	EVC name	AS	B	EF	Q	ST	SM	SF
Heathlands	Damp Heathland	10	10	10	10	20	10	10
	Sand Heathland	10	10	10	10	20	10	10
Heathy Woodlands	Heathy Woodland	5	10	10	10	5	10	10
Herb-rich Woodlands	Damp Sands Herb-rich Woodland	5	10	10	10	7.5	10	10
Lower Slopes or Hills Woodlands	Grassy Woodland	7.5	10	10	10	10	10	10
Lowland Forests	Lowland Forest	7.5	10	10	10	40	10	10
Plains Grasslands and Chenopod Shrublands	Plains Grassland/Plains Grassy Woodland Mosaic	7.5	10	10	10	7.5	10	10
Riparian Scrubs or Swampy Scrubs and Woodlands	Swamp Scrub	15	10	7.5	10	20	10	10
	Swampy Riparian Woodland	10	10	7.5	10	7.5	10	10
	Swampy Riparian Woodland/Swamp Scrub Mosaic	12.5	10	7.5	10	9	10	10
	Swampy Woodland	10	10	7.5	10	7.5	10	10
Salt-tolerant and/or succulent Shrublands	Coastal Saltmarsh	10	40	40	10	40	10	10
	Mangrove Shrubland	20	40	40	10	40	40	10

Table 3: Ratings for non-transitional areas in the 1750s EVCs dataset (AS=Artefact scatters; B=Burials; EF=Earth features; Q=Quarries; ST=Scarred trees; SM=Shell middens; SF=Stone features).

Transitional - A	Transitional - B	AS	B	EF	Q	ST	SM	SF
Coastal Saltmarsh	Damp Sands Herb-rich Woodland	5	40	40	10	7.5	10	10
	Grassy Woodland	7.5	40	40	10	40	10	10
	Heathy Woodland	5	40	40	10	5	10	10
	Mangrove Shrubland	20	40	40	10	40	40	10
	Swamp Scrub	15	40	7.5	10	30	10	10
Damp Heathland	Heathy Woodland	5	10	10	10	5	10	10
Damp Sands Herb-rich Woodland	Grassy Woodland	2.5	10	10	10	7.5	10	10
	Heathy Woodland	1	10	10	10	2.5	10	10
	Mangrove Shrubland	5	10	10	10	7.5	10	10
	Swamp Scrub	5	10	7.5	10	7.5	10	10
Grassy Woodland	Heathy Woodland	2.5	10	10	10	5	10	10
	Lowland Forest	5	10	10	10	40	10	10
	Plains Grassland/Plains Grassy Woodland Mosaic	5	10	10	10	7.5	10	10
	Swamp Scrub	7.5	10	7.5	10	15	10	10
	Swampy Riparian Woodland	7.5	10	7.5	10	7.5	10	10
	Swampy Woodland	7.5	10	7.5	10	7.5	10	10
Heathy Woodland	Grassy Woodland	2.5	10	10	10	5	10	10
	Mangrove Shrubland	5	40	40	10	5	40	10
	Plains Grassland/Plains Grassy Woodland Mosaic	2.5	10	10	10	2.5	10	10
	Sand Heathland	5	10	10	10	5	10	10
	Swamp Scrub	5	10	7.5	10	5	10	10
	Swampy Riparian Woodland	5	10	7.5	10	2.5	10	10
	Swampy Woodland	5	10	7.5	10	2.5	10	10
	Salt-tolerant and/or succulent Shrublands	5	40	40	10	5	10	10
Lowland Forest	Swamp Scrub	7.5	10	7.5	10	30	10	10
	Swampy Riparian Woodland	7.5	10	7.5	10	7.5	10	10
Plains Grassland/Plains Grassy Woodland Mosaic	Swampy Riparian Woodland/Swamp Scrub Mosaic	7.5	10	7.5	10	6	10	10
Sand Heathland	Swampy Riparian Woodland	10	10	7.5	10	7.5	10	10
Swamp Scrub	Swampy Riparian Woodland	15	10	7.5	10	7.5	10	10
	Swampy Woodland	15	10	7.5	10	7.5	10	10

Table 4: Ratings for transitional areas in the 1750s EVCs dataset (AS=Artefact scatters; B=Burials; EF=Earth features; Q=Quarries; ST=Scarred trees; SM=Shell middens; SF=Stone features).

2.3 Geological Units

Because the 1:50,000 seamless geology dataset does not extend into the study area, the Cranbourne and Westernport 1:63,360 geology maps (Geological Survey of Victoria 1967) were digitized. Where possible, these were correlated to the 1:250,000 seamless geology dataset. **Table 5** shows the resulting categories and their ratings for the various types of Aboriginal cultural heritage places.

Name	AS	B	EF	Q	ST	SM	SF
Brighton Group (Nb)	5	5	7.5	20	10	10	40
Red Bluff Sandstone (Nbr)	5	5	7.5	20	10	10	40
Monbulk Volcanic Group (Nuo)	10	40	10	30	10	10	40
Alluvium(Qa1)	7.5	7.5	7.5	30	10	10	40
Alluvium and colluvium(Qb)	7.5	7.5	7.5	30	10	10	40
Colluvium(Qc1)	7.5	7.5	7.5	30	10	10	40
Inland dune deposits (Qd1)	2.5	2.5	10	40	10	10	40
Coastal dune deposits (Qdl1)	2.5	2.5	10	40	10	5	40
Coastal lagoon deposits (Qg)	10	20	10	40	40	7.5	40
Swamp and lake deposits (Qm1)	7.5	20	10	40	7.5	7.5	40
Murrindindi Supergroup(Sm)	6	7.5	10	9	10	10	40
Recent mangrove deposits (not in 1:250,000 dataset)	30	30	30	40	40	10	30

Table 5: Ratings for geological units dataset (AS=Artefact scatters; B=Burials; EF=Earth features; Q=Quarries; ST=Scarred trees; SM=Shell middens; SF=Stone features).

2.4 Distance from Freshwater

The freshwater dataset was created by combining data from a number of sources (see **Table 1**): pre-European freshwater wetlands (from both wetlands_pre_european and wetlands_current datasets), water areas of natural origin, water courses of natural origin and waterholes digitized from the 1865 Plan of the Agricultural Area of Tyabb (Land and Survey Office, Melbourne). The watercourses were buffered by a nominal 2.5m buffer to create stream polygons. A multiple ring buffer was then created around the combined water polygons. The ratings for the various distance intervals can be found in **Table 6**.

Distance from freshwater (m)	AS	B	EF	Q	ST	SM	SF
<0 (in water)	20	20	10	10	10	10	7.5
0-50	5	10	5	10	7.5	5	7.5
50-100	5	10	5	10	7.5	7.5	10
100-200	5	10	7.5	10	10	9	10
200-500	5	10	10	10	10	10	10
500-1000	10	10	15	10	10	20	10
1000-3000	15	10	20	10	10	20	10
3000+	20	10	20	10	10	40	10

Table 6: Ratings for distance from freshwater dataset (AS=Artefact scatters; B=Burials; EF=Earth features; Q=Quarries; ST=Scarred trees; SM=Shell middens; SF=Stone features).

2.5 Distance from (Meso-)Saline Water

The (meso-)saline water dataset was created by combining data from a number of sources (see **Table 1**): areas naturally subject to inundation that are directly connected to the coast (from the water areas dataset), pre-European wetlands directly connected to the coast (from the wetlands_current dataset) and Westernport Bay (from the VicMap Boundary dataset). A multiple ring buffer was then created around the combined water polygons. The ratings for the various distance intervals can be found in **Table 7**.

