WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Report

Inverloch Region Coastal Hazard Assessment – Data Assimilation & Gap Analysis

Department of Environment, Land, Water and Planning

30 June 2022

Document Status

Version	Doc type	Reviewed by	Approved by	Date issued
V01	Initial Draft	CLA	EAL	05/03/2021
V02	Draft	CLA	EAL	19/03/2021
V03	Final	CLA	EAL	03/05/2021
V04	Final + Appendix B Updates	AMC	EAL	10/06/2022
V05	Final	AMC	AMC	30/06/2022

Project Details

Project Name	Inverloch Region Coastal Hazard Assessment – Data Assimilation & Gap Analysis
Client	Department of Environment, Land, Water and Planning
Client Project Manager	Cass Philippou
Water Technology Project Manager	Elise Lawry
Water Technology Project Director	Dr. Andrew McCowan
Authors	Elise Lawry
Document Number	21010025_R02v05a_InverlochCHA_DataGapAnalysis.docx

VICTORIA State Government | Environment, Land, Water and Planning

15 Business Park Drive
Notting Hill VIC 3168
Telephone (03) 8526 0800
Fax (03) 9558 9365
ACN 093 377 283
ABN 60 093 377 283

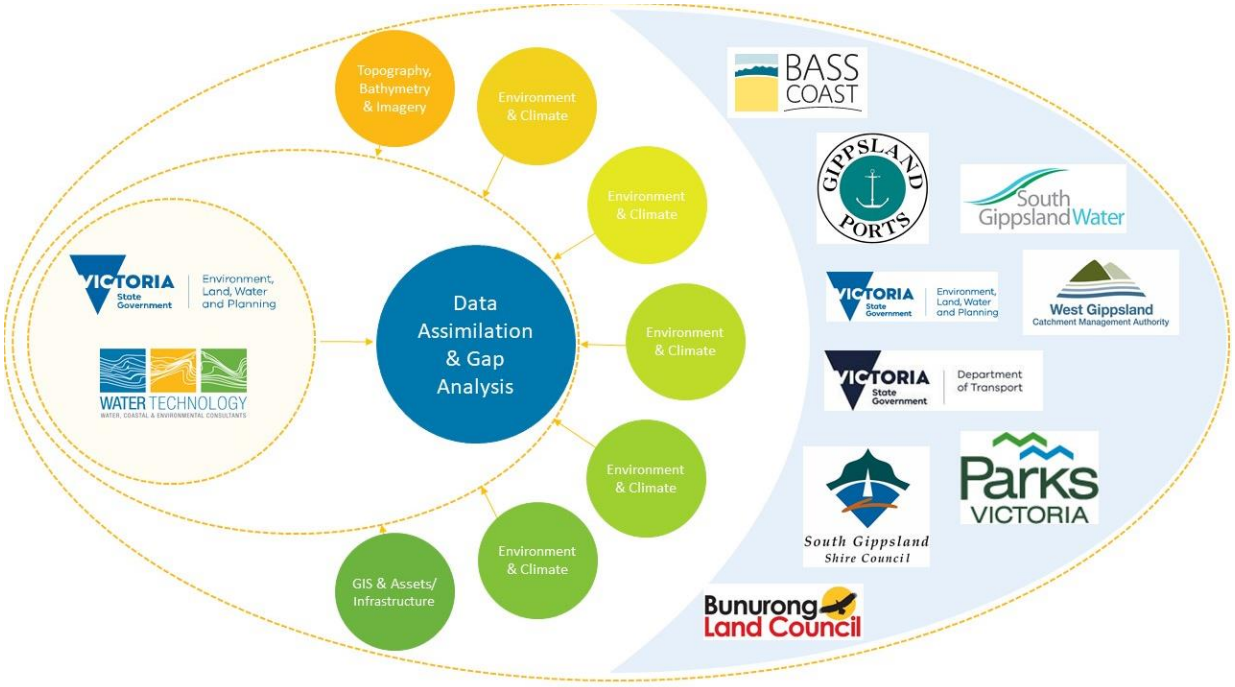
EXECUTIVE SUMMARY

The Inverloch Region Coastal Hazard Assessment (Inverloch Region CHA) covers an extensive stretch of coastline, from east of Cape Paterson at Undertow Bay to Morgan Beach at Cape Liptrap. The coastline varies significantly throughout the Study Area and is both heavily urbanised and engineered as well as remote and inaccessible to all but overnight beach hikers or pastoralists whose properties extend adjacent to the coastal park.

The Inverloch Region CHA is a key piece of work for the Inverloch Regional and Strategic Partnerships (RaSP) Cape to Cape Resilience Project and will develop an understanding of the coastal environment which will support decision making around coastal hazards both now and in the future.

A key undertaking of the CHA is to collate, review and analyse the existing available data which can be used to inform and drive scientific investigations of the CHA. Review of this data also highlights areas where missing, outdated, or incomplete datasets may impact the quality and completeness of the scientific outcomes.

The Data Assimilation has resulted in the collection of a wide range of data from a large number of key stakeholders, regulators and agencies which carry out various works in the Study Area. The data collected has been described in seven subcategories, developed to reflect their technical application.



An analysis of the data indicated existing data and knowledge in a number of key areas was lacking. The analysis looked at how easily these gaps could be filled and if it was practical and important for the project to pause and gather this data.

The analysis identified 4 areas of knowledge where major data gaps existed which, if not filled, would significantly limit the robustness of the analysis and compromise the ability of the study team to achieve the study objectives. Without filling these **high** consequence data gaps, listed below, the detailed assessment could not proceed.

- The position of the Baseline Shore from which erosion and inundation would be “measured” from, particularly along the coastline at the Inverloch township where considerable change has occurred in recent times;

- The accurate and complete stormwater network details for Inverloch township to ensure coastal inundation from storm tides could be accurately considered;
- Identification of existing coastal protection structures to ensure erosion calculations considered the existence of such structures, regardless of origin, ownership and quality;
- The location of utility data to properly consider the impact of hazards and design of adaptation options to ensure essential services are maintained or adapted in line with coastal hazards.

A total of 11 areas of knowledge or data where information was lacking were considered a significant data gap and their existence was likely to have some bearing on the robustness and ability to achieve the study objectives. These **medium** consequence ranked data gaps were considered important to fill, however would not prevent a version of the project proceeding. The knowledge and data gaps are noted below.

- Recent high resolution topographic survey of the study area
- Recent high resolution and full overage of the entrance channels and bars
- Recent survey of the offshore waters
- Beach profiles of the open ocean coast along Venus Bay
- The extent and depth of rock outcrops offshore of Point Norman
- Understanding of the regional level sediment sources and sinks
- Global wave model step change
- Spectral analysis of Inverloch VCMP wave data
- Definition of the “Present Day” mean sea level
- Identification of sites of cultural significance
- Mapping of Heritage sites

Lastly, 6 areas of knowledge or data were considered as having a low level of consequence if left unfilled. These data gaps were identified, however were able to be overcome by additional analysis if not filled. The **low** level consequence data gaps were:

- Sediment size characteristics across the whole study area
- Sediment age and origin characteristics across the whole study area
- Measured water levels offshore within Venus Bay
- Measured wave data within Anderson Inlet
- Defined impact of climate change on wind directions
- Measured data from coastal aquifers in the study area

Water Technology has made a series of recommendations to DELWP to fill a number of these data gaps. Scope and costs associated with the data collection have been provided and collection of data is currently underway or commissioned which fills all high consequence data gaps. Data collected will be noted and summarised in Appendix B of this report.

A number of the medium consequence data gaps could not be filled, such as recent full topographic survey of the study area and measurement of the rock outcrop off Point Norman. Primary reasons for these continued data gaps include impractical timeframes or excessive costs. Data gaps which cannot be filled should be noted and planning and preparation commenced to begin data collection or funding plans at the locations of future coastal hazard assessments.

CONTENTS

EXECUTIVE SUMMARY 2

1 INTRODUCTION 6
1.1 Scope of Work 6
1.2 Study Area 7
1.3 Reporting 7

2 METHODOLOGY 9
2.1 Overview 9
2.2 Data Collection & Assimilation 10
2.3 Gap Analysis 10

3 PROJECT DATABASE 12
3.1 Overview 12
3.2 Data / Document Catalogue 12
3.3 Geodatabase Structure 13
3.4 Data Ownership / Copyright 13

4 DATA COLLECTION 14
4.1 Overview 14
4.2 Topography, Bathymetry and Aerial Imagery 14
4.3 Geology and Geomorphology 21
4.4 Oceanographic and Coastal Processes 25
4.5 Environment and Climate 31
4.6 Catchment and Stormwater 32
4.7 Groundwater 33
4.8 Asset and Infrastructure 33

5 GAP ANALYSIS 36
5.1 Recommendations 42
5.2 Gaps to be filled 43

6 CHA ASSUMPTIONS 44

APPENDICES

Appendix A New Data Collection Scope
Appendix B New Data Collected
Appendix C Victoria's Resilient Coast Framework

LIST OF FIGURES

Figure 1 Inverloch CHA Project Phases 6
Figure 2 Study Area Coastline 7

Figure 3 Data Assimilation and Gap Analysis Process Overview 9
Figure 4 Example of Geodatabase Structure 13
Figure 5 Topographic Survey Extents 15
Figure 6 Bathymetric Survey Extents 18
Figure 7 Aerial Imagery Capture and Extent 20
Figure 8 Study Area Geology (Rosengren, 2019) 22
Figure 9 Sediment Sampling Locations 24
Figure 10 Oceanographic Data 26
Figure 11 Recent Shoreline Change at Inverloch (from Doumtsis, 2020) 29

LIST OF TABLES

Table 1 Contacted Organisations and Primary Contacts 10
Table 2 Summary of Data Gap Rating Scale 11
Table 3 Structure of Data Catalogue 12
Table 4 Available Topographic Datasets 15
Table 5 Available Bathymetric Datasets 18
Table 6 Available Aerial Imagery Datasets 20
Table 7 Data Gap Analysis 37
Table 8 Gap Priorities 42
Table 9 Consequence and Assumptions of Data Gap 44

1 INTRODUCTION

In 2020 the Inverloch Regional and Strategic Partnership (RaSP) was established, comprising nine agencies and the Bunurong Land Council Aboriginal Corporation, working together to address the problem of erosion and inundation at Inverloch and surrounds. The Department of Environment, Land, Water and Planning (DELWP) is leading the RaSP.

The RaSP's project is called the Cape to Cape Resilience Project, and a key piece of work is the Inverloch Region Coastal Hazard Assessment (CHA), which is an assessment of coastal hazards for the stretch of coast between Cape Paterson and Cape Liptrap, including Inverloch, Anderson Inlet and Venus Bay.

Water Technology has been commissioned by DELWP to undertake the Inverloch Region CHA.

This report details step one of the CHA process – the assessment of available data and identification of the impacts of missing, outdated or incomplete data. The data collated for this report, along with any data collected as an outcome of recommendations in Section 5.1, will be used to inform future stages of the CHA (Figure 1).

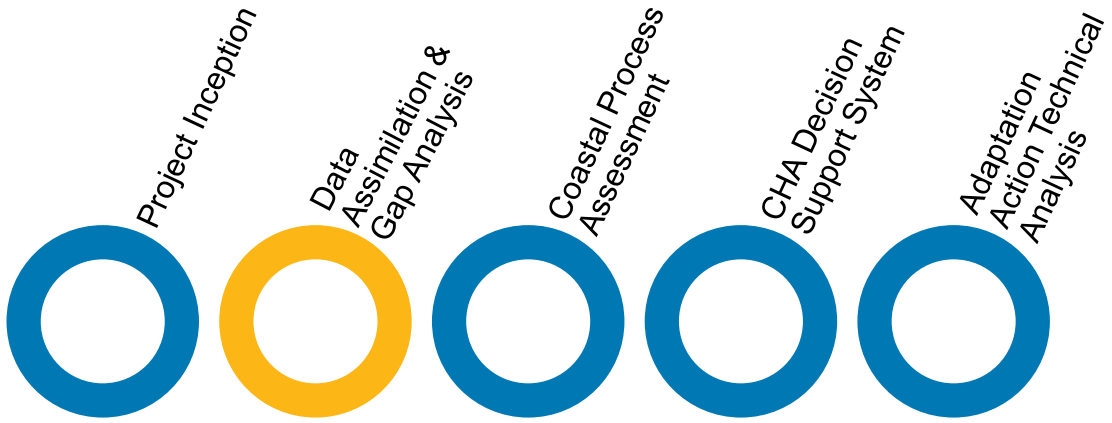


FIGURE 1 INVERLOCH CHA PROJECT PHASES

1.1 Scope of Work

The scope of the Phase 1: Data Assimilation and Gap Analysis (Phase 1) was to search and identify existing data sources and information relevant to the Cape Paterson to Cape Liptrap coastline (referred to herein as the Inverloch region and Study Area), to provide baseline data in preparation for this and any future local coastal hazard studies within this region.

The scope of work for the data assimilation and gap analysis was as follows:

1. **Liaison** with agencies and stakeholders to obtain relevant baseline data, information and reports related to the Inverloch region, focussing on seven priority information source areas shown in Figure 3;
2. **Collation** of the baseline data, information and reports;
3. **Analysis** and a critical **assessment** of the baseline data and background information;

4. **Identification** of potential data gaps and the possible **consequence** these data gaps will have on the CHA project outcomes;
5. Where the gap is significant and will impact on the quality of the outputs, approaches to **address** the gap are described.

In addition to the data assimilation and gap analysis, this report also provides some detail of the assumptions and practical implications of those assumptions and uncertainties on the resulting hazard assessment with a sensitivity analysis on key parameters.

1.2 Study Area

The project study area extends from east of Cape Paterson's most eastern beach “Undertow Bay” to the eastern end of Morgan Beach, located just west of Cape Liptrap. The project includes the shorelines of Venus Bay and Anderson Inlet, as presented in Figure 2.