Distance from (meso-)saline water (m)	AS	B	EF	Q	ST	SM	SF
<0 (in water)	20	20	10	20	20	10	7.5
0-50	5	10	7.5	20	20	5	7.5
50-100	5	10	7.5	10	20	7.5	10
100-200	5	10	10	10	20	9	10
200-500	5	10	10	10	10	10	10
500-1000	7.5	10	10	10	10	20	10
1000-3000	9	10	10	10	10	20	10
3000+	10	10	10	10	10	40	10

Table 7: Ratings for distance from (meso-)saline water dataset (AS=Artefact scatters; B=Burials; EF=Earth features; Q=Quarries; ST=Scarred trees; SM=Shell middens; SF=Stone features).

2.6 Local Relief

Rather than using absolute elevation and/or slope it was decided that a Local Relief Model would be constructed from the 0.5m contours, so as to allow the identification of sandy rises and dunes and swales within the study area. A 1m Digital Elevation Model (DEM) was generated from the 0.5m contours, and this was converted into a Local Relief Model (LRM) following the methodology

outlined in Novák 2014, using ArcGIS and Global Mapper software. The resulting LRM was classified into three classes: convex landforms (rises), concave landforms (depressions) and intermediate landforms. Convex and concave landforms of <2000m^2 were removed except where they were clearly related to the coastal dune system. The data were manually cleaned up to remove obviously artificial features such as road-side ditches and banks and banks associated with square dams. All convex/concave areas removed gained the status of areas of intermediate relief. The ratings for the local relief classes are shown in **Table 8**.

LRM Class	**AS**	**B**	**EF**	**Q**	**ST**	**SM**	**SF**
Concave (depressions)	12.5	10	9	9	9	12.5	10
Convex (rises)	1	7.5	10	7.5	10	7.5	10
Intermediate	5	10	7.5	10	10	9	10

Table 8: Ratings for Local Relief dataset (AS=Artefact scatters; B=Burials; EF=Earth features; Q=Quarries; ST=Scarred trees; SM=Shell middens; SF=Stone features).

3

MODEL WEIGHTINGS

To finalise the construction of the predictive models, the rated layers were combined. Rather than averaging the input of these layers, they were weighted differentially to reflect their differential importance in relation to each other in influencing heritage place distribution.

The rated base layers were then converted to rasters and geoprocessed using the ArcGIS Spatial Analyst Raster Calculator. This geoprocessing involved adding up the rating values for each raster cell in a weighted fashion, resulting in a normalized predictive value for each cell. The weightings for the five base layers were constructed by expert comparison of each layer against each other layer, in each case determining which layer was deemed the more influential one in affecting Aboriginal cultural heritage occurrence. The resulting weightings are given in **Table 9.**

Dataset	**AS**	**B**	**EF**	**Q**	**ST**	**SM**	**SF**
EVC	0.14	0.14	0.09	0.12	0.31	0.12	0.10
Geology	0.19	0.34	0.17	0.37	0.10	0.09	0.30
Distance to fresh water	0.29	0.18	0.26	0.15	0.23	0.26	0.22
Distance to (meso)saline water	0.12	0.14	0.22	0.15	0.17	0.32	0.19
Local elevation	0.26	0.21	0.25	0.22	0.19	0.21	0.19
Total	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

Table 9: Normalised weightings for the five base layer datasets (AS=Artefact scatters; B=Burials; EF=Earth features; Q=Quarries; ST=Scarred trees; SM=Shell middens; SF=Stone features).

MODEL CLASSIFICATION

Once the rating and weightings were established, the seven predictive models were constructed through raster calculation in an ESRI ArcGIS environment. The models were created using the formulae expressed in **Table 10**, and subsequently classified into classes ranging from most likely to least likely.

Place type	Model	Formula used in modelling
Artefact scatters	ars_mod_1	(0.136986*"ars_evc_rat")+(0.191781*"ars_geo_rat")+(0.287671*"ars_dfw_rat")+(0.123288*"ars_dsw_rat")+(0.260274*"ars_lrm_rat")
Burials	bur_mod_1	(0.136986*"bur_evc_rat")+(0.342466*"bur_geo_rat")+(0.178082*"bur_dfw_rat")+(0.136986*"bur_dsw_rat")+(0.205479*"bur_lrm_rat")
Earth features	earf_mod_1	(0.091954*"earf_evc_rat")+(0.172414*"earf_geo_rat")+(0.264368*"earf_dfw_rat")+(0.218391*"earf_dsw_rat")+(0.252874*"earf_lrm_rat")
Quarries	qua_mod_1	(0.117647*"qua_evc_rat")+(0.367647*"qua_geo_rat")+(0.147059*"qua_dfw_rat")+(0.147059*"qua_dsw_rat")+(0.220588*"qua_lrm_rat")
Scarred Trees	scat_mod_1	(0.308642*"scat_evc_rat")+(0.098765*"scat_geo_rat")+(0.234568*"scat_dfw_rat")+(0.172840*"scat_dsw_rat")+(0.185185*"scat_lrm_rat")
Shell middens	shmid_mod_1	(0.117647*"shmid_evc_rat")+(0.094118*"shmid_geo_rat")+(0.258824*"shmid_dfw_rat")+(0.317647*"shmid_dsw_rat")+(0.211765*"shmid_lrm_rat")
Stone features	stf_mod_1	(0.096386*"stf_evc_rat")+(0.301205*"stf_geo_rat")+(0.216867*"stf_dfw_rat")+(0.192771*"stf_dsw_rat")+(0.192771*"stf_lrm_rat")

Table 10: Formulae used to create the model rasters.

5

OBSTACLES, LIMITATIONS AND ASSUMPTIONS

The predictive models created have a number of limitations. Some of these are inherited from the input data. The 1750 EVC layer, for instance, is a modelled dataset; the assumptions underlying this modelled dataset also underlie the rated EVC model layers and hence the models themselves. The proximity to water dataset was derived from various watercourses data, which is a line dataset that does not take into account the width of watercourses. The limitations of the parent datasets are set out in the relevant metadata statements.

In addition to the inherited limitations, there are a number of additional assumptions and limitations:

- No input was received on the site predictive model from the RAP applicant and/or Traditional Owners.
- No cultural values workshops were undertaken.
- No cultural values spatial mapping was prepared for non-archaeological and/or intangible heritage sites.
- Other relevant datasets not considered in this model exist were not accessible for various reasons.
- Absolute elevation data was of limited value without consideration of relative elevation from point to point.
- The outputs are models of the predicted occurrence of specific Aboriginal activities in the landscape and the resulting formation of particular types of Aboriginal cultural heritage places.
- The assumption inherent in the use of the parent datasets is that these datasets adequately reflect the class of phenomena they purport to reflect for the time period during which Aboriginal people were present in the area.
- Expert knowledge of Aboriginal activities in the study area and their surroundings is based on knowledge of what is a highly incomplete archaeological record. As a result of this incompleteness there are limitations to the expert assessments.
- The predictive models are limited by the fact that they represent a single modelling iteration, and have not benefited from systematic ground-truthing.
- Gaps occur in the existing datasets that will likely require ground-truthing.
- Inconsistencies in the available datasets across the study area exist (e.g. 1:250 and 1:50 geologies are represented in different areas).
- Condition of preservation differs between site types.
- Artefact scatter model only considers places of moderate to high scientific significance (as per The Burra Charter, ICOMOS). Places of low scientific significance are considered to be evenly distributed across the landscape.

6

RESULTS

The results of the site predictive modelling for the Project area are represented in Figure 6 to Figure 12.

In consideration of the models, it is important to recognise an overall model, which would represent the quantum of issues that could potentially be managed within the context of a Cultural Heritage Management Plan (CHMP), has not been produced at this stage. Additional consultation and assessment involving the Aboriginal stakeholder groups in the creation of a cultural values model and a detailed land-use/disturbance model is necessary.

FIGURES

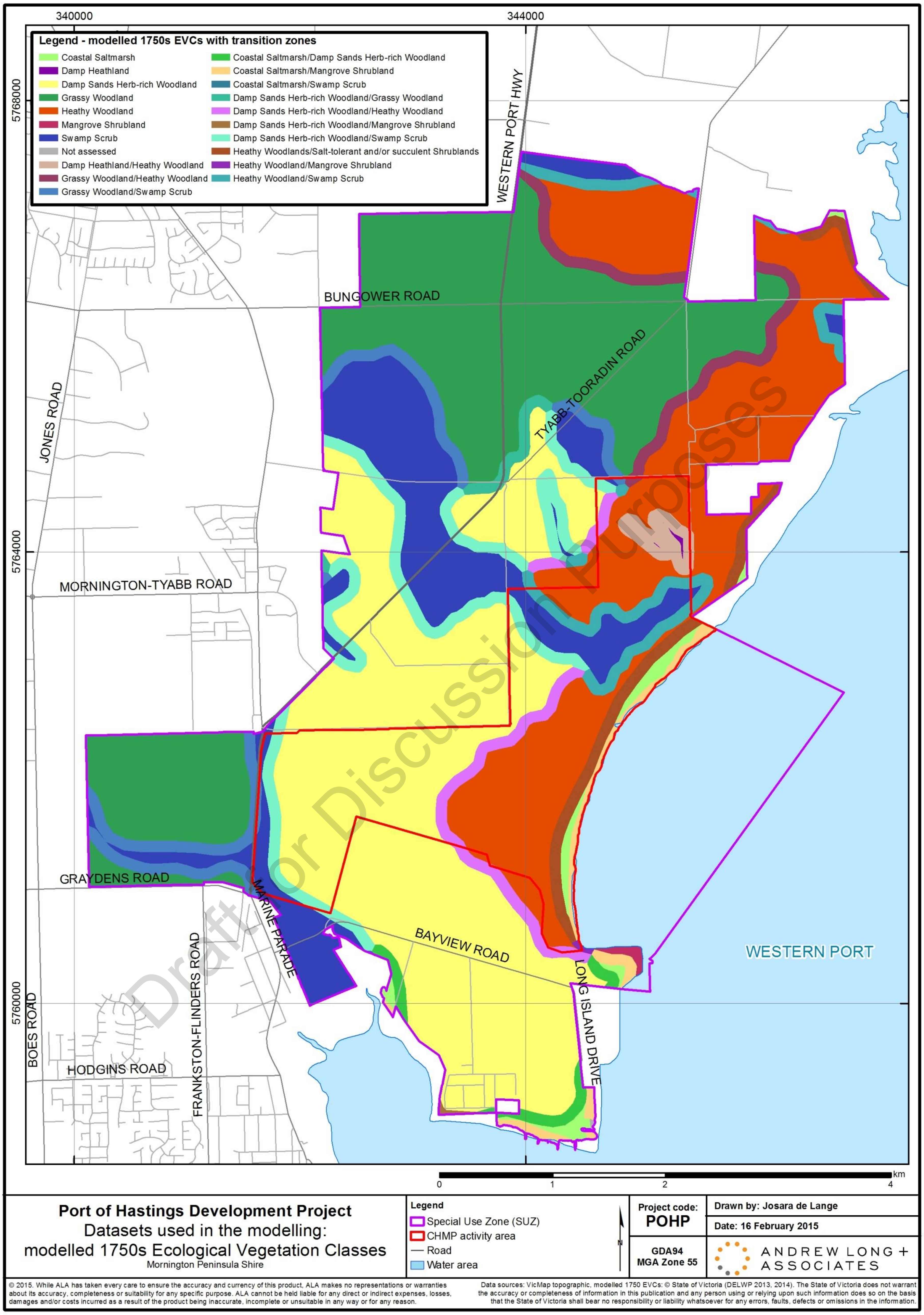

Figure 1: Datasets for modelling 1750s Ecological Vegetation Classes

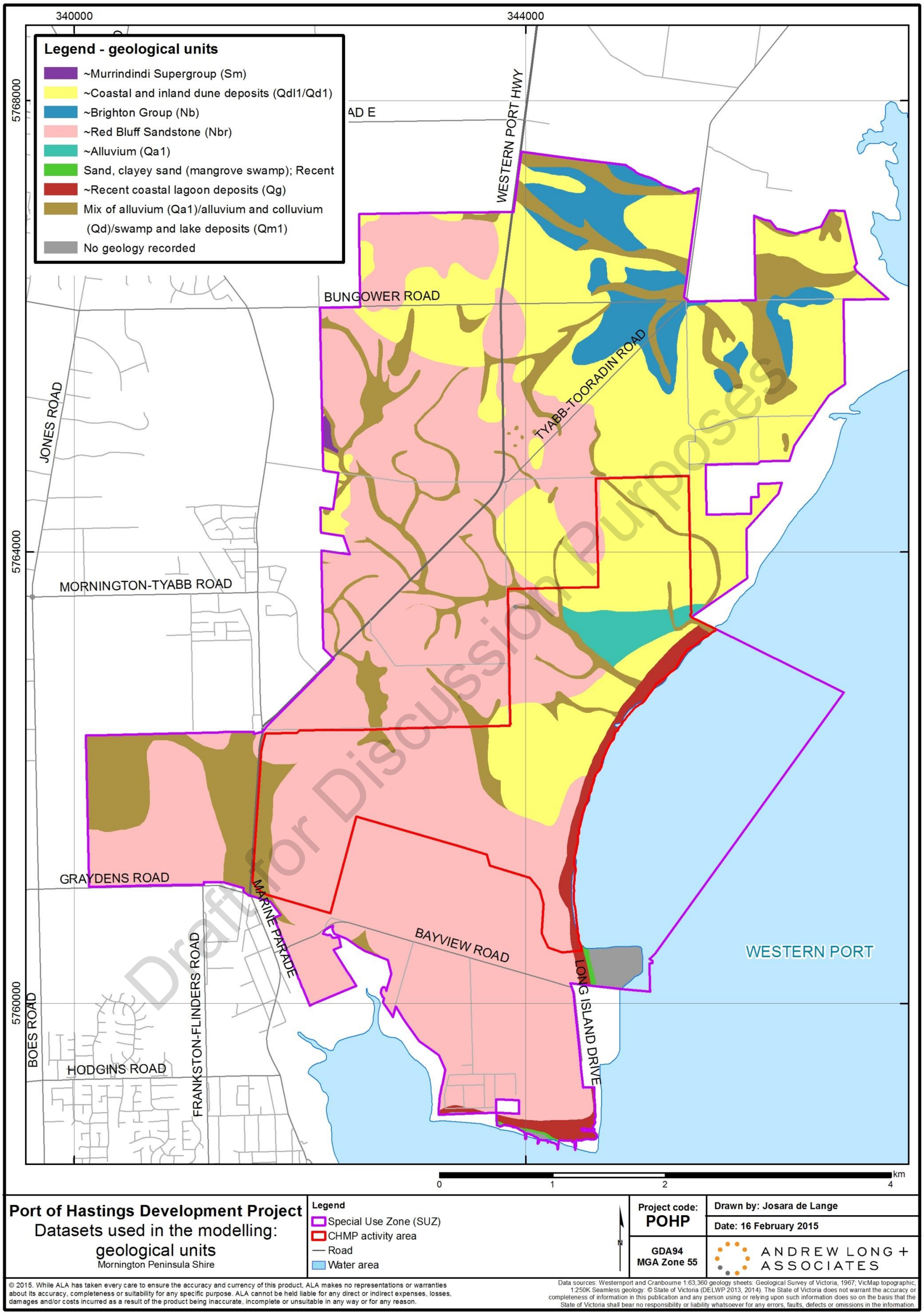

Figure 2: Datasets for modelling geological units