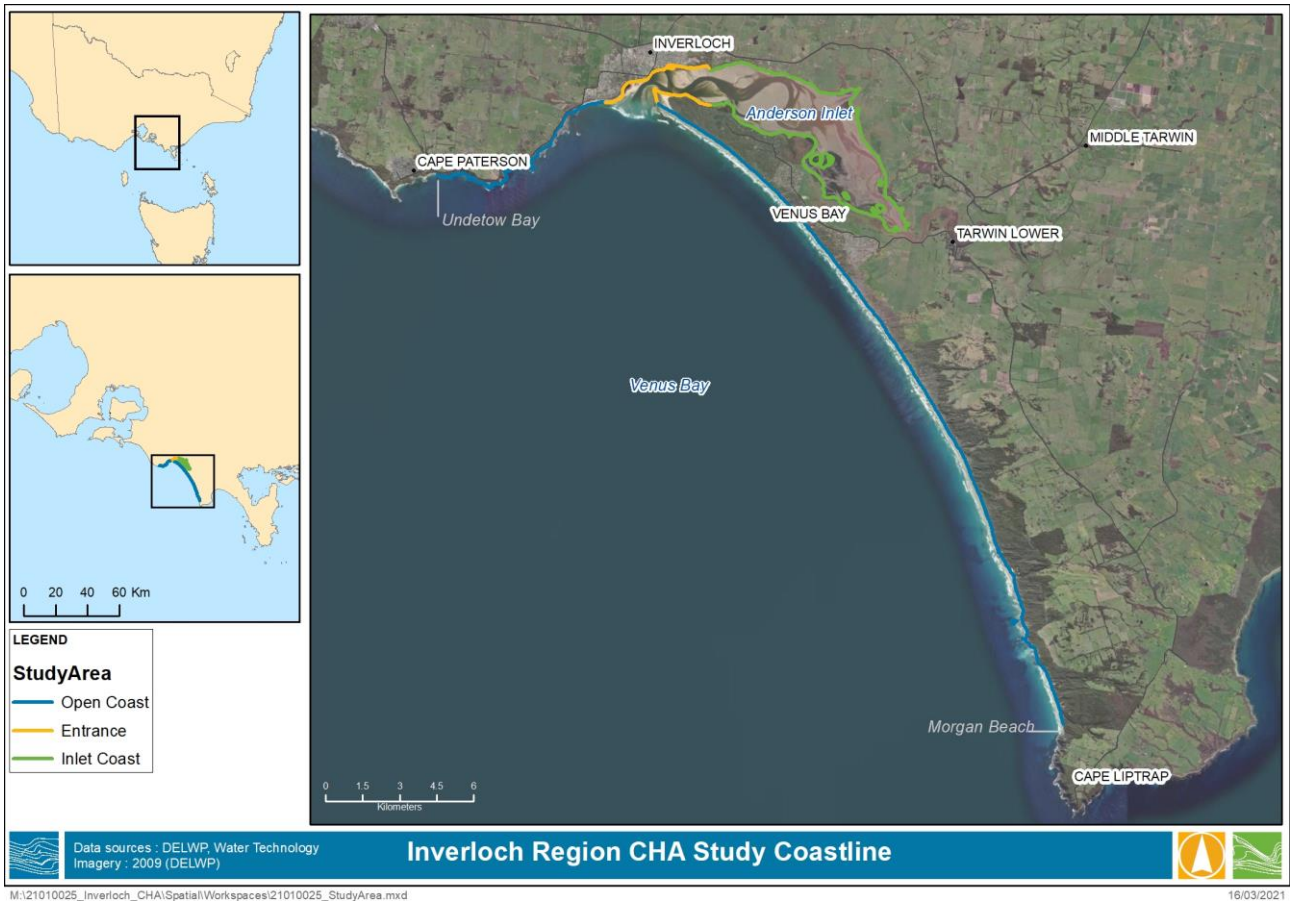


FIGURE 2 STUDY AREA COASTLINE

1.3 Reporting

This report describes the work that has been completed as part of this data assimilation, review and gap analysis:

- Section 1 **introduces the project** and outlines the scope of work,

- Section 2 **summarises the methodology** including organisations, databases and libraries contacted as part of the background data research and assimilation.
- Section 3 provides a **description of the structure and functionality** of the database and data catalogue provided as deliverables for this study. A description of the structure of the GIS geodatabase developed as part of the data assimilation is also included.
- Section 4 **details the results** of the data collation.
- Section 5 describes the **results of the gap analysis** and the implications to the project of these gaps, including recommendations for the additional data collection if required.
- Section 6 **details assumptions** that will be required to complete the CHA and the practical implications of assumptions and uncertainties.

Appendix A details the data collated following the initial data assimilation and gap analysis. **Appendix B** provides details on further data which was collected or made available during the progression of the Study.

To provide integrity to the data collation and analysis part of this project, the main body of the report has not been updated as new data is collected and the full report should be read to understand the data assessed and available for the project.

This document is Report 2 of a series of reports produced as part of the Inverloch Region Coastal Hazard Assessment project. It should be read in conjunction with the following:

- Report 1: Project Summary Report
- **Report 2: Data Assimilation and Gap Analysis**
- Report 3: Technical Methodology
- Report 4: Coastal Processes and Erosion Hazard Assessment
- Report 5: Inundation Hazards
- Report 6: Coastal Asset Exposure Assessment
- Report 7: Adaptation Action Technical Assessment

The Inverloch Region Coastal Hazard Assessment has been a pilot project for the *Pilot Guidelines – Victoria's Resilient Coast – Adapting for 2100+* (DELWP, 2022). The framework for the *Guidelines*, and the function of this report, and the full suite of reports prepared for the Inverloch CHA, is detailed in Appendix C.

2 METHODOLOGY

2.1 Overview

The types of information sourced for Coastal Hazard Assessments can be broadly classified under: Imagery and Survey, Geology and Geomorphology, Oceanographic and Coastal Processes, Environmental and Climate, Catchment and Stormwater Inundation, Groundwater, and Assets and Infrastructure.

This data is sourced through a range of organisations, databases and libraries and must be assimilated and catalogued. Once all the data has been collated, each dataset is then reviewed to determine its relevance, any gaps in the information for the purposes of a coastal hazard assessment, and its relative importance and impact to the outcomes of such a study. From this the scope required to fill the data gaps is identified.

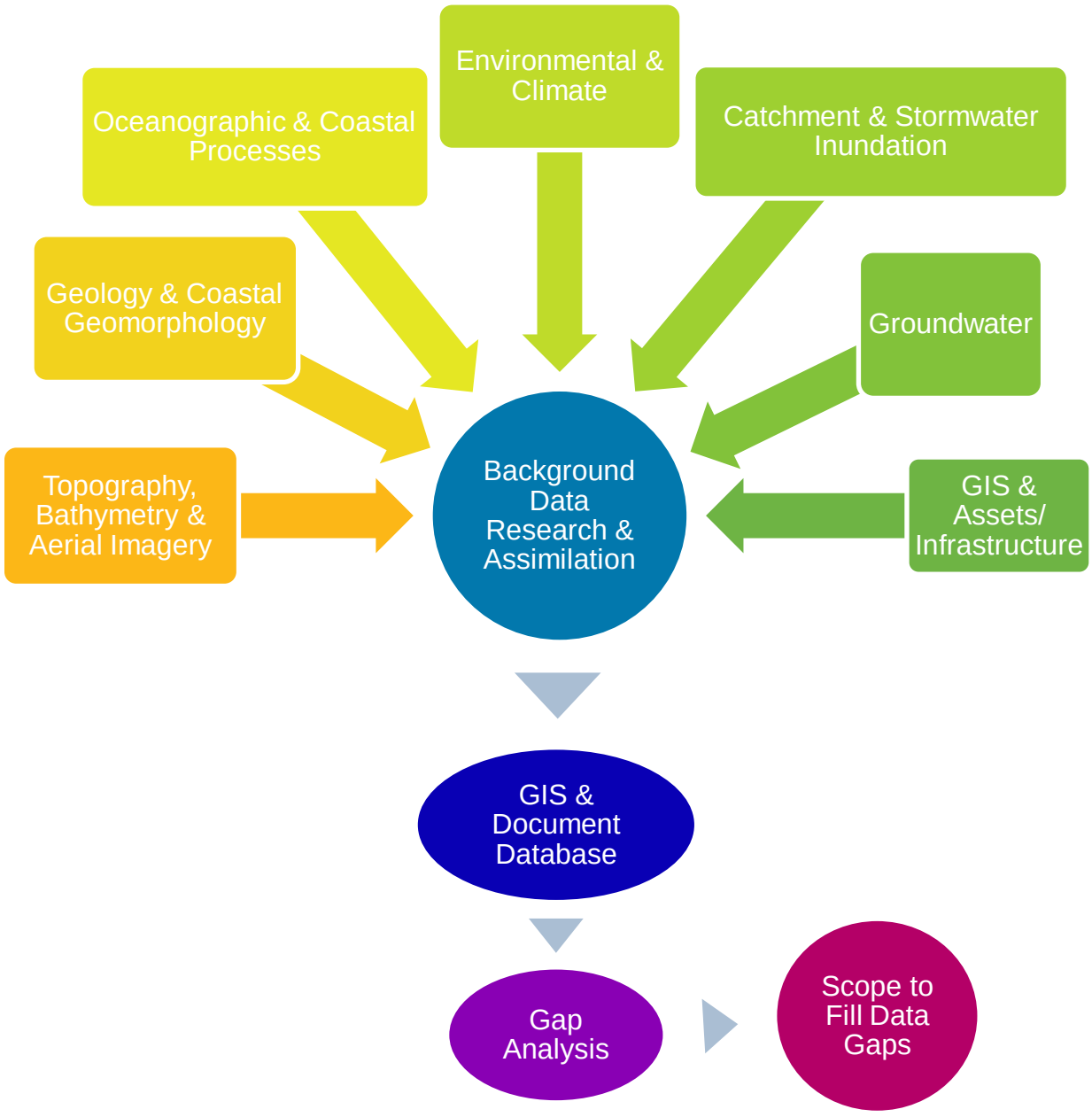


FIGURE 3 DATA ASSIMILATION AND GAP ANALYSIS PROCESS OVERVIEW

2.2 Data Collection & Assimilation

The background data research and assimilation for the Inverloch region was undertaken using the following approach:

- A list of all relevant organisations, databases and libraries that were identified as potentially holding relevant data was compiled. Table 1 below summarises all the organisations, databases and libraries compiled for the project.
- An introduction email was sent from DELWP to all the relevant organisations that had been identified as likely to hold relevant information. The introduction email outlined the background of the project and types of data that were potentially of interest to the project.
- Follow up phone calls and specific email requests for data from Water Technology were then undertaken with individual organisations.
- Internet and library database searches were also undertaken to identify any additional literature and/or published reports relevant to the project.
- The study team were also able to draw on extensive project experience in the study area. Extensive searches of the Water Technology project archives were used to identify addition data.

TABLE 1 CONTACTED ORGANISATIONS AND PRIMARY CONTACTS

Organisation / Source	Primary Contact	Status
Bass Coast Shire Council	Derek Hibbert	Contacted, data supplied
South Gippsland Shire Council	Ken Griffiths	Contacted, data supplied
West Gippsland CMA	Adam Dunn	Contacted, data supplied
South Gippsland Water	Lucy Allsop	Contacted, data supplied
Southern Rural Water	Matthew Hudson	Contacted, data being collated
Gippsland Ports	Peter Hahnemann	Contacted, data supplied
Parks Victoria	Gerard Delaney	Contacted, data supplied
Department of Transport	Laurie Jeremiah	Contacted, data supplied
South Gippsland Conservation Society	Philip Heath	Contacted, data supplied
Victorian Coastal Monitoring Program	David Kennedy	Contacted, data supplied
Department of Environment Land Water Planning	Darren James	Contacted, data supplied
Heritage Victoria	Liam Phillips	Contacted, no relevant data
Bunurong LC	Rohan Henry	Contacted, no response
University of Melbourne	David Kennedy	Contacted, data supplied
State Library of Victoria	Internet search	Archive Search
Study Team (Water Technology and Environmental Geosurveys)	Elise Lawry / Neville Rosengren	Archive Search

2.3 Gap Analysis

Based on the collation and review of available data and information a gap analysis has been used to identify gaps and their significance for this and future coastal hazard assessments. Ranking of the significance of the data gap recognises that the absence or incompleteness of different types and sources of data may have

varying impacts. A significant data gap could limit the ability to proceed with a detailed assessment within the study area.

A description of the qualitative scale adopted to rate the relative importance and consequence of identified data gaps on the ability to proceed and/or objectives of the detailed coastal hazard assessment is presented in Table 2.

TABLE 2 SUMMARY OF DATA GAP RATING SCALE

Data Gap Rating	Description of Relative Importance	Consequence
None	No Data Gap has been identified. Adequate information is considered available to assist with a detailed coastal climate change study assessment.	No additional information or data required
Low	While a data gap has been identified, it is considered to be of limited consequence to the overall study objectives and/or the data gap can be overcome by routine analysis or minimal additional data collection efforts.	The detailed assessment can proceed, but additional data/information may need to be developed during the assessment.
Medium	A significant data gap has been identified that is likely to have some bearing on the robustness of the analysis that can be undertaken and the ability to achieve the study objectives and/or the data gap can be overcome but only with substantive additional analysis or data collection efforts.	An assessment of the ability to fill the data gap and the value of the data to the detailed assessment would need to be considered before proceeding with a detailed assessment.
High	A major data gap has been identified that will significantly limit the robustness of the analysis that can be undertaken and significantly compromise the ability to achieve the study objectives and/or the data gap can be overcome only by extensive additional analysis or data collection efforts.	The detailed assessment cannot proceed until this data gap has been completed

3 PROJECT DATABASE

3.1 Overview

All data sources identified as part of the background data research and assimilation have been compiled into a project database. The various data sources were categorised within the database into the following logical data streams:

- Imagery and Survey
- Geology and Coastal Geomorphology
- Oceanographic and Coastal Processes
- Environment and Climate
- Catchment and Stormwater Inundation
- Groundwater
- Asset and Infrastructure

Within each of the above data streams, the data sources were further categorised into the following data types:

Data – contains files that are not readily identified as either reports or as spatial information such as excel spreadsheets, photos, text files, figures etc.

Documents – contains all assimilated reports and papers

Spatial – a GIS geodatabase containing all assimilated spatial data.

3.2 Data / Document Catalogue

All data and documents identified and/or obtained as part of the background data assimilation and incorporated into the Inverloch CHA database structure described in Section 3 has been catalogued in a Microsoft Excel spreadsheet. This catalogue is the key tool for navigating through the database and identifying information and datasets of interest. The catalogue is setup in a logical manner to allow for easy search capabilities, filtering and hyper-linking to relevant information. The GIS datasets are also referenced in the catalogue database. Table 3 outlines the details of the structure of the Inverloch data catalogue.

TABLE 3 STRUCTURE OF DATA CATALOGUE

ID	A unique identification number has been provided to each specified data. The I.Ds have been developed based on a unique number and the year the document was created. e.g. 54_1999_ 37_2005_
Filename	The original filename of the data
Type	Data, document, spatial
Format	The format in which the data exists, e.g. shp, docx
Category	The category which the data falls into based on the data source categories
Description	A brief description of the data content to enable keyword searches
Year	The year the data was published/created
Creator	The author/organisation that produced the data

Custodian	The organisation/individual that currently owns the data
Location	The specific area within the study area the data relates to
License Condition	Any license conditions relating to access of the data. Where appropriate, the organisation/individual that licenses the data is provided.
Hyperlink	Where appropriate, a hyperlink provides direct navigation to the specific data
Relevance/ Importance	A qualitative assessment of the relative relevance or importance of the data set to the assessments to be undertaken as part of the detailed coastal climate change study has been provided as follows: Low – Dataset considered of limited relevance to the detailed coastal climate change study. Medium – Dataset considered to hold some significance and may provide important input/information for the detailed coastal climate change study. High – Dataset holds significant value/ is a critical input/source of information for the detailed coastal climate change study.

3.3 Geodatabase Structure

An ESRI geodatabase of available data has been created. The geodatabase can be viewed in ArcGIS. The geodatabase contains a list of Feature Datasets which hold a number of relevant Feature Classes. An example of the geodatabase structure is provided in Figure 4.

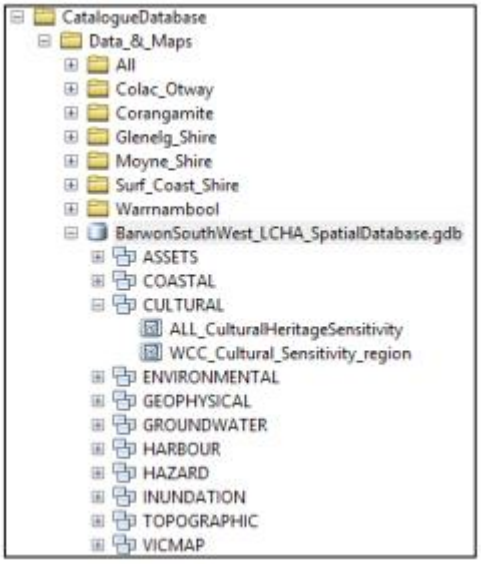


FIGURE 4 EXAMPLE OF GEODATABASE STRUCTURE

3.3.1 Spatial Coordinates

The spatial coordinates for the geodatabase delivered as part of this project is in MGA Zone 55, GDA94 datum.