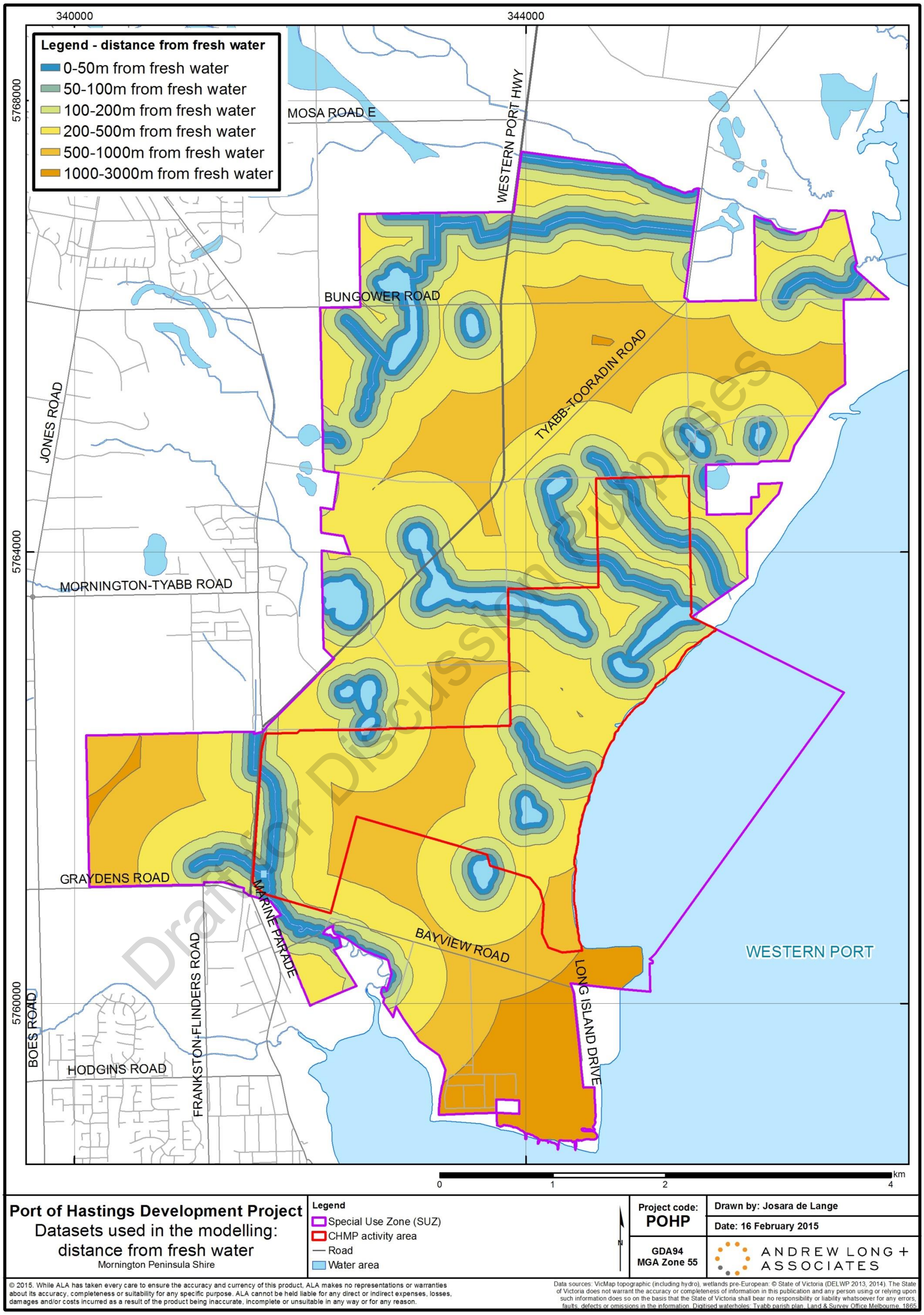

Figure 3 Datasets for modelling distance from fresh water

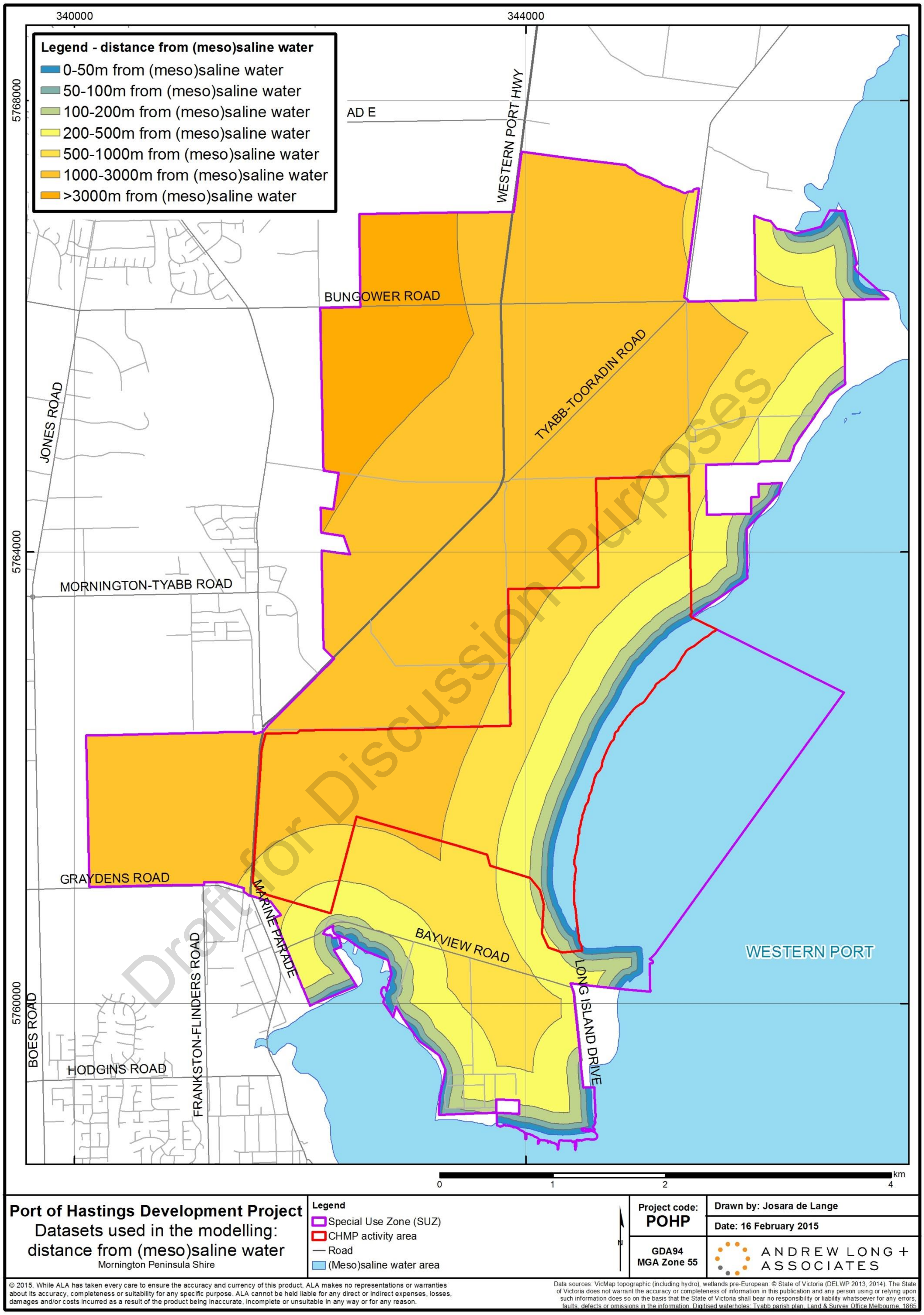

Figure 4: Datasets for modelling distance from (meso-)saline water

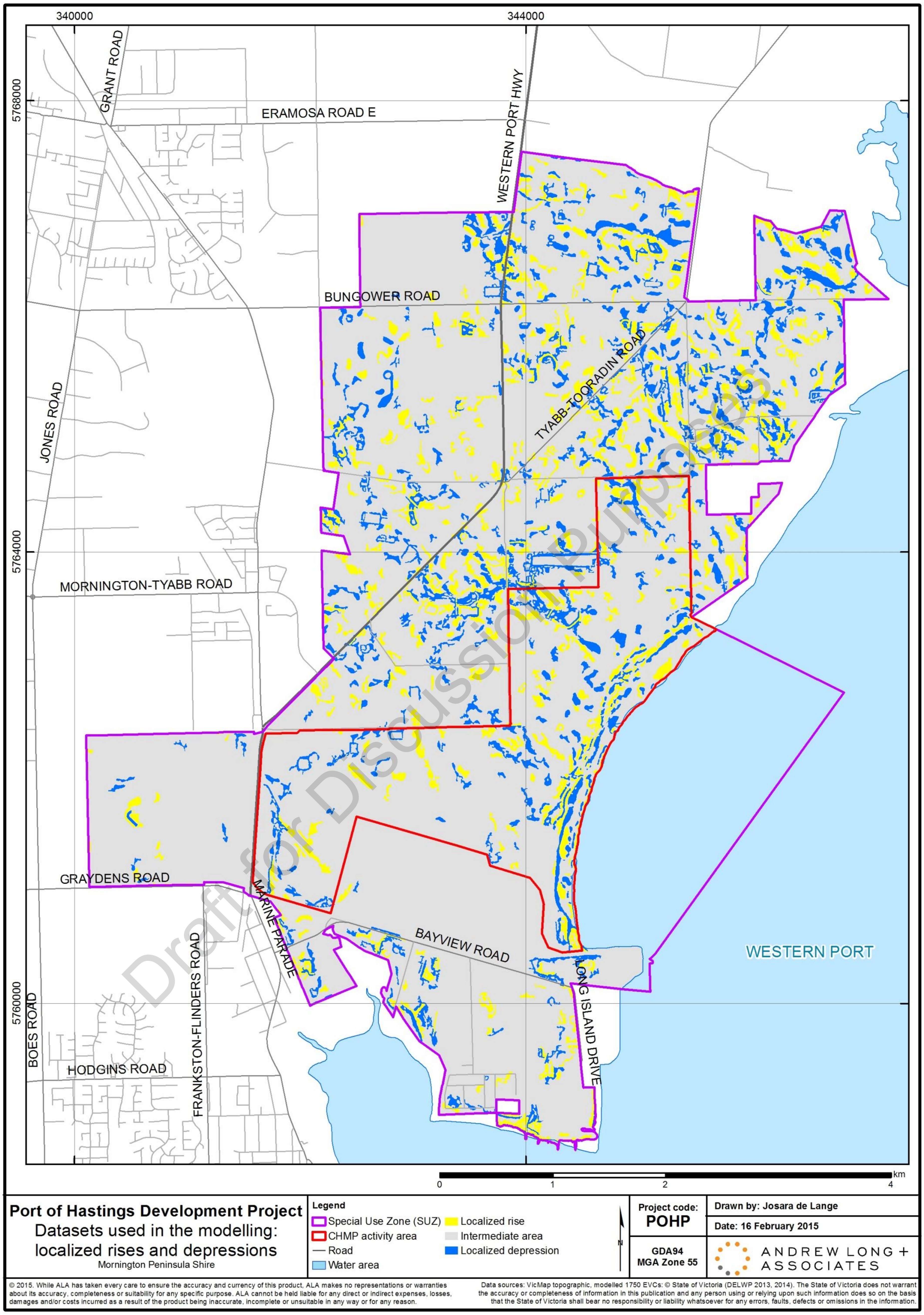

Figure 5: Datasets for modelling localised rises and depressions

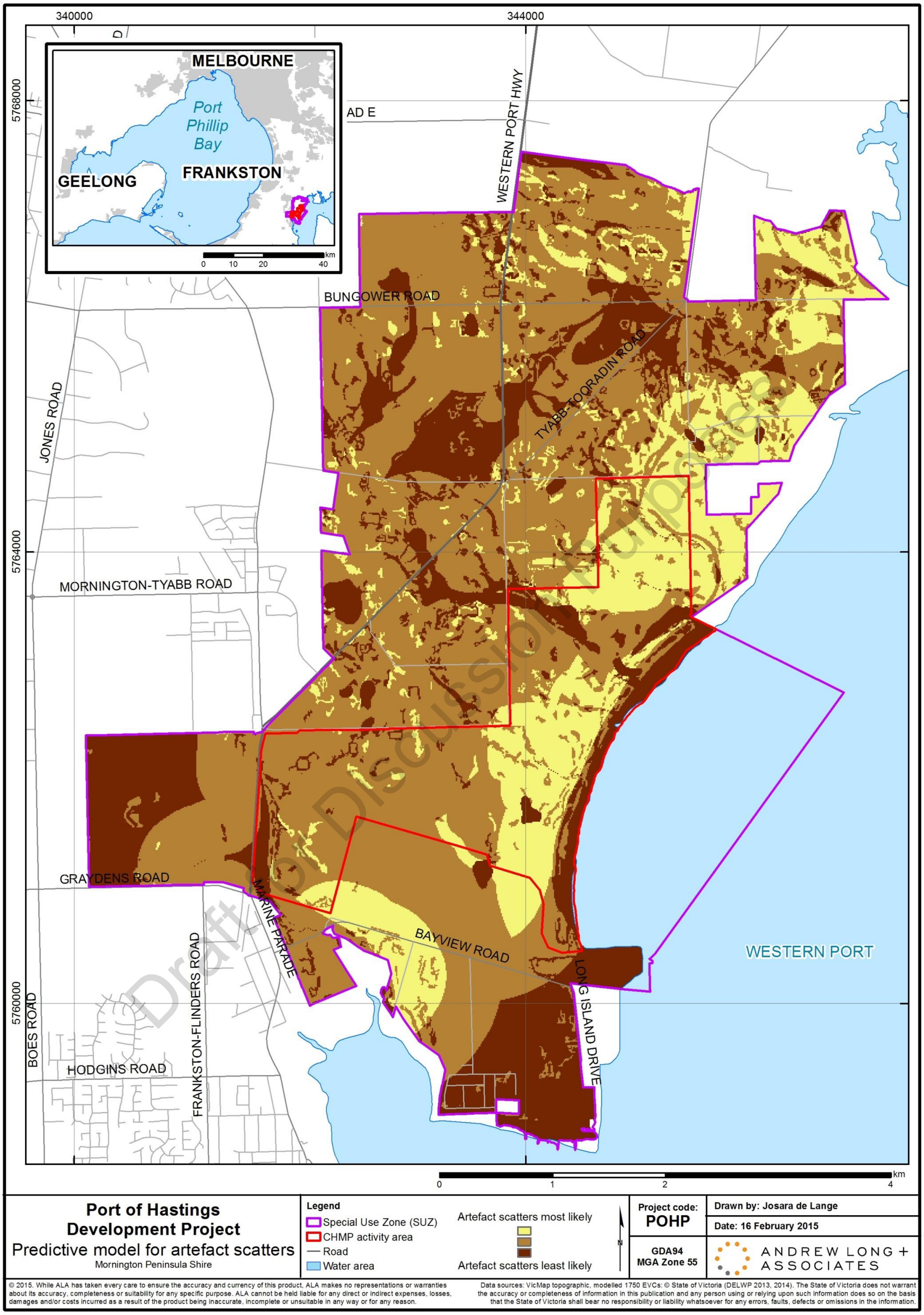