3.4 Data Ownership / Copyright

All data collected for the Inverloch CHA has received permission from the data custodian for use in the Inverloch CHA. Future use of datasets may require a license agreement from the data custodian noted.

4 DATA COLLECTION

4.1 Overview

Data has been collected from a number of government agencies, research organisations, community sources and consultants. A thorough search has been undertaken to collate all available data, however Water Technology notes that more data may be available which has not been uncovered during this Data Assimilation and Gap Analysis portion of the Inverloch Regional Coastal Hazard Assessment. As additional data becomes available at during the course of the study it will be noted in an amendment to this document and added to the data catalogue prior to finalisation of the project. Appendix A has been added in this Version 3 of the report and provides details on scopes and fees associated with filling the key gaps detailed below. Appendix B has been added which included details of new data collected to date.

4.2 Topography, Bathymetry and Aerial Imagery

4.2.1 Topographic Data

Data Requirements Overview

Topographic survey data is required to support the development of floodplain, urban and sediment transport models of the study area. Comparison of historical topographic survey data sets across the beaches in the Study Area will also assist in interpretation of coastal processes and quantification of coastal sediment movements.

Summary of Available Data

High resolution topographic (and bathymetric) data for the study area is limited to the 2008-2011 Future Coast LiDAR DEM. The coverage is close to complete with a small area to the west of Inverloch at the top of the coastal cliffs missing from the topographic dataset. The Future Coast DEM is available as a 1.0m grid resolution with 0.1m accuracy (horizontal and vertical), providing an exceptional representation of the study area between 2008 and 2009 (exact dates of capture of data within the study area is unknown).

Localised and more recent topographic survey data is available from the Victorian Coastal Monitoring Program (VCMP) Citizen Science Drone Program. The VCMP program captures drone based photogrammetry of beaches across Victoria. At Inverloch the program has been capturing the beach and dune topography along the Surf Beach at 6-8 week intervals between 2018 and 2020. Some additional photogrammetry has been captured by the University of Melbourne researchers as part of the VCMP which extends the survey into the Inlet entrance.

The South Gippsland Conservation Society (SGCS) has been capturing laser level survey of beach profiles along the Surf Beach since August 2018. The beach profiles begin at a reference point and extend along a bearing with data collected every 5m. Profiles at 10 different locations have been captured, as indicated in Figure 5 on average 9 times. The beach profiles show a trend of recession with significant (64m) recession at the Point Norman profile as the beach shape has changed. Along Surf Beach, and towards Flat Rock drops in beach level of 1.0m are common over the monitoring period and recession of the 0m AHD line by 10m+.

The extent of topographic surveys relevant to the study are shown in Figure 5 and summarised in Table 4.

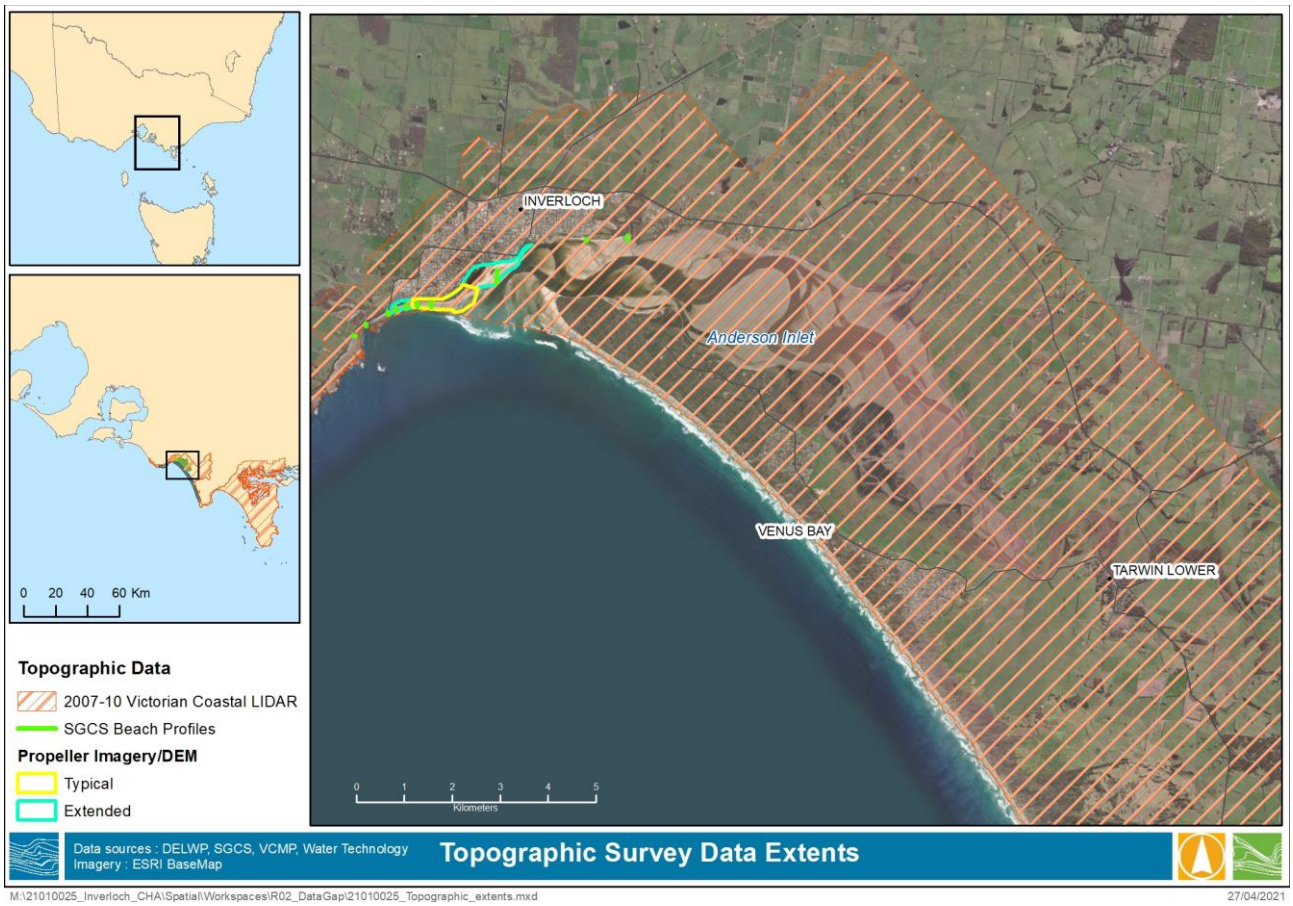


FIGURE 5 TOPOGRAPHIC SURVEY EXTENTS

TABLE 4 AVAILABLE TOPOGRAPHIC DATASETS

Extent	Date	Capture	Custodian
Study Area	2008 – 2009	Topographic LiDAR	DELWP
Inverloch Surf Beach	22/08/2018 15/10/2018 30/11/2018 21/02/2019 01/04/2019 07/06/2019 30/07/2019 03/09/2019 22/10/2019 28/11/2019 19/12/2019 28/01/2020 10/03/2020 13/05/2020	Drone based photogrammetry	VCMP

Extent	Date	Capture	Custodian
	10/07/2020 26/08/2020 20/10/2020 11/12/2020		
Inverloch Surf Beach	17/09/2019 30/10/2019 28/11/2019 5/12/2019 17/01/2020 25/02/2020 15/04/2020 04/05/2020 12/06/2020 27/06/2020 12/10/2020 19/12/2020	Laser level beach profile	SGCS

Data Gap

The FutureCoast DEM provides excellent coverage and resolution of topography in the Study Area. However, this dataset is now over 10 years old and captures conditions at Inverloch between Wreck Creek and Point Hughes in particular which are significantly different from the current coastline configuration and Anderson Inlet entrance channels and bars.

The technical assessments of the Coastal Hazard Assessment can be completed without updating this data, however significant gains in understanding of coastal processes and the potential impact of adaptation options could be achieved by updating this dataset. A highly engaged community in the Study Area will also be sensitive to the use of outdated data, particularly in this key zone.

Beach profiles captured by SGCS are a valuable resource in verifying beach profile response models. The lack of beach profiles across the whole of the Study Area however, is a significant data gap, particularly on the open coast east of Point Smythe where regular aerial imagery tracking shoreline change is also less prevalent. This data cannot be retrospectively captured and the period between the FutureCoast DEM capture and now is too large of a gap to calibrate a model to. Beach profiles could be captured now and again in a month in the event that a storm even may trigger some significant beach change to calibrate the model to, however this would be speculative.

4.2.2 Bathymetric Data

Data Requirements Overview

Bathymetric survey data is required to support the development of hydrodynamic, wave and sediment transport models of the study area. Comparison of historical bathymetric survey data sets may also assist in interpretation of coastal processes and quantification of coastal sediment movements.

Summary of Available Data

Future Coast LiDAR

High resolution bathymetric data for the study area is limited to the 2008-2011 Future Coast LiDAR DEM. The coverage is close to complete with small sections of bathymetry missing in turbid waters where wave break or sediment is suspended. The Future Coast DEM is available as a 1.0m grid resolution with 0.1m accuracy (horizontal and vertical), providing an exceptional representation of the study area between 2008 and 2009 (exact dates of capture of data within the study area is unknown). The bathymetry extends to a depth of around 20m below mean sea level along the open coast, providing excellent capture of the Flat Rock and adjacent outcrops.

Hydrographic Survey

Gippsland Ports has captured hydrographic survey of the navigable channels at the entrance to Anderson Inlet since 2009. This data is of a high standard but primarily limited to the navigable channels present at the time. Survey has been captured annually from 2009 to 2020 with gaps in 2010, 2014 and 2015. The survey extends generally from offshore of the tidal delta, through the primary navigation channel and approximately 4km within the Inlet (to Navigation Buoy No. 5).

Additional survey in May 2019 and November 2020 surveys were extended at the request of DELWP to include the areas offshore of the Surf Beach (May 2019 & 2020) and the channels within Anderson Inlet (2020). The May 2019 survey included photogrammetry of the beach along the Inverloch shoreline and Point Smythe. The May 2019 hydrographic survey did not include the navigation channels which were captured in December 2018 and 2019. The 2020 survey captured the nearshore zone of the Surf Beach and the western half of the entrance, including sandbars.

Survey has been collected by Gippsland Ports using single beam survey equipment.

Bathymetric survey of the channels within Anderson Inlet is available from hydrographic charts prepared in the late 1800s through 1910. Hydrographic survey of the channels was captured in 2004 as part of the works completed by Water Technology and again in 2012, 2016, and 2020 by Gippsland Ports using single beam survey equipment. The survey is limited to the navigable channels and some overbank detail where water levels allow.

Venus Bay Offshore

Offshore of the study area beyond the 20m depth limit of the FutureCoast LiDAR there is little data available. The highest resolution bathymetric product available is the GeoScience Australia 250m DEM which was generated in 2005 and updated in 2009, covering all Australian coastal waters.

The extent of bathymetric surveys relevant to the study are shown in Figure 6 and summarised in Table 5.

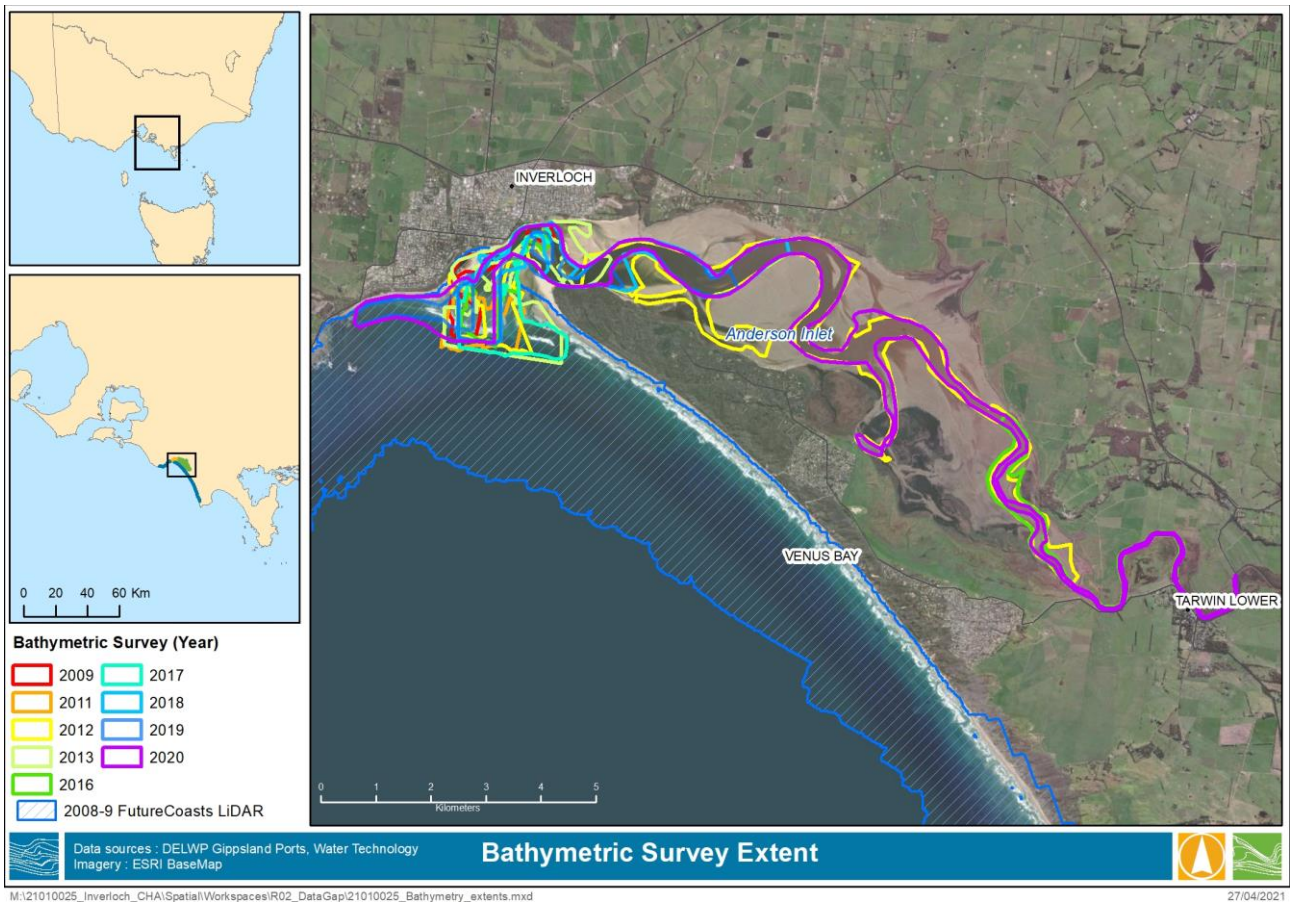


FIGURE 6 BATHYMETRIC SURVEY EXTENTS

TABLE 5 AVAILABLE BATHYMETRIC DATASETS

Extent	Date	Capture	Custodian
Anderson Inlet	26/09/2012 18/09/2016 11/11/2020	Single beam – jet ski	Gippsland Ports
Entrance Channels	2004 12/11/2009 30/06/2011 24/01/2012 01/08/2013 17/11/2016 30/11/2017 06/12/2018 09/12/2019 11/11/2020	Single beam – boat Single beam – jet ski	Water Technology Gippsland Ports
Inverloch Surf Beach	01/05/2019 11/11/2020	Single beam – jet ski	Gippsland Ports

Extent	Date	Capture	Custodian
Entrance Delta	11/11/2020	Single beam – jet ski	Gippsland Ports
Nearshore waters of Study Area (covering all above)	2008-2009	Bathymetric LiDAR	DELWP
Offshore waters of Study Area	2005	Multibeam / Ships of Opportunity / Satellite	GeoScience Australia

Data Gap

The FutureCoast bathymetric DEM provides excellent coverage and resolution of bathymetry through the entrance to Anderson Inlet. However, this dataset is now over 10 years old and captures conditions within the entrance in particular which are significantly different from the current tidal channels and bars.