Figure 6: Site predictive model for artefact scatters

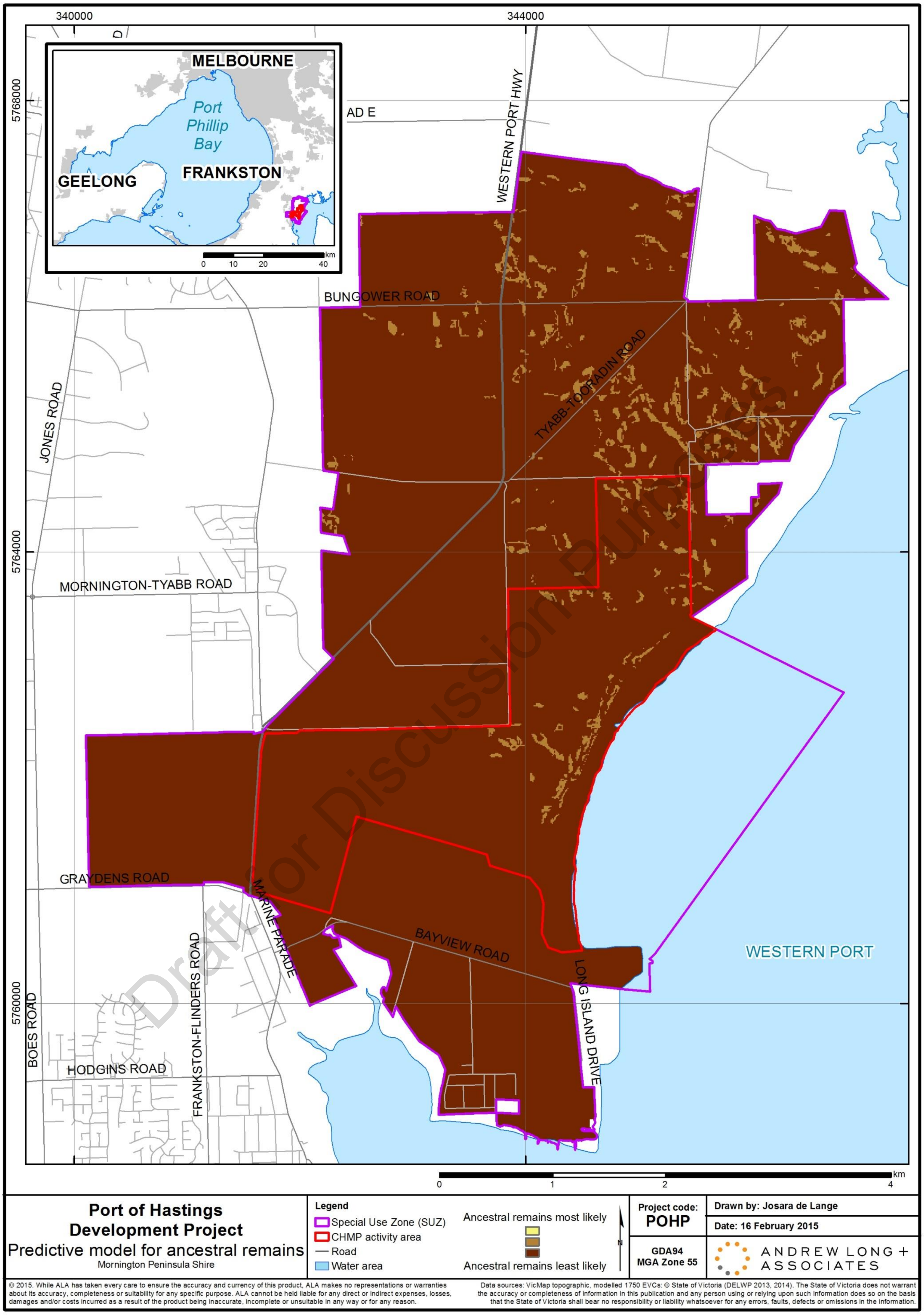

Figure 7: Site predictive model for ancestral remains

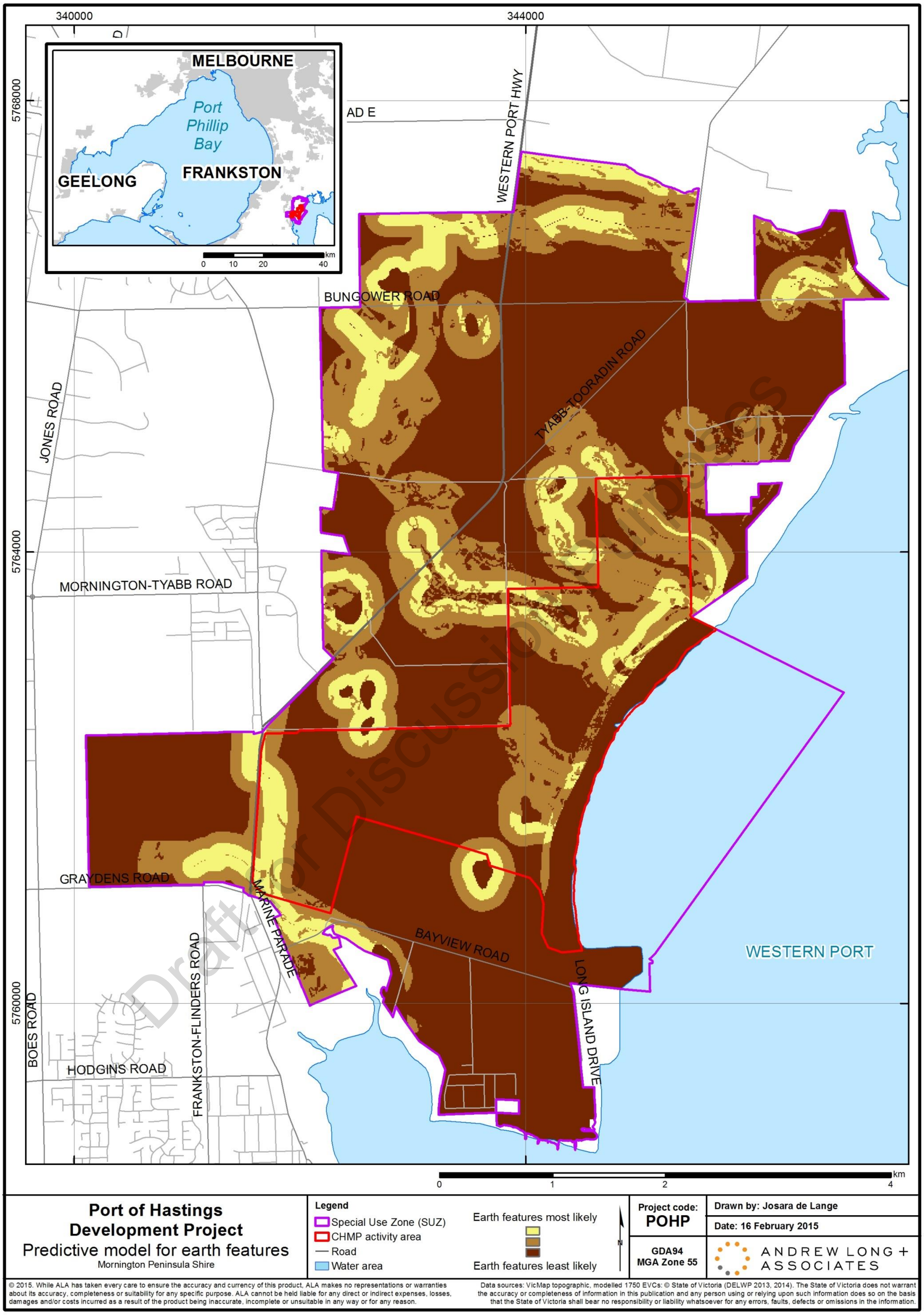

Figure 8: Site predictive model for earth features

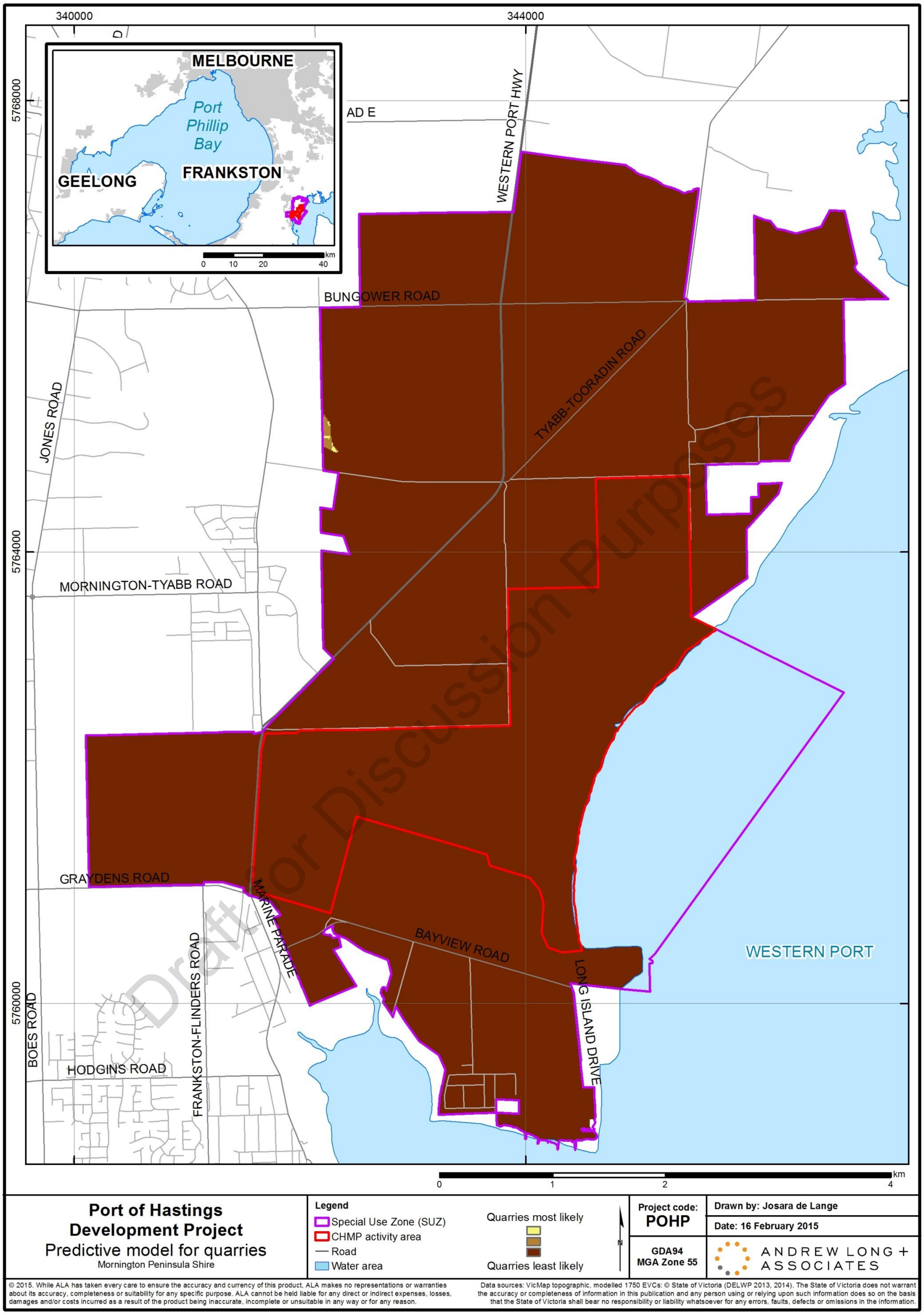

Figure 9: Site predictive model for quarries

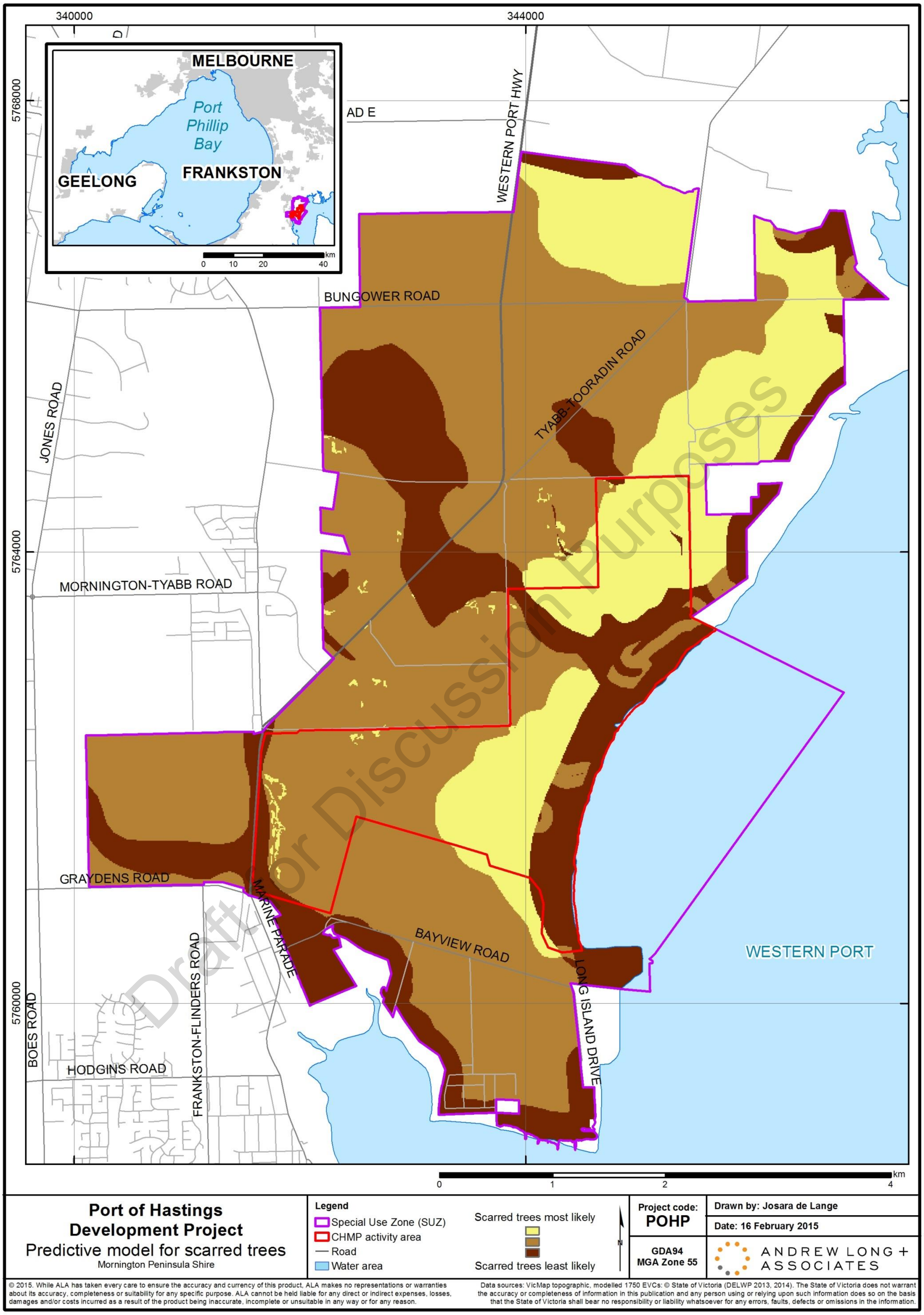

Figure 10: Site predictive model for scarred trees