The technical assessments of the Coastal Hazard Assessment can be completed without updating this data, however significant gains in understanding of coastal processes and the potential impact of adaptation options could be achieved by updating this dataset. A highly engaged community in the Study Area will also be sensitive to the use of outdated data, particularly in this key zone.

The lack of high resolution, survey derived bathymetric data in the offshore waters of Venus Bay limits the ability to identify sources and sinks of sediment which contribute to the coastal processes within the Study Area. Understanding from where sand is coming into the system (i.e. areas of significant change since the FutureCoast LiDAR capture) and where it is available offshore (for example from multibeam backscatter analysis) may impact the ability to accurately predict the impact of adaptation options during the study.

4.2.3 Aerial Imagery

Data Requirements Overview

Aerial imagery is required to support analysis of coastal and estuarine changes in the study area. Comparison of vegetation extent and type may also assist in interpretation of coastal processes and quantification of coastal sediment movements and long term change of the shoreline through beach and vegetation analysis.

Summary of Available Data

A good suite of aerial imagery is available for the Inverloch region, with imagery of the entrance available at least once per decade between 1950 and 2006 and at least biannually from 2006 through to 2020, as presented in Figure 7.

The VCMP Citizen Science Drone Program data project has also captured aerial imagery on a more frequent temporal scale since inception in 2018, with imagery of Surf Beach collected every 6-8 weeks.

A list of the aerial imagery collated for the project is presented in Table 6.

Data Gap

Historic aerial imagery of the whole study area coastline, especially towards Cape Liptrap is more limited. Full coverage of the study area is available in 1950, 1979, and 1991, with full coverage then available from 2006 onwards during South Gippsland Shire photographic runs. The periodic extent of data collection is presented in Figure 7. Satellite imagery does not provide the resolution required to assess historic beach change on this coast and cannot be used to fill the gaps. The less frequent imagery of the whole coast prior to 2006 is a

significant gap, however the data available in 1950, 1979 and 1991 is sufficient to assess historical coastline change for this area of the study.

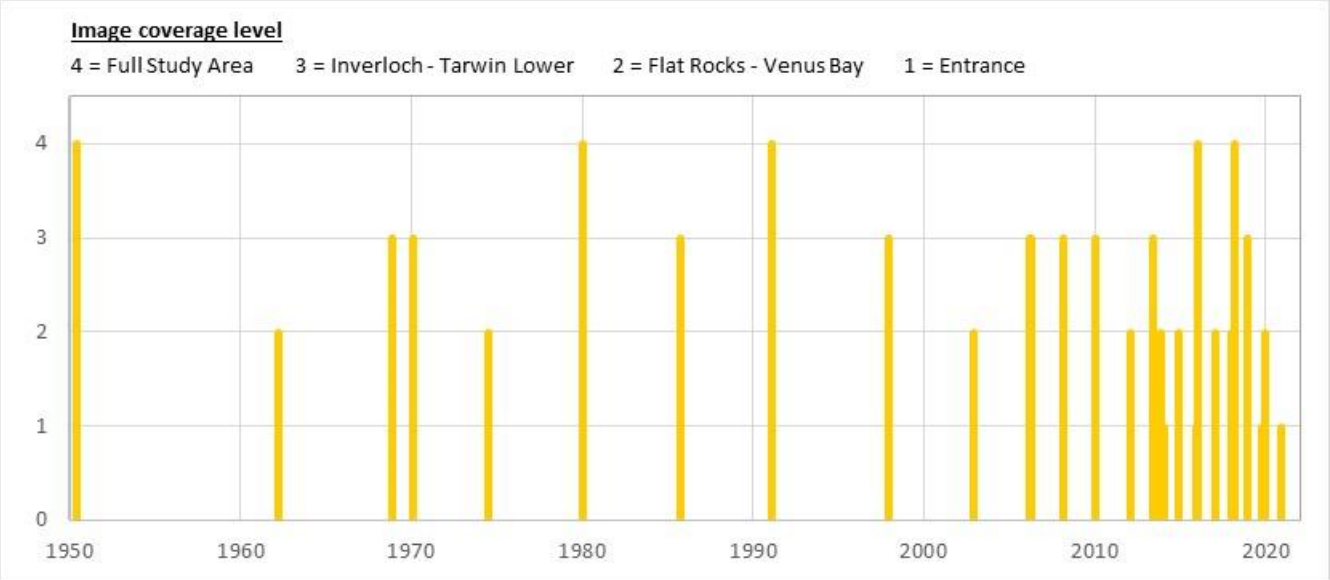


FIGURE 7 AERIAL IMAGERY CAPTURE AND EXTENT

TABLE 6 AVAILABLE AERIAL IMAGERY DATASETS

Data	Date	Custodian	Format
Inverloch-Liptrap 1950	24/04/1950	DELWP	Black and White Scanned Aerial Photo Mosaic
Inverloch 1962	16/03/1962	DELWP	Black and White Scanned Aerial Photo Mosaic
Inverloch 1968	3/11/1968	DELWP	Colour Scanned Aerial Photo Mosaic
Inverloch 1970	7/01/1970	DELWP	Black and White Scanned Aerial Photo Mosaic
Inverloch 1974	31/05/1974	DELWP	Colour Scanned Aerial Photo Mosaic
Inverloch-Liptrap 1979	14/12/1979	DELWP	Colour Scanned Aerial Photo Mosaic
Inverloch 1985	8/09/1985	DELWP	Black and White Scanned Aerial Photo Mosaic
Inverloch-Liptrap 1991	3/01/1991	DELWP	Colour Scanned Aerial Photo Mosaic
Cape Paterson	1/12/1997	DELWP	Colour Scanned Aerial Photos
Inverloch & Pound Creek 2002	16/11/2002	Water Technology	Colour Scanned Aerial Photo
Inverloch 2006	4/03/2006	DELWP	Single-frame digital Aerial Photo
Bass Coast 2006	22/03/2006	DELWP	Single-frame digital Aerial Photo
Sth Gippsland 2006	22/03/2006	DELWP	Single-frame digital Aerial Photo
Sth Gippsland 2008	18/02/2008	DELWP	Single-frame digital Aerial Photo
Wonthaggi 2009	13/12/2009	DELWP	Single-frame digital Aerial Photo
Bass Coast 2012	22/01/2012	DELWP	Single-frame digital Aerial Photo
Anderson Inlet	05/2013	Gippsland Ports	Single-frame digital Aerial Photo

Bass Coast 2013	5/11/2013	DELWP	Single-frame digital Aerial Photo
Anderson Inlet	01/2014	Gippsland Ports	Single-frame digital Aerial Photo
Bass Coast 2014	9/11/2014	DELWP	Single-frame digital Aerial Photo
Anderson Inlet	11/2014	Gippsland Ports	Single-frame digital Aerial Photo
Anderson Inlet	12/2015	Gippsland Ports	Single-frame digital Aerial Photo
South Gippsland 2015	14/12/2015	DELWP	Single-frame digital Aerial Photo
Bass Coast 2015	17/12/2015	DELWP	Single-frame digital Aerial Photo
Bass Coast 2017	4/01/2017	DELWP	Single-frame digital Aerial Photo
Bass Coast 2017	26/12/2017	DELWP	Single-frame digital Aerial Photo
Anderson Inlet 2018	17/01/2018	Gippsland Ports	Single-frame digital Aerial Photo
Sth Gippsland 2018	7/02/2018	DELWP	Single-frame digital Aerial Photo
Bass Coast 2018	1/12/2018	DELWP	Single-frame digital Aerial Photo
Anderson Inlet 2018	12/2018	Gippsland Ports	Single-frame digital Aerial Photo
Anderson Inlet	10/2019	Gippsland Ports	Single-frame digital Aerial Photo
Bass Coast 2019	17/12/2019	DELWP	Single-frame digital Aerial Photo
Anderson Inlet	11/2020	Gippsland Ports	Single-frame digital Aerial Photo

4.3 Geology and Geomorphology

4.3.1 Geology

Data Requirements Overview

Geology and geologic interpretation data will be required to identify variations in geologic settings within the study area and classify discrete coastal sub systems and landforms as well as identify variations in the stratigraphy and composition of cliff, shore platform and dune formations in the study area.

Summary of Available Data

A significant volume of available data has been reviewed and summarised by Environment GeoSurveys in the Inverloch Coastal Resilience Project's (ICRP) Coastal Geomorphology Study. Figure 8, from the Geomorphology study, presents an overview of the main geology types of the Study Area.

Relevant previous studies reviewed:

- Bird, E.C.F. (1993). The Coast of Victoria – the shaping of scenery, Melbourne University Press
- GHD (2018). Inverloch Coastal Protection Options - DRAFT Advice Letter Report to Department of Environment, Land, Water and Planning, Bairnsdale
- Rosengren (2019). Inverloch Coastal Resilience Project – Coastal Geomorphology, Geomorphological Values, prepared for South Gippsland Conservation Society
- Silva (2021). Andersons Inlet Evolution and Surf Beach Erosion, Griffith Centre for Coastal Management

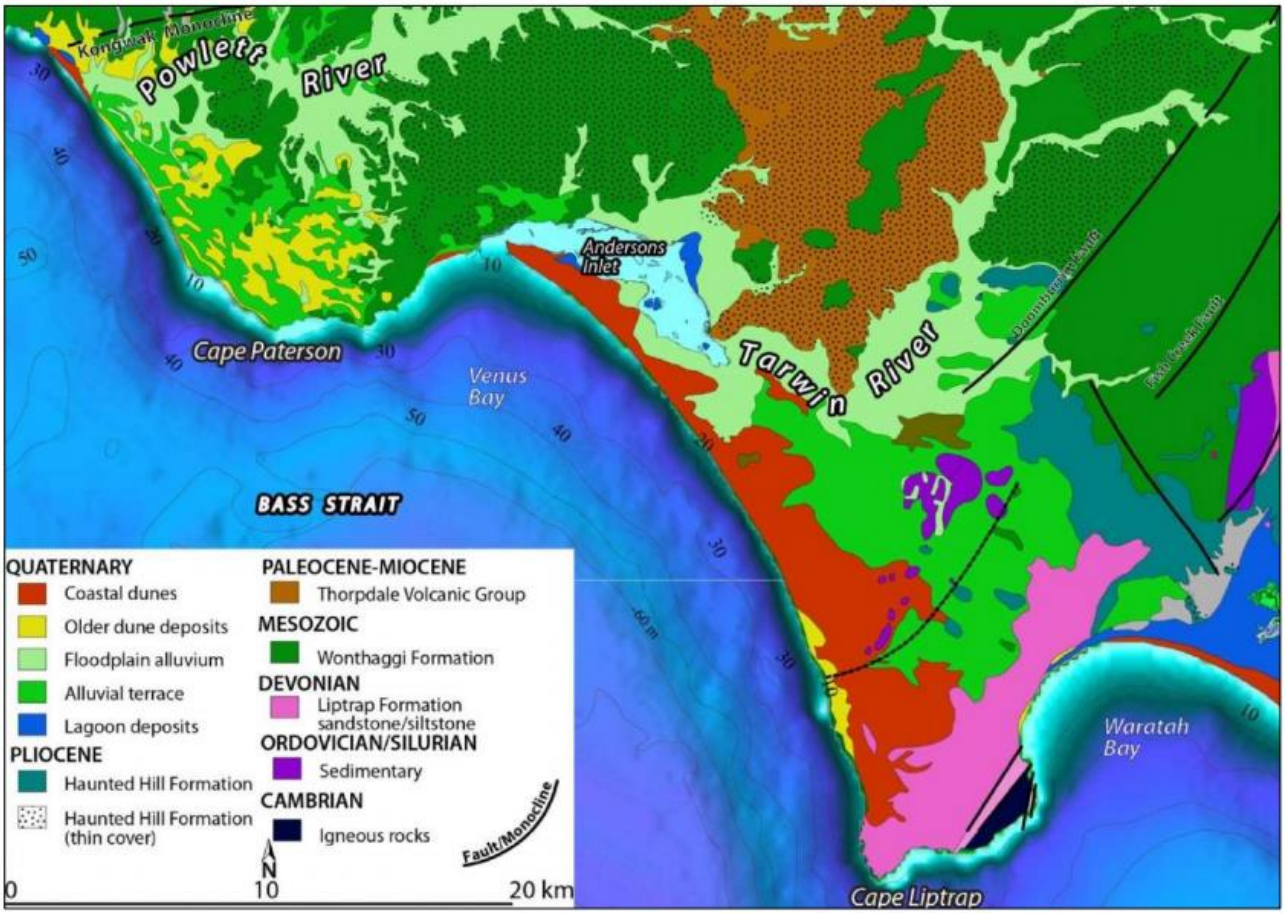


FIGURE 8 STUDY AREA GEOLOGY (ROSENGREN, 2019)

Data Gap

The underlying geology within the entrance at Anderson Inlet may be a limiting factor in how the entrance can evolve under different oceanographic and climate scenarios. It is known from observations that a rock outcrop is present off Point Norman which is intermittently exposed depending on the entrance configuration.

However little more is known regarding the outcrop such as how deep or where it extends. This is a significant gap in information and filling this gap would enhance the understanding of how the entrance channels and sand bars can evolve and what limitations on the entrance migration exists. The gap is not critical to the outcomes of the study but would assist in understanding the limits to erosion at the entrance.

4.3.2 Geomorphology

Data Requirements Overview

Interpretation of the geomorphology of the study area will be required to establish the broad geomorphic processes that have shaped and reshaped the study area coastline, interpret the study area coastline's response to past changes in sea level, and identify sources and characteristics of littoral and fluvial sediments.

Summary of Available Data

Previous assessment of the geomorphology of the Inverloch Region coastline have been conducted and an array of data collated. The following data have also been identified for this study:

- Geomorphological descriptions of the area,
- Desktop and field assessment and ground truthing along the coastline.
- Field observation of the cliff sections around the study area
- Historical conditions of the coastline.
- Information on the Anderson Inlet entrance, including recent channel survey, beach change and coastline analysis.
- Activity maps showing annual areas of treatment of Spartina weed in Anderson Inlet.

Aerial obliques images and video of the coastline was collected during the inception phase of this project to assist with geomorphological studies.

Relevant previous studies reviewed:

- Smythe, G.D. (1848-49). Survey of the Coast from Cape Paterson to Cape Liptrap - Two Inches to the Mile with rivers, creeks, lakes, marshes swamps scrubs, plains and ranges within one days work of coast. Public Records Office Victoria microfiche CS14.
- Department of Mines (1909). Memoirs of the Geological Survey of Victoria (E.J. Dunn, F.G.S., Director): Report on the Lower Powlett, Cape Paterson, and Inverloch Quarter Sheets with maps and plates by W.H. Ferguson. No. 8. Issued by W. Dickson, Secretary for Mines, under the authority of the Hon. Peter McBride, M.P., Minister for Mines.
- Bird, E.C.F. (1993). The Coast of Victoria – the shaping of scenery, Melbourne University Press.
- Vantree (2000). Inverloch Foreshore Coastal Process Assessment, Report prepared for Bass Coast Shire Council.
- Water Technology (2016). Geomorphic & Ecological Investigation between Western St and Cape Paterson-Inverloch Road, Inverloch March 2016. Report Prepared for Bass Coast Shire Council.
- Gwyther, B. and Barton, J. (2018). Ayr Creek Lagoon Investigation and Options Analysis. Prepared for Bass Coast Shire Council.