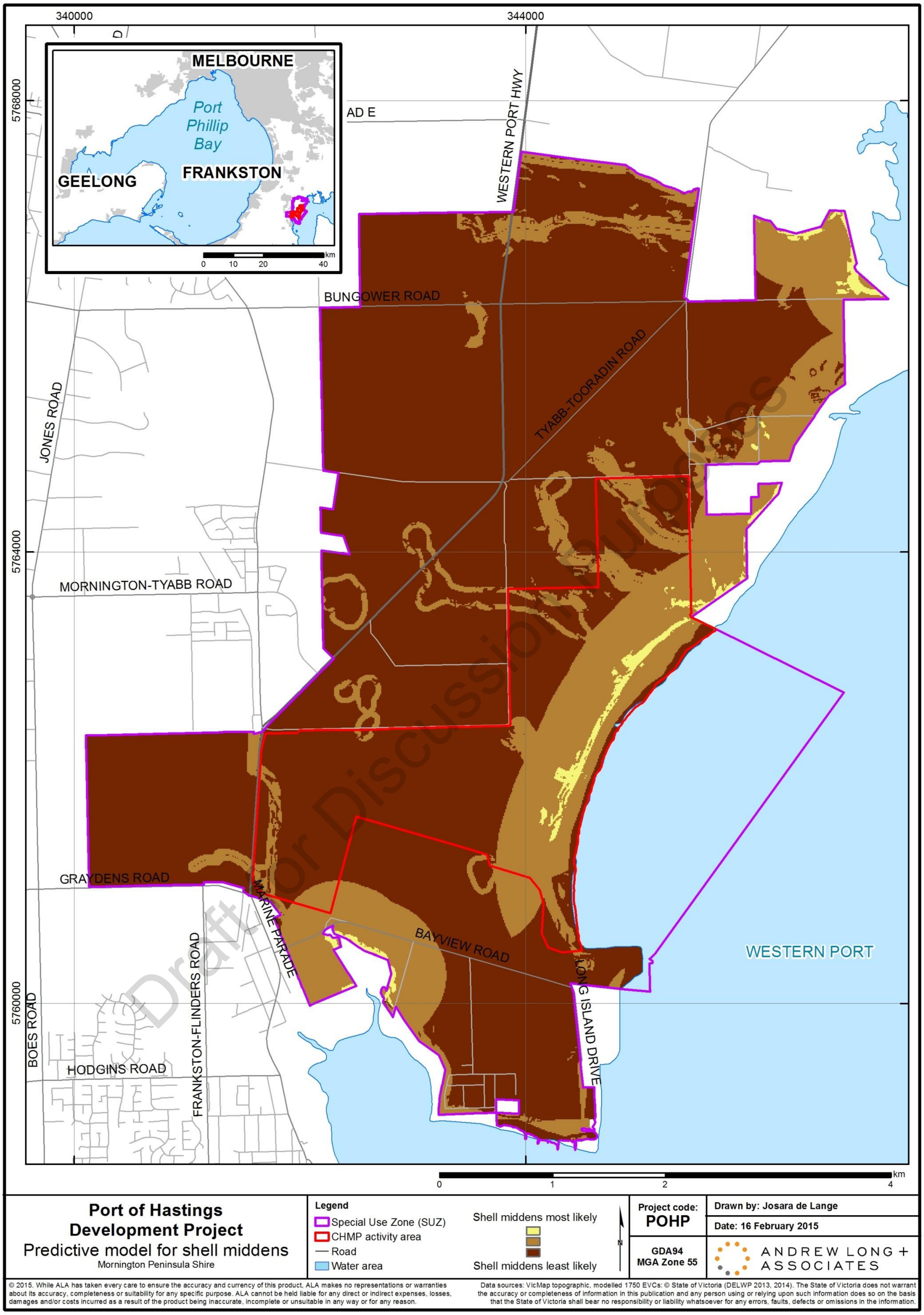

Figure 11: Site predictive model for shell middens

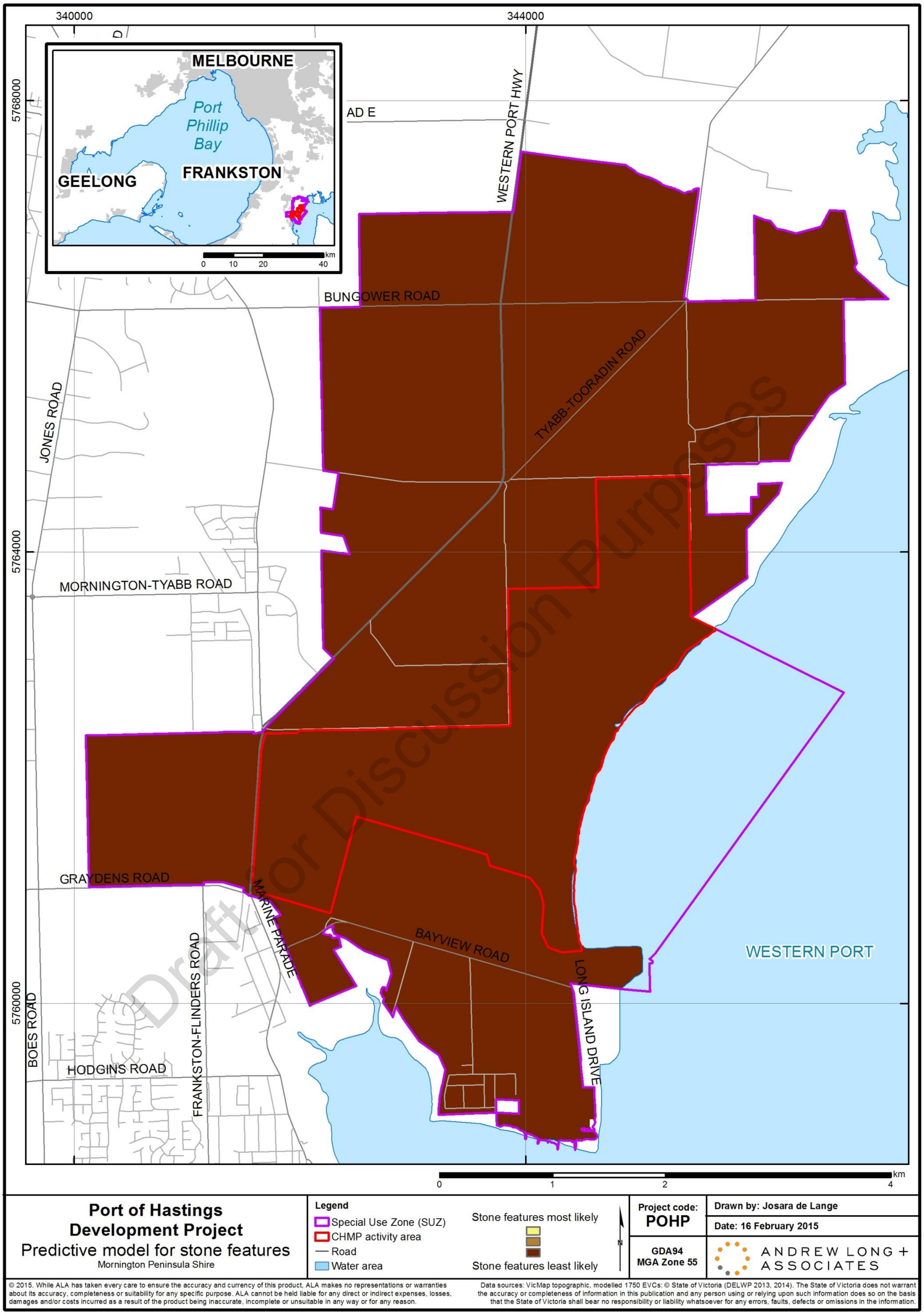

Figure 12: Site predictive model for stone features