Data Gap

There is limited understanding of the sources and sinks of nearshore and beach sediment in the entire coastal compartment between the eastern end of Cape Paterson and Cape Liptrap. While this gap is considered significant, it will not limit the ability to undertake coastal hazard assessments. However, filling the data gaps will improve the certainty of the outcomes of any such study.

A significant gap of quantifiable data exists regarding the change in coastline and entrance channels at Anderson Inlet. Whilst survey data of the channels is provided by Gippsland Ports, there is a lack of large scale and concurrent data regarding the volume of sand banks within and offshore of the entrance. This gap is considered significant and whilst assumptions and qualitative or partial calculations can be made to estimate the volumetric change of the entrance, in-filling this data gap will improve the ability of the study to understand the change at the entrance and more fully assess adaptation options along this coastline.

Availability of vertical profiles (bore logs) of subsurface geology across the site is limited which restricts the understanding of the shoreline and backshore resilience and sensitivity to change. The geology can be inferred from the LiDAR and imagery however the age and depth of sand along the Surf Beach section is unknown.

There are numerous coastal protection structures at Inverloch which have been built to prevent erosion of the coastline landward. An accurate history of the construction of these structures would be beneficial and provide additional confidence in the comparison of shoreline positions from historical imagery.

4.3.3 Sedimentology

Data Requirements Overview

Characterisation and analysis of sediment samples will be required to compliment the understanding of the movement of sediment along the coastline and as input into numerical modelling assessing sediment transport and erosion potential.

Summary of Available Data

Sediment sampling has been completed at Inverloch as part of several University research programs and previous studies, including those by the SGCS. The location of samples available are shown in Figure 9. Samples have been collected at the water line and at the back of the beach. Samples collected are generally surface or shallow (<0.5m depth) sub samples. Also included in the figure are additional sampling locations (red dots) to supplement the available data which are to be completed as part of the existing study scope. Green stars indicate where further sediment samples could enhance the study but are outside the scope of the existing study due to safety and access concerns.

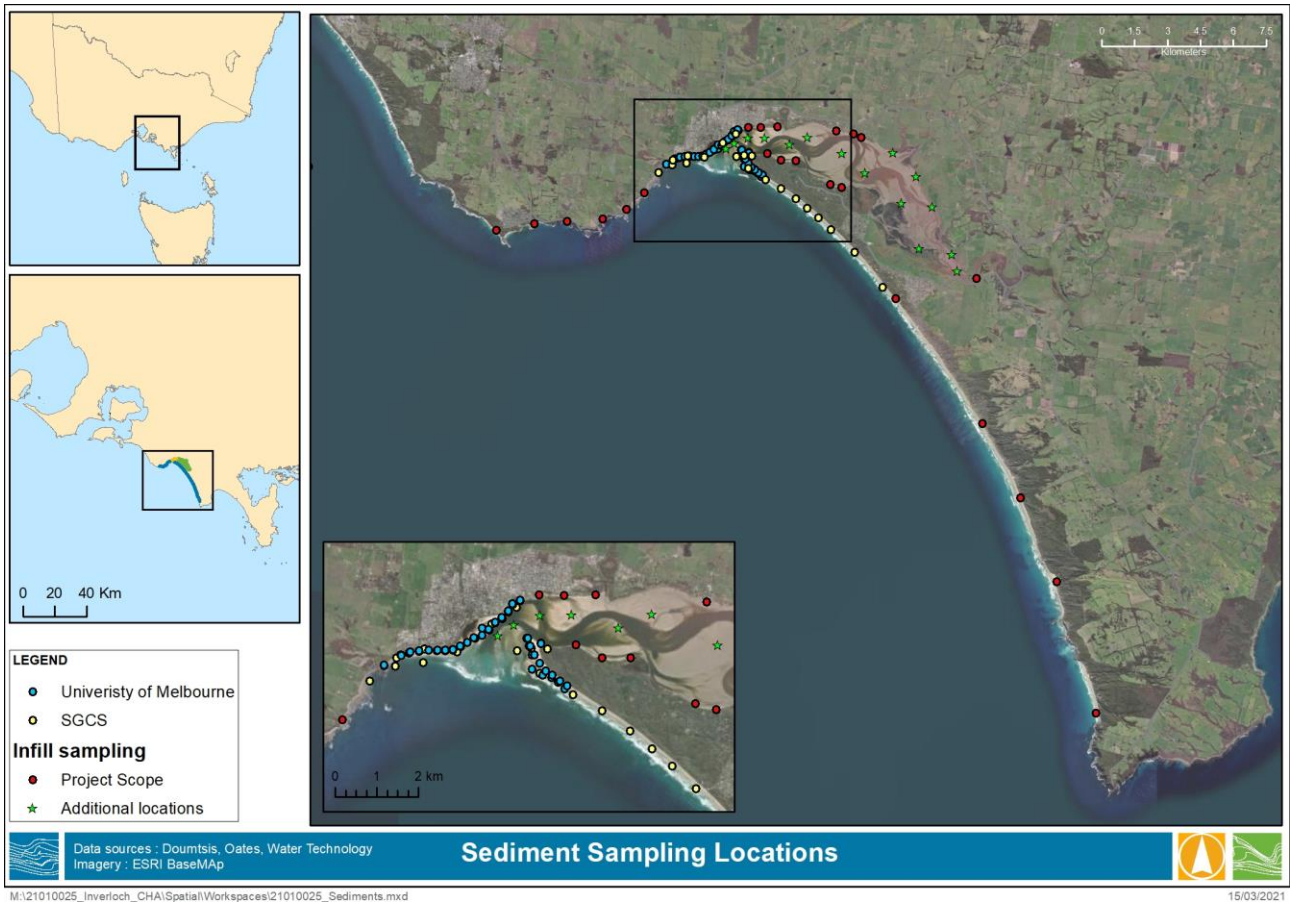


FIGURE 9 SEDIMENT SAMPLING LOCATIONS

Relevant previous studies reviewed:

- Li, L. (2000). Holocene Sea Levels and Related Environmental Changes in Anderson Inlet, Victoria, Australia. Thesis submitted for a Doctor of Philosophy degree, University of Melbourne

- Oates, A. (2019). Ecological Values of the Inverloch and Point Smythe Coastal Dune System. Report prepared for the South Gippsland Conservation Society, 2019. (Oates Environmental Consulting Pty Ltd).
- Doumtsis (2020). Beach Dynamics in Response to Varying Boundary Conditions: The Role of Rocks & Tidal Deltas. Prepared as part of a thesis for the Masters of Geography Degree, University of Melbourne

Data Gap

Additional information regarding sediment size, composition and sources is missing from the geographical extents of the study area. Samples from the pocket beaches between Cape Paterson and Flat Rocks will be collected by the study team around the locations noted in Figure 9, however limited public access to the eastern extent at Cape Liptrap will hinder the collection of sediment in this area. Although this is a significant data gap, it will not hinder the deliverables for the study and sensitivity analysis can be completed to assess a range of potential sediment sizes for erosion assessments.

Similarly, data pertaining to sediment size, age and characterisation within Anderson Inlet and the entrance is limited. Options are being assessed to collect sediment data within Anderson Inlet and on the sand bars, however, particularly within the entrance, access safety is a significant impediment to overcome. Whilst the missing data here is a significant data gap, it will not hinder the deliverables for the study and sensitivity analysis can be completed to assess a range of potential sediment sizes for erosion assessments.

Analysis of sediment characteristics offshore to allow for comparison to that onshore would assist in defining potential sources and sinks of coastal sediments. Divers or long lead grab samples would be required to collect sediments in depths of 2-10m.

4.4 Oceanographic and Coastal Processes

4.4.1 Wave Data

Data Requirement Overview

Long term wave climate data is required to support sediment transport modelling of longshore and cross shore sediment dynamics and to estimate wave setup and run-up components of coastal inundation hazards and extreme event analysis.

Summary of Available Data

Historically, measured wave data has not been readily available in Victoria outside data captured by the Port of Melbourne at Point Nepean. Project-based measurement has been completed by various private and public bodies, such as for the Wonthaggi desalination plant, however data records cover a limited timeframe and spatial period.

Wave data has been captured by the VCMP at a point offshore of Inverloch and Wilsons Promontory for since December 2019. This data is complimented by other VCMP data captured since 2019 across Bass Strait which will be used to validate wave modelling.

Offshore wave climate information can also be sourced from a number of global and regional wave reanalysis models. These models are operated by a variety of national and international research organisations, including the Bureau of Meteorology and CSIRO, discussed further in Section 4.4.4.

Data Gaps

The wave data measured at Venus Bay and Wilsons Promontory is provided as a timeseries of significant wave height, peak and mean wave period and peak wave direction. The raw data from the wave loggers provide surface displacement variance, which can be used to establish the frequency spectrum measured. This provides additional information by separating the waves generated by more local wind (wind seas) from waves generated by distant storms (swell waves). Classification of this can improve the model calibration, particularly where long period swells are at a differing direction to local storm winds.

However, wave climate data for the Venus Bay shoreline and within Anderson Inlet can be developed by standard wave model hindcasting techniques or global wave reanalysis model outputs as part of the detailed modelling to be undertaken in the CHA.

No measured wave data is available within the entrance or within Anderson Bay. Additional local wave data at these locations would benefit the assessment and calibration of numerical models, however the lack of measured data will not limit the ability to undertake coastal hazard assessments.

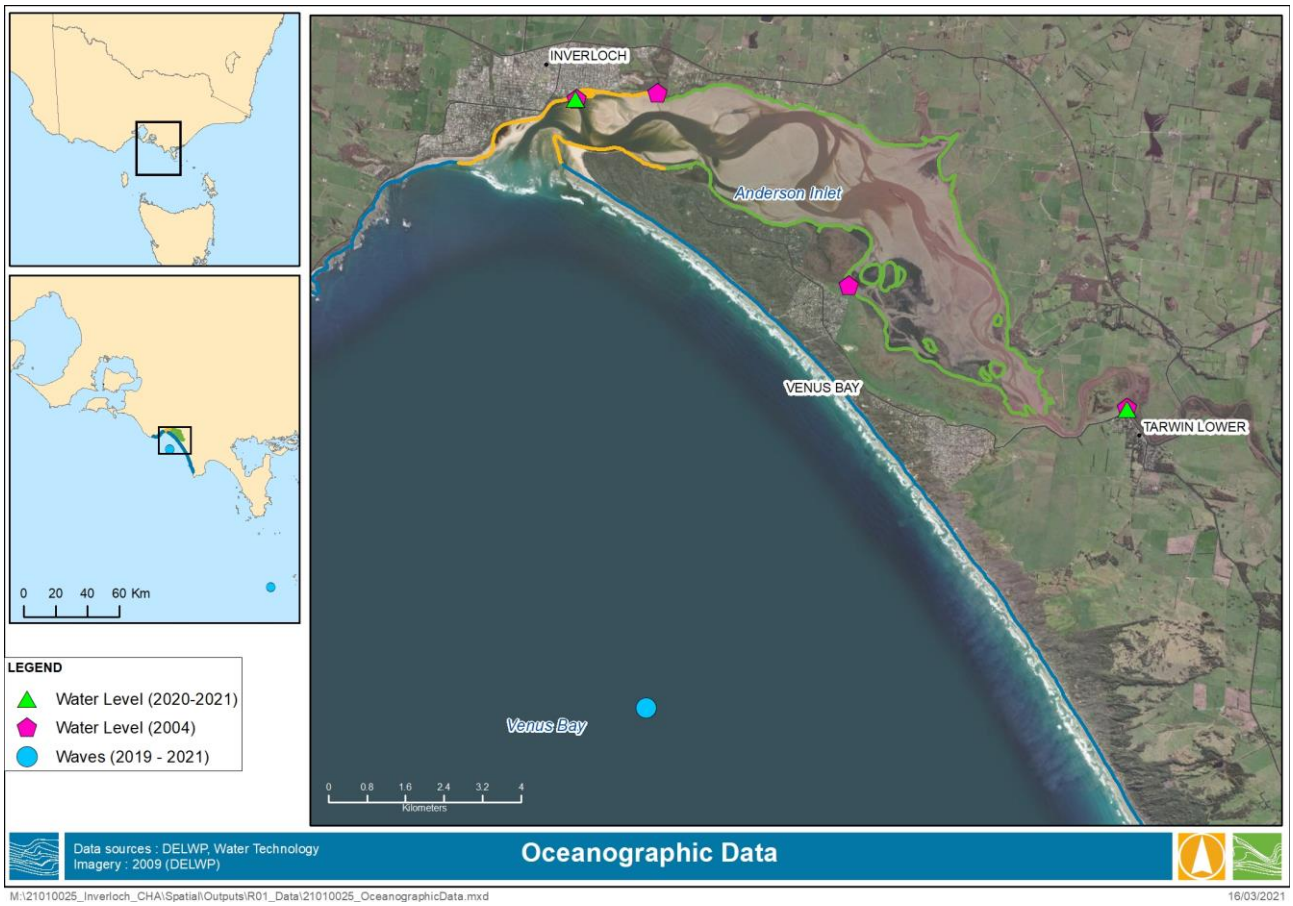


FIGURE 10 OCEANOGRAPHIC DATA

4.4.2 Water Level and Current Data

Data Requirement Overview

Measured tide and storm surge water level data and information will be required to calibrate numerical modelling and support assessments of coastal inundation hazards.

Measured current data can support the understanding of sediment transport and hydrodynamics of the estuary and be used to calibrate numerical models.

Summary of Available Data

Measured water level data is available in the study area from the following sources and shown in Figure 10:

- Lower Tarwin Flood Study, 2004: 6-8 weeks of water levels measured at the following locations:
  - Inverloch Jetty
  - Mouth of Screw Creek
  - Tarwin Lower Jetty
  - Venus Bay Jetty
- Tarwin and Inverloch jetties, captured by Gippsland Ports as part of RaSP (2019-present)

More distant measured water level data to be used in modelling is available via the BoM Australian Baseline Sea Level Monitoring Program (ABSLMP) which has been collecting high quality measured water levels at Portland, Lorne and Stony Point in Victoria since 1991.

As with the wave data, coastal water levels and currents have been measured along the Victorian coast for various private and public projects, such as the Wonthaggi desalination plant. These datasets are of limited value given the spatial distance to the Inverloch CHA Study Area and limited temporal period of data capture.

Relatively reliable sea surface information can also be sourced from a number of global and regional climate reanalysis models. These models are operated by a variety of national and international research organisations, including the Bureau of Meteorology and CSIRO, and are discussed further in Section 4.4.4.

Data Gaps

Measured water level is not available outside of Anderson Inlet. Measured water levels have been collected at the Inverloch jetty within the vicinity of the entrance, however calibration of water levels at the open coast model will not be possible without measured data. It will be assumed that calibration of water levels at Inverloch infers calibration of water levels along the open coast.

Extreme water level data for the Venus Bay exposed shoreline and within Anderson Inlet can be appropriately developed by standard numerical modelling techniques with the existing data as part of the detailed modelling to be undertaken in the CHA.

Measured current data within the study area could not be identified, however calibration of ocean models to the Inverloch Jetty water level gauge will ensure the hydraulic capacity of the entrance is calibrated correctly and the lack of measured current data within the entrance channel will not limit the ability to undertake coastal hazard assessments.

4.4.3 Historic Coastal Processes

Data Requirement Overview

Background historical data and information relating to coastal processes, sediment transport/dredging and shoreline responses to artificial structures will be required to guide and support coastal process assessments in the study area.

Summary of Available Data

Background historical information has been identified and assimilated into the database. A number of previous coastal process study reports contain a review and analysis of historical coastal process issues in the study area including specifically the erosion at the Surf Beach.

Reports completed prior to the change in entrance dynamics in 2012 consistently consider the coastline along Inverloch and along the Surf Beach to be stable or accreting. The dynamic nature of the entrance channels and bars are noted, however large-scale change is not considered a threat as hydrographic charts and aerial imagery dating back 20 and 50 years respectively indicate a consistency in the shoreline position around the town. This is supported specifically at the Surf Beach by a number of investigations and peer reviews of investigation as part of the development application for the new Inverloch Surf Life Saving Clubhouse, beginning 2009.

Assessment of erosion and coastal processes since the increased dynamism of the entrance have focussed on finite locations along the coast to identify feasible mitigation or coastal protection options at hotspots.

Relevant Reports reviewed:

- Vantree (2000). Inverloch Foreshore Coastal Process Assessment. Prepared for the Bass Coast Shire Council
- BCSC (2003). Inverloch Foreshore Reserve: St Kilda Street to Ayre Creek Foreshore Master Plan. Published by Bass Coast Shire Council, Wonthaggi.
- Water Technology (2010). Inverloch Life Saving Clubhouse CHVA. Prepared for the Inverloch Life Saving Club
- Oldfield (2010). Peer Review of Water Technology's report. Prepared for Department of Sustainability and Environment
- Cardno (2010). Peer Review of Water Technology's report. Prepared for Department of Sustainability and Environment
- Oldfield (2011). Abbott St, Inverloch Foreshore Reserve: An Investigation into Management Options. Prepared for Bass Coast Shire Council
- Zavadil (2015). Memo: Anderson Inlet sediment dynamics pilot study – literature review. A Memo prepared for the West Gippsland CMA by the School of Geography, Melbourne University
- GHD (2018). Inverloch Coastal Protection Options - DRAFT Advice Letter Report to Department of Environment, Land, Water and Planning, Bairnsdale.
- Silva (2021). Andersons Inlet Evolution and Surf Beach Erosion, Griffith Centre for Coastal Management

The creation of the VCMP has driven more detailed assessment of the coastal processes at Inverloch with a number of studies reaching or approaching conclusion as the CHA begins.

Detailed photogrammetric analysis from the available series of historical aerial photographs has been undertaken through the entrance through projects supported by the VCMP and the SGCS. This type of analysis has also been completed for the Point Smythe coastline (Figure 11).

Reports and papers prepared as part of the VCMP which have been reviewed are as follows:

- Rosengren (2019). Inverloch Coastal Resilience Project – Coastal Geomorphology, Geomorphological Values, prepared for South Gippsland Conservation Society
- SGCS (2020). Inverloch Coastal Resilience Project – Inverloch Beach Monitoring Report, August 2018 – June 2020. Prepared by the South Gippsland Conservation Society
- SGCS (2021). Inverloch Coastal Resilience Project – Inverloch Beach Monitoring Report, July – December 2020. Prepared by the South Gippsland Conservation Society
- Doumtsis (2020). Beach Dynamics in Response to Varying Boundary Conditions: The Role of Rocks & Tidal Deltas. Prepared as part of a thesis for the Masters of Geography Degree, University of Melbourne
- Leach (2021). Identifying oceanographic conditions conductive to coastal impacts on temperate open coastal beaches and the importance of empirical data. Draft Paper prepared for publication
- Leech (2021). <Modelling paper, reference to be updated on preparation>

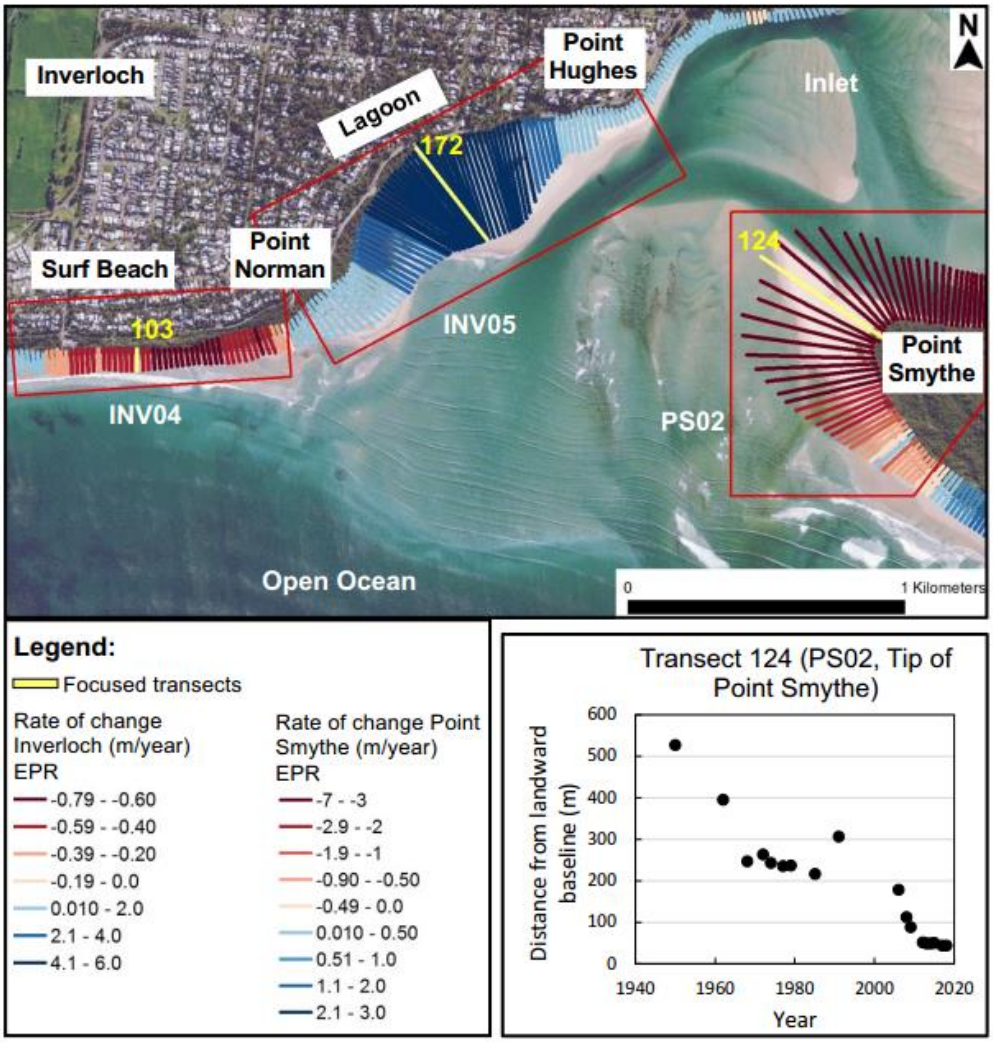


FIGURE 11 RECENT SHORELINE CHANGE AT INVERLOCH (FROM DOUMTSIS, 2020)

Data Gaps

Quantification of the longshore sediment transport has not been completed previously within the study area in any detail. The modelling studies completed as part of the CHA will provide this data.

There is a lack of data (sediment analyses and bathymetry) to identify potential sources and sinks of nearshore and beach sediment in the coastal compartment between Cape Paterson and Cape Liptrap. While this gap is considered significant, it will not limit the ability to undertake coastal hazard assessments. Filling of this gap would however reduce the uncertainty in the outcomes of any such investigation.

4.4.4 Model Data

Data Requirement Overview

Hindcasting numerical models (i.e. using a model to simulate the past conditions) will be used to generate timeseries of water level and wave conditions within the study site. Analysis of these timeseries will be used to generate estimates of extreme storm tide and wave events.

Global model outputs will be used in a downscaled model of Bass Strait and Anderson Inlet to capture the local features of the study area.

Summary of Available Data

A number of global wave models are available which hindcast wave data for the period from 1979 through to the end of 2020. The wave models are based on a limited number of peer reviewed and tested numerical schemes, with adjustments made for model resolution, centring, and parameters, depending on the focus of the model.

Review of wave models which have higher resolution around Australia has concluded that the CSIRO-BoM product CAWCR is most suitable for this project. The CAWCR model provides wave and wind climate data on a 4 minute (approx. 7.5km) grid scale and a one-hour timestep.

A suitable source for hindcast modelled water levels has been identified as the CSIRO ROMS model. This model provides timeseries of water levels along the coast of Australia and is considered suitable for adding any long period residual that may be present along the south coast of Australia.

Data Gaps

A change in model scheme in 2013 may have resulted in a stepped change in modelled wave conditions within Bass Strait which correlates to around the same time as the change in entrance dynamics at Inverloch. Further assessment of the global wave model is required to establish if the change in wave conditions is due to model schematisation and thus not a driver of change at Inverloch, or if the change in schematisation is purely coincidental with unfortunate timing and there was a real stepped change in conditions within Bass Strait at this point in time.

Understanding this stepped change is quite critical in understanding the drivers of the change at Inverloch. Assessment is currently underway at the University of Melbourne to determine this. The impact of these studies may have an impact on the modelling methodology adopted by the CHA study.

4.5 Environment and Climate

4.5.1 Meteorological Data

Data Requirement Overview

Long term hydrologic data (i.e. rainfall and stream flow) is required to support riverine and urban modelling projects which feed into the CHA and will be used to generate extreme terrestrial flood levels and flows.

Long term meteorologic data (i.e. wind and pressure) is required to supplement coastal wave and hydrodynamic modelling, providing a validation of global model data.

Summary of Available Data

Rainfall data is available from the BoM at the Inverloch station located northwest of the town since 1884. Similarly, long record stations (albeit with some data gaps) are located further north at Outtrim, Wonthaggi and at Tarwin Lower. A rainfall station was established at Pound Creek in 2007, with additional stations present at Koonwarra, Stony Creek, Cape Liptrap and Fish Creek. More recent data available from the BoM includes 6 min radar grids of rainfall.

Measured meteorological data is available from the BoM at Wonthaggi (1968 - present), Pound Creek (2007 - present) and Yanakie (2013 – present). Wind and pressure data is also available at the Wilsons Promontory Lighthouse station, although this is known to be impacted by updrift winds due to the position and height of the station.

Data Gaps

Whilst there is a lack of long term wind and pressure data available near the coastline or Anderson Inlet, the available data will be sufficient for the study, combined with wind simulated by the CSIRO global wave model described in Section 4.4.4 to capture offshore meteorological conditions for coastal modelling.

4.5.2 Climate Change Predictions

Data requirement Overview

The Coastal Hazard Assessment will assess hazards on the coast both now and into the future. Stepped increases in mean sea level to be considered in the study have been provided by DELWP. In addition to this, changes to rainfall and wind conditions will be considered in the prediction of future conditions.

Summary of Available Data

The BoM and CSIRO produce a biennial “State of the Climate” summary, with the most recent summary released in 2020. This report details the observed changes in Australia’s climate and surrounding oceans. Of particular note, there has been a decline of rainfall in the southeast of Australia since the late 1990s which is predicted to continue and will contribute to continuing decline in streamflow. Whilst total rainfall has reduced, storms are becoming more intense with greater rainfall over a short period, resulting in short duration flash flooding.

The State of the Climate notes that sea levels are continuing to rise around Australia, however it is noted that the scope of works as directed by DELWP is to consider mean sea level of “Present Day” and increases on Present Day of 0.2m, 0.5m, 0.8m, 1.1m, and 1.4m.

The Victorian Government partnered with CSIRO in 2019 to undertake high resolution climate modelling to provide an updated set of climate projections for Victoria. The outcomes of the works include a 5km resolution dataset of climate projection ranges and an excel summary chart which provides a summary of predicted wind

speed changes in the Gippsland region. Projected wind speed changes vary from a *reduction* in annual average wind speed of between 6% and 9% (RCP4.5, Lower Bound) to an *increase* of 4% to 5% (RCP8.5, Upper bound). The median of the projections for 2030 through 2090 indicate a slight (0 to -1%) reduction in wind speed from two different climate scenarios through to the end of the century is probable.

Relevant Reports reviewed:

- Timbal et.al. (2016). Climate Change Science and Victoria. Bureau of Meteorology Research Report 014
- Clarke, J.M., et al (2019) Gippsland Climate Projections 2019. Prepared by CSIRO

Data Gaps

The project scope has directed that Present Day mean sea level and rises above Present Day mean sea level Present Day be considered. Present Day mean sea level is not defined at Inverloch. This needs to be established for the Study Area.

Detailed climate modelling of Gippsland by CSIRO indicates close to negligible change in local, land based annual wind speeds due to climate change in future scenarios, however wind directions are not included in the high-resolution assessment. Likewise changes to offshore wind condition storminess is not considered. A prediction of more intense rainfall events could indicate a potential for more intense wind in these events however this has not been quantified.

The University of Melbourne is currently undertaking a detailed numerical modelling study as part of the VCMP to assess the implications of climate change scenarios on wave conditions along the Victorian coastline. This data will be sought as it becomes available.

4.6 Catchment and Stormwater

Data Requirement Overview

Urban and rural runoff into Anderson Inlet and the open coast will pose hazards to the local coastline and may impact the options and impacts of adaptation measures. Outfalls of the urban catchment network at the shoreline can become a hazard with SLR and extreme water levels causing back flow into the catchment.

Flood modelling will be completed as part of the study to ensure these inputs to the coast are considered in the study, and as such data for catchment and urban modelling is required.

Summary of Available Data

A detailed flood study was completed for the Tarwin River by Water Technology in 2004. The flood study model is unavailable, however much of the input data and background knowledge is available through the report and from staff at Water Technology. Updated flow data is available on the Tarwin River at a number of flow gauges maintained by DELWP.

A number of flood impact assessments have been carried out by Water Technology for developments on the Screw Creek floodplain and modelling completed here is available for the study.

Stormwater network details for Inverloch township are being sourced from the Bass Coast Shire Council. Pipe network data including pit levels, pipe size and inverts will be used in stormwater modelling, along with coastal outfall details.

Data Gaps

Gauged flow data is not available for the smaller catchments of Pound and Screw Creeks, however the hydrology can be scaled down from the Tarwin River given the close proximity and similar catchment characteristics.

4.7 Groundwater

Data Requirement Overview

The distribution and hydraulic properties of the stratigraphy in the region are required to prepare the hydrogeological conceptual model and predict changes to significant receptors. To consider the shallow processes, seasonal information on groundwater movement (including saline intrusion), rainfall recharge and maps of potential coastal acid sulphate soils (CASS) is required.

Summary of Available Data

Available data include published geological map sheets (e.g. Warragul 1:250,000 geology), the SRW Gippsland Groundwater Atlas, the Southern Rural Water Groundwater Hub website, Tarwin GMA Local Management Plan, Visualising Victoria's Groundwater, the Bureau of Meteorology (including Explorer and GDEAtlas), Water Measurement Information System, maps of CASS and existing reports including the SKM report of groundwater at Anderson Inlet.

Data Gaps

The findings could be improved using drillhole information near the coastline to determine depths to groundwater, which ranges from 20 – 75 m, and salinity for which little measured data exists.

Increasing the resolution of the distribution of CASS and significant receptors, including groundwater dependent ecosystems and other Beneficial Uses such as groundwater extractions can also lead to improved project outcomes, however sufficient data is available to generate a Concept Model of groundwater for the study area suitable for the CHA.

4.8 Asset and Infrastructure

4.8.1 Coastal Protection Structures

Data Requirement Overview

The location and age of coastal protection structures within the Study Area will be used to inform the historical coastal processes and used in the modelling to indicate a hard shoreline.

Summary of Available Data

Limited technical historical data has been identified regarding the construction of coastal protection structures. Anecdotal information can be gleaned from review of aerial imagery and historical photo archives such as those from the State Library of Victoria. A number of photographs reviewed show significant coastal walls along Inverloch in the early 1900s.

More recent coastal protection structures built at Inverloch such as the rock walls around the jetty, Toys Backwater, the Cape Paterson Road and the Surf Club will have more detailed information such as Detailed Design and As Constructed drawings and coastal process investigations.

The DELWP Coastal Assets Condition Assessment is currently underway assessing the condition and location of all coastal protection structures around Victoria. The information from this study is required for input to the CHA.

Data Gaps

The location, dimensions and condition of coastal protection structures within the study area will be required to ensure any erosion predictions consider these structures. It is assumed this will be made available from the DELWP Coastal Assets Condition Assessment.

A timeline of construction of coastal protection structures would enhance the review of coastal geomorphology through aerial imagery, however the extent of impact is limited.

4.8.2 Coastal Levees

Data Requirement Overview

Coastal levees have been constructed within Anderson Inlet to prevent the egress of storm surges and high tides onto farmland. The location, height and condition of these levees will be used to assess coastal inundation risks in the Study Area.

Summary of Available Data

A detailed assessment of the coastal levees within the South Gippsland Shire Council around Anderson Inlet has been completed in 2019 by Water Technology. This comprehensive study provides a full asset database of the levee location, height and condition.

Data Gaps

Not all levees were physically inspected for the condition assessment, and as such broad assumptions regarding condition were made, however these will be sufficient for use in the coastal hazard assessment. Where critical levees are identified in the project, an inspection should be carried out and assumptions updated during the project.

4.8.3 Civil Infrastructure

Data Requirement Overview

Identification of civil infrastructure such as roads, utilities and buildings will be required to consider the impact of hazards and the assets that adaptation options will seek to protect within the Study Area.

Summary of Available Data

The stormwater pipe network data has been sourced from the Bass Coast Shire Council for Inverloch. This data is currently being reviewed for completeness. A stormwater drainage network is not present at Tarwin Lower or Venus Bay.

The road network and cadastral dataset for the Study Area is available via the Vic Data website.

Coastal paths and community assets along the foreshore have been identified through site inspections, aerial imagery and Council communications. GIS layers will be established for the project indicating these assets.

Coastal assets such as the Inverloch jetty and pier, Mahers Landing boat ramp, Tarwin Lower jetty and the Venus Bay jetty have been identified, however little additional information such as construction details or

maintenance is available with exception of the data provided by Gippsland Ports for the Inverloch and Lower Tarwin jetties.

Coastal access stairs have been identified through site inspections and aerial imagery and are noted.

Data Gaps

Utility data is not available from the Councils and must be sourced separately from the network operators. This data is not critical for undertaking modelling, however is required to assess adaptation options and hazard risks.

4.8.4 Cultural and Heritage Features

Data Requirement Overview

Identification of sites and features of significant cultural or heritage value will be required to consider the impact of hazards and the assets that adaptation options will seek to protect within the Study Area.

Summary of Available Data

The *Amazon* shipwreck is located on the Surf Beach at Inverloch, and in the intertidal zone closer to Flat Rocks. Part of the shipwreck has been exposed during the recent erosion on Surf Beach near Wreck Creek and a study completed by Heritage Victoria along with excavation and cataloguing of the part of the wreck on the beach.

Data Gaps

No response was received from efforts to contact the Bunurong Land Council Aboriginal Corporation to establish sites of Aboriginal cultural significance. If sites are not identified they cannot be considered for protection by adaptation works and may be impacted by any adaptation works if their location is within the zone of influence.

Additional site of heritage significance outside of the Amazon were not identified. There may be additional sites which should be considered for protection by adaptation works.

5 GAP ANALYSIS

A gap and knowledge identification process was undertaken whilst collating and reviewing the available data. The following outstanding data, information or knowledge gaps are summarised below in Table 7 with recommendations made in Section 5.1.

Ranking of the significance of the data or knowledge gap recognises that the absence or incompleteness of different types and sources of information may have varying impacts. A significant gap could limit the ability to proceed with a detailed assessment within the study area.

TABLE 7 DATA GAP ANALYSIS

Knowledge Area	Gap Identified	Relative Importance/Consequence	Scope required to Fill Gap	Overall Gap Rating
Topography, Bathymetry & Imagery	Recent high resolution and contiguous topographic survey of the study area	The Future Coast data set is 10+ years old and significantly out of date for entrance area. The Future Coast data provides the only high resolution, continuous coverage topographic representation of the whole study area. Assumptions will be required in numerical modelling setup to estimate the surface elevation through entrance which may impact accuracy of results and ability to calibrate models to high level.	Concurrent topographic and bathymetric LiDAR, flown with high accuracy on a day with minimal wave activity and low flow through Tarwin River to reduce data gaps	Medium
	Entrance bathymetry	The entrance channels can be surveyed with relative ease, and have been completed many times by Gippsland Ports, however survey of the sand bars are more difficult due to access and safety. Capturing survey of the bars will enable some (in area of coverage) volume changes (with respect to Future Coast) to be calculated within the entrance area, enhancing the understanding of the entrance dynamics. A “Present Day” environment can be established to more accurately model adaptation options under the current topography, increasing understanding and potential perception of work relevance to the public.	Survey of entrance channels at high tide to include as much of bank edges as possible. Survey of sand bars via photogrammetry or LiDAR at low tide to include as much of bank edges as possible. An alternate option could include survey of the channels and banks at high tide using shallow craft such as jet skis or remote operated survey boats. Gippsland Ports conducted survey which covered some of the entrance bars in late 2020, however focussed on the western side of the entrance.	Medium
	Recent high-resolution survey offshore to identify sand sources and sinks	Understanding the availability of sediment to the system will assist with developing the conceptual model of coastal processes, numerical modelling and adaptation options. An assumption will be required regarding the availability of sediment to the system without additional data.	Multi-beam survey could be used to generate full offshore coverage for comparison with Future Coast DEM. Alternatively, single beam profiles could be captured for comparison with targeted multibeam limited to areas where change is observed.	Medium
	Aerial imagery between 1991 and 2006	No evidence of lead into the period of significant change in the entrance. Infilling imagery will help to identify any patterns which are unknown	Images have been sourced during Data Assimilation An assumption that the beach change modelling works adequately based on experience and model skill will be required without this data being sourced.	None

Knowledge Area	Gap Identified	Relative Importance/Consequence	Scope required to Fill Gap	Overall Gap Rating
	Beach profiles across Study Area	Cross shore models simulating short term beach erosion cannot be calibrated without pre- and post storm profile data. An assumption that the model provides suitable outcomes will thus be based on experience and modelling skill without this data being sourced.	Beach profiles could be speculatively captured along the beach south of Point Smythe with hope that a significant storm occurs in a period soon enough to enable inclusion in modelling. The cost of beach profiling is relatively low, however the potential beneficial use of the survey could also be quite low.	Medium
Geology & Geomorphology	Extent and depth of rock outcrop offshore of Point Norman	Will help define any hard barriers or obstacles influencing movement of entrance channels	Borehole drilling around known extent of outcrop to identify extent, or ground penetrating radar (GPR) capture of entrance.	Medium
	Particle grain size distribution data to parameterise numerical sediment transport models	Will affect the sediment transport estimates, in particular, storm erosion and movement of sediment through the entrance. Without additional data assumptions can be made based on the available sediment data. Lack of sediment data in the upper reaches of the Inlet will result in more general assumptions of storm erosion along the shore.	Some sediment is to be collected and analysed as part of the project scope however due to safety and access issues, it will be difficult to collect sediment from the tidal delta bars and to the south of the study area.	Low
	Radio carbon dating of sediments to establish age and origin	Will assist in understanding geomorphology and potential sources of sediment. Some data is available to infer origin, however greater levels assumptions will be required based on existing data.	Sediment for analysis can be collected at the same time as sample collection for PSD. Analysis can be completed by local laboratories.	Low
	Limited understanding of the sources and sinks of nearshore and beach sediment in the coastal compartment between Cape Paterson and Cape Liptrap	Understanding these sources and sinks will improve the ability to understand future coastal sediment transport and erosion responses. Assumptions regarding sediment supply will be required without additional data.	Multi-beam survey could be used to generate full offshore coverage for comparison with Future Coast DEM. Alternatively, single beam profiles could be captured for comparison with targeted multibeam limited to areas where change is observed.	Medium
Oceanographic & Coastal Processes	Understanding of sources and sinks in Study Area (as above)	Assumptions will be made in modelling regarding sand supply to system which will influence coastal process modelling	Detailed, and potentially more regional assessment on sources and sinks of sand.	Medium

Knowledge Area	Gap Identified	Relative Importance/Consequence	Scope required to Fill Gap	Overall Gap Rating
	The position of the "Baseline" shore is difficult to define within the entrance and along the Inverloch shoreline without widespread and up to date topography to identify mean sea level or the high water mark. However even with this data, the Baseline position of the shore at Inverloch in particular is complicated by the significant rapid fluctuation.	Setting the Baseline is key to establishing from where coastal erosion begins. Whilst the Baseline shore can be established from available data such as aerial imagery or the FutureCoast DEM, firm agreement and buy in from all Stakeholders is required to ensure outcomes of the study are accepted.	If using the existing coastline, survey of the existing coastline is required. If using existing coastal protection structures, survey of these structures is required. Confirmation of the shoreline is required from stakeholders.	High
	Global wave model schematisation changes are coincident with the beginning of the change in entrance coastline. It is currently unknown if the change in wave conditions in the global model are due to schematisation or real climate and meteorological conditions.	Hindcast models will be used to simulate change in coastal processes and predict future conditions. Ensuring hindcast conditions are representative of actual (rather than model influenced) change is importance for understanding the entrance dynamics and carrying out the adaptation assessment. Erroneously assuming changes are due to real climate and meteorological change instead of model schematisation may lead to a misunderstanding of the entrance dynamics.	Assessment of input wind and climate drivers, comparison to measured data and other modelled hindcast data. Alternatively, source different input options to local models.	Medium
	Measured water levels offshore	Determination of storm tides along the open coast requires a calibrated tide and storm surge model hindcast. The lack of measured data offshore will result in the offshore model needing to be extended within Anderson Inlet to the Inverloch jetty. Additional model time may be required to simulate the intertidal channels and bars.	Deployment of a water level logger offshore.	Low
	Spectral analysis of measured wave data	An improved calibration of the numerical wave model by comparing model data to the spectral components will ensure wind and swell wave components in the wave area accurately simulated and used int eh coastal process modelling. A poorly calibrated swell and sea state may lead to inaccuracies of sediment transport rates due to a misstep in wave direction.	Determination of wave spectra from raw wave data	Medium

Knowledge Area	Gap Identified	Relative Importance/Consequence	Scope required to Fill Gap	Overall Gap Rating
	Measured wave data within Anderson Inlet	Determination of wave conditions within Anderson Inlet requires a calibrated model hindcast. The lack of measured wave data within Anderson Inlet will result in the assumption that the model is correctly resolving wave growth and decay across the bars and channels of the Inlet.	Deployment of a wave logger within Anderson Inlet	Low
Environment & Climate	Lack of long term (>14 years) measured wind or pressure data within Study Area	Storm surge within the Inlet may be affected by local wind direction and speed. Lack of long term data limits determination of accurate design wind conditions specific to the site. Regional wind station data, and regional design wind conditions will be used for extreme events, compared with global model hindcast data. This is an approach used before and is generally acceptable.	None – the consequence is low and it is not possible to infill the data gap.	None
	Definition of “Present Day” mean sea level	Climate change scenarios to be considered include increasing mean sea level above Present Day sea level. Present day sea level is likely to be above 0m AHD as this was established based on mean sea level at 1968.	Assessment of high resolution and accuracy nearby water levels (i.e. Stony Point ABSLMP monitoring gauge) and agreement on “Present Day” sea level by DELWP.	Medium
	The impact of climate change on wind direction has not been studied for the Gippsland coast in any detail	Changes to the wind and resulting wave directions offshore of the Study Area could result in significant changes to coastal processes. Sensitivity testing will be required to establish a range of potential future coastal process changes	A detailed climate change study assessing global circulation and many other factors would be required to fill this gap. This is not feasible as an input to the current study.	Low
Catchment and Stormwater	Stormwater network data has just been received from BCSC. This data is being reviewed for gaps for stormwater network modelling in Inverloch	Missing data, particularly of pipe network in the coastal zone will impact accuracy of storm tide inundation works	Surveyed pit and pipe network data, particularly within the coastal zone	High
	Gauged flow data on smaller creeks (Wreck, Ayr, Screw and Pound Creeks)	Modelling of flood flows with storm tide events would normally use calibrated flood flows, however given the small size of these catchments compared with flood tide influence, consequence is negligible	None	None

Knowledge Area	Gap Identified	Relative Importance/Consequence	Scope required to Fill Gap	Overall Gap Rating
Groundwater	No analysis, or capture, of data specifically for coastal aquifers in the study area has been completed.	Interaction of groundwater with surface water systems and rising sea levels may be significant, especially for agricultural areas. Groundwater levels have been known to impact buried infrastructure assets within the study area. However, the project scope is for a conceptual review of groundwater only and a more detailed groundwater study may be required if the CHA indicates a significant risk to groundwater is present.	A conceptual groundwater model is to be developed as part of the study. The outcomes of the groundwater assessment may suggest additional scope be included to assess the impacts of climate change, however at this stage there is sufficient data for the desktop conceptual review to be undertaken.	Low
Asset and Infrastructure	The location, dimension, and condition of coastal protection structures within the study area	Erosion and inundation modelling needs to consider existing coastal protection structures	This data being collected as part of existing DELWP contract. The condition assessment and mapping of assets within the Study Area should be prioritised if data has not yet been collected.	High
	Utility data such as power and gas lines are provided by utility network provides rather than local councils.	Impact of erosion or inundation will need to take into account critical services such as power and water. Adaptation options may also be driven by the need to protect these assets.	GIS layers and/or updated survey of assets is required from the utility agents. Fees may be payable to retrieve this data.	High
	Sites of cultural significance sites are unknown	Sites cannot be considered for protection if they area unknown and ensuring adaptation options do not harm significant sites cannot be achieved if their location is not disclosed to the study team	Response from Bunurong LC	Medium
	Heritage mapping	Sites cannot be considered for protection if they area unknown and ensuring adaptation options do not harm significant sites cannot be achieved if their location is not disclosed to the study team	Mapping layers from Heritage Victoria	Medium

5.1 Recommendations

High and Medium data gaps as identified in the assessment are presented in Table 8. A rating of potential cost to fill the data gap, indicative of Low – less than $5,000 ($), Medium – between $5,000 and $10,000 ($$) or High – greater than $10,000 ($$$) is provided, along with an effort and time rating to establish which gaps are feasible to infill without risks to project budgets and timeframes.

TABLE 8 GAP PRIORITIES

Knowledge Area	Gap	Cost	Effort	Time
HIGH				
Oceanographic & Coastal Processes	Position of Baseline shore	$	Minimal: workshop, survey	Short – 1-2 weeks
Catchment & Stormwater	Stormwater network details in coastal zone	$	Minimal: survey	Short – 1-2 weeks
Asset & Infrastructure	Details of existing coastal protection structures	n/a	Already being completed by DELWP	Potential for fast-tracking Inverloch
	Utility data	$/ n/a	Minimal, DELWP may be able to source	Dependent on Utilities
MEDIUM				
Topography, Bathymetry & Aerial Imagery	Recent topographic survey of study area	$$$	Considerable given Study Area	Long (>3months)
	Recent full coverage survey of the entrance	$ - $$	Co-ordination of multiple survey teams may be required along with reliance on calm weather and high tides	Short (1-2 days survey) however weather and tide dependent
	Recent survey of offshore waters	$ - $$$	Stepped effort within single beam ($) profiles to identify significant areas of change Multibeam ($$$) to map larger areas in details	Short (single beam) 1-2 days, weather dependent Medium (multibeam) 1-2 months, due to equipment, and processing
	Beach profiles across the study area	$	Minimal	Value highly dependent on weather and second storm for model calibration
Geology & Geomorphology	Extent and depth of rock outcrop offshore of Point Norman	$$$	Either physical works (core logs or excavation) or survey (GPR) in a boat, both of which will be influenced by tidal and weather conditions	Medium (1-2 months): lead in time for planning, equipment and weather for excavation; and Long (2+ months) for mobilisation delays for GPR
	Limited understanding of the sources and sinks of beach sediment in the Study Area	$$	Wider region coastal process assessment, collection of additional survey and sediment sampling and analysis	Long (2+ months)

Knowledge Area	Gap	Cost	Effort	Time
Oceanographic & Coastal Processes	The driver of a step identified in global wave model hindcast data – model or climate influenced	$ Unknown	Assessment of global wind and wave data Source alternative local model boundary inputs	Short (1-2 weeks) Unknown
	Spectral analysis of measured wave data	$	Data analysis / programming	Short (1 week)
Environment & Climate	Definition of "Present Day" mean sea level	$	Data analysis / Agreement	Short (1 week)
Assets & Infrastructure	Identification of sites of cultural significance	none	Medium	Dependent on response from Bunurong LC
	Mapping of Heritage sites	none	Medium	Dependent on response from Heritage Victoria

5.2 Gaps to be filled

High Importance Knowledge Gaps

It is recommended that each of the three knowledge gaps identified as High importance be filled as soon as possible. The data or information required to fill these gaps are of minimal cost and effort and can be collected in a short amount of time with minimal impact on the study timelines.

Medium Importance Knowledge Gaps

The following actions are recommended to infill medium importance knowledge gaps:

- It is recommended that quotes for survey to provide full coverage of the entrance channels and sand bars be sought for the project to establish more accurate cost and timeframes. This data will be of significant value both technically and from a community perspective.
- Collection of beach profiles can be completed for a low cost by a local surveyor. It is recommended that these be completed in hope a significant storm will occur in April.
- Analysis of the measured wave climate from the VCMP buoys should be completed to ensure wave models are accurately resolving wind and sea waves.
- Definition of Present Day Sea Level should be completed and approved by DELWP.
- Analysis of global data inputs to assess stepped change, or identification of an alternative source for local model boundaries.
- Continued efforts to contact Bunurong LC and Heritage Victoria to provide sites of cultural and heritage significance.

Low importance knowledge gaps

In addition to the High and Medium gaps detailed in Table 8, the following low priority gaps are considered "low hanging fruit", i.e. easy to acquire, and should be collected to enhance the study outcomes:

- Collection of surface sediments from entrance sand bars – potentially could be completed whilst surveying entrance bars
- Collection of sediments from within Anderson Inlet – whilst survey vessels are in the water there is potential for additional samples to be collected within the entrance. Alternatively, the SGCS could have volunteers with boat access able to collect samples for analysis.

6 CHA ASSUMPTIONS

The following knowledge gaps have been identified through the Data Assimilation process; however, the gaps are considered impractical to fill in the bounds of the current study. The consequence and assumptions that are required due to the lack of this data are presented in Table 9.

TABLE 9 CONSEQUENCE AND ASSUMPTIONS OF DATA GAP

Data Gap	Consequence	Assumption to be made
Recent Study Area Topography	Any recent (since 2008/2009) changes in land surface outside of beaches captured by VCMP or SGCS data will not be included in inundation or coastal erosion mapping	Topography is as represented in FutureCoast DEM (2008-2009) This includes the exposed tidal banks of Anderson Inlet outside of the surveyed channels
Offshore bathymetry	Changes to the offshore bathymetry and movement of sediment offshore will be unknown. Significant change indicating a source or sink of sand will be unidentified.	Coastal process modelling will assume a limitless supply of sediment to the system Limited sensitivity testing of entrance sources will be undertaken.
Sediment sampling within entrance and Anderson Inlet (assumes cannot be completed in conjunction with recommended bathymetric survey)	Characteristics and source of sediments within the entrance and Anderson Inlet will be unknown. Numerical modelling may over or underpredict sediment movement due to differing characteristics.	Sediments will be assumed to be consistent with other nearby sediment samples
Radio carbon dating of sediments	The age and morphology of dunes landward of Inverloch will be less understood. A more accurate prediction of potential future shorelines will not be possible.	Area will be considered to be the same material as the sediments on the beach, both across the Study Area, and through profile unless additional data shows otherwise
Extent and depth of the rock outcrop at Point Norman	Any disruption to coastal process or channel migration will not be established beyond the observed position of the outcrop.	The outcrop is assumed to be limited to the extent observed in aerial imagery and to the level established by survey or assumptions based on imagery.
Measurement of offshore water level	The numerical Ocean model hydrodynamics will be calibrated to water levels within the entrance. This is less accurate as requires better entrance survey for the monitoring period than available.	Minor discrepancies in calibration may occur and may be attributed to tidal flow in the entrance rather than the wider Ocean model
Measured waves within Anderson Inlet	The Anderson Inlet model will simulate wind generated waves. Calibration will not be possible.	It will be assumed the model provides a good representation of the wind generated waves within the entrance. Sensitivity testing of bed friction will be used to ensure reliable results.
Climate change predictions regarding wave direction are not available	An established and science based adjustment to wave direction cannot be used to establish predicted change in coastal processes.	Sensitivity testing of wind and wave directions will be used to establish a range of potential future possibilities.

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

APPENDIX A
NEW DATA COLLECTION SCOPE

A-1 Gap Filling

Through the development and review of this report, and discussion with DELWP, works to close knowledge and data gaps identified in the main body of the report have been scoped for quotation, are to be carried out in the near future, or have been closed. This Appendix details the knowledge and data gap status as of the publication of version 3 (v03, Document Status, page 1).

The knowledge and data gaps recommended to be filled are described in Section 5.2.

A-2 High Priority Gaps

A-2-1 Position of Baseline Shore

The position of the Baseline shore along the Inverloch shoreline is required to base inundation, erosion and adaptation measures upon. Continued discussion regarding the shoreline position has determined that there are several options for the Baseline with advantages and disadvantages associated with each delineation. These are presented in Table 10.

TABLE 10 BASELINE SHORE POSITION

Shore position	Advantage	Disadvantage
Mean Sea Level / MHWS / HAT	Allows for a continuous Baseline level through entrance. Can be established from existing data. Provides an accurate description of inundation (at time of survey)	There may be a step change in position of the shoreline based on tidal planes at the border of the Inverloch/wider study region if he Inverloch topography is updated to 2021 levels compared with FutureCoast used in wider region.
Vegetation line from latest Aerial Image	Can be established from existing data. Provides a reasonable estimation of current extent of erosion/coastal impact zone.	Does not provide a known height of a continuous level. Inundation mapping resulting from this “baseline” may be confusing if line is not a set elevation.
Tidal plane based on Future Coast Lidar	Continuous line across whole study area. High resolution and accuracy.	Quite out of date along town. Will provide confusion when overlain with current imagery. Context may be difficult for some members of the public.
Tidal plane based on Propeller data	Available and provides high resolution imagery of coastline at Surf Beach	Photogrammetry extent limited to Surf Beach. Does not remove vegetation to provide ground level.
Tidal plane based on new photogrammetry	Provides complete photogrammetry coverage of Inverloch – would be beneficial for presentation and communication of project outcomes and adaptation options	Will not provide enough detailed ground level data due to tree coverage. Of limited use technically.
Tidal plane based on new LiDAR	Current and accurate description of the full Inverloch town coastline. Imagery will be provided with Lidar which will add value to outputs. Will remove vegetation effects of photogrammetry. Could be combined with survey of entrance bars.	More expensive than feature survey or using existing propeller data.

Shore position	Advantage	Disadvantage
Tidal plane based on feature survey	Identification of type and quality of backshore structures and shoreline. Low cost.	Will need to know where to run the feature survey line – should it be based on imagery? Or develop in situ? Needs more information to fill data gap

The preferred option is to capture LiDAR of the shoreline and establish the Baseline shore at the HAT level.

The HAT (highest astronomical tide) level based on measured water levels at Inverloch is in the order of 1.1-1.2m AHD. The HAT is preferred above MSL (mean sea level) or MHWS (mean high water springs) as inundation and storm erosion may be noted regularly above these levels.

Two costs to collect LiDAR data used to establish the baseline shore are presented in Table 11.

TABLE 11 BASELINE SHORE LIDAR COSTS

Provider	Cost (ex GST)
AAM	$ 12,500.00
AUAV	$ 11,000.00

A-2-2 Stormwater Network Details

The stormwater network details have been provided by Bass Coast Shire Council and are at a level of completeness such that no further survey is required.

A-2-3 Details of Existing Coastal Protection Structures

The data gap regarding the full extent of coastal protection structures, their condition and elevation has not been fully filled with the provision of data from the DELWP Coastal Assets project. LiDAR survey collected to establish the baseline will provide elevation data however will not establish condition or structure. A feature survey and georeferenced photos are required to identify and detail the conditions of the structures.

Feature survey and condition assessment can be completed for $ 2,060.00 ex GST for the Inverloch town coastline.

A-2-4 Utility Data

DELWP is collecting this data from relevant agencies.

A-3 Medium Priority Gaps

A-3-1 Entrance Topography / Bathymetry

A scope and fee for survey of the entrance has been established to establish the channel and bank elevation at the present time. Survey will be carried out using single beam sounders through a combination of jetskis for the channels and offshore areas and on amphibious vehicle which can traverse the channel from Inverloch and survey across the sand bars and Point Smythe. An alternative methodology of using airborne LiDAR for surveying the sand bars has also been investigated and is detailed below in Table 12 with spatial coverage provided in Figure 12.

TABLE 12 ENTRANCE SURVEY DETAILS

Section	Surveyor / Methodology	Cost (ex GST)
Channels, offshore	Gippsland Ports, single beam sounder via jetskis	$ 12,560.00
Sand bars, Point Smythe	Farron Group, single beam sounder via amphibious vehicle	$ 5,000.00 For 2 days in the field, including collection of sediment samples (Section A-4)
Sand bars, Point Smythe	AUAV using airborne LiDAR	$ 21,000.00 Combined with LiDAR survey of the coast to establish Baseline shore as per Section A-2-1
	AAM using airborne LiDAR (Price fluctuated heavily with timeframe. It is far cheaper to coincide with other projects running at the same time, however this would not be in the short term)	$ 16,500 – 33,000.00 Combined with LiDAR survey of the coast to establish Baseline shore as per Section A-2-1

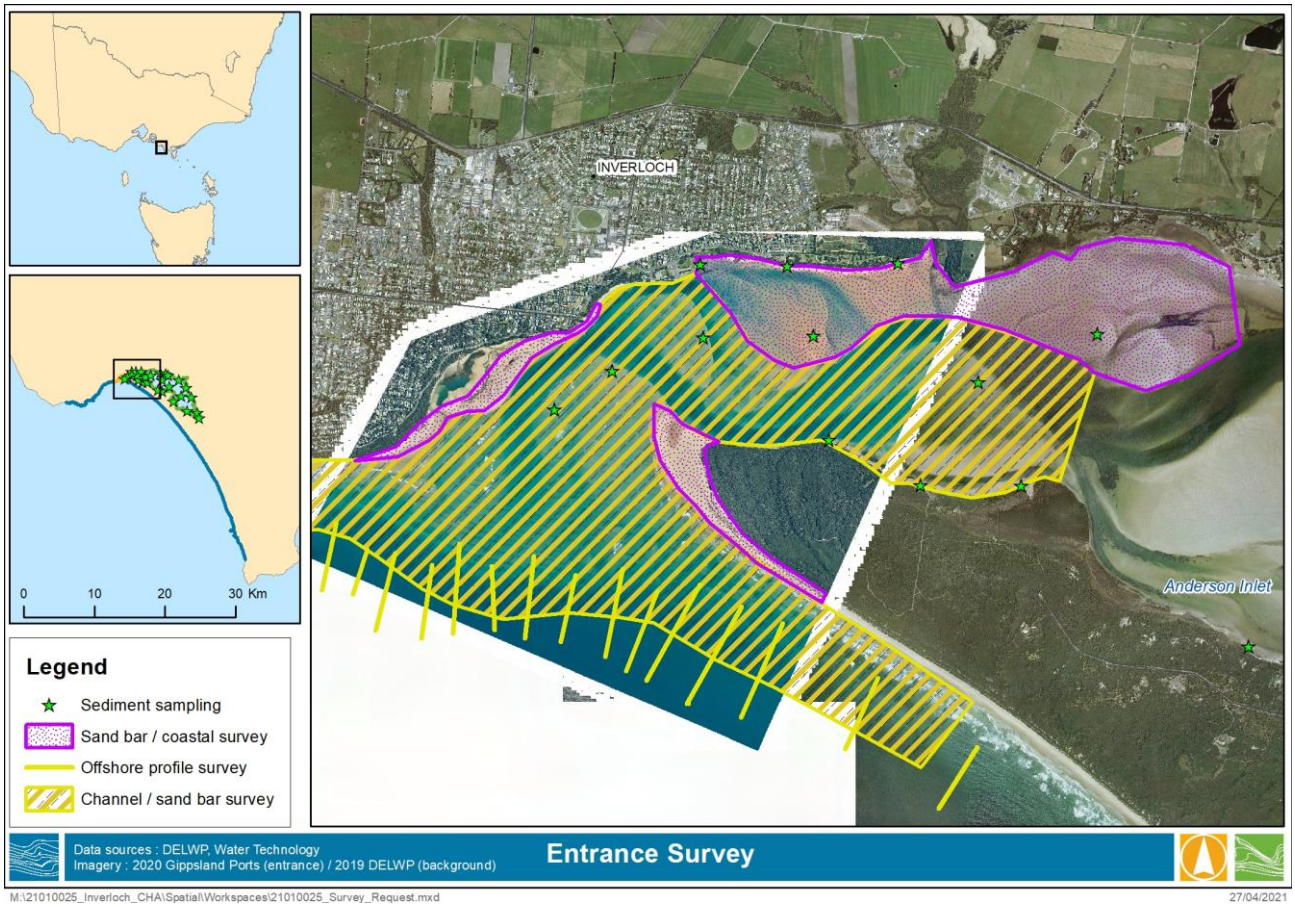


FIGURE 12 ENTRANCE SURVEY EXTENT

An emerging market involves the analysis of satellite derived imagery to determine bathymetric and topographic elevation at the time of the image capture. This was investigated as a potential method of filling this data gap and has the potential to provide both good temporal and spatial coverage. The use of satellite derived elevation requires satellites to capture the study area when there is low to zero cloud cover and (for bathymetric data) when wave action and turbidity in the study are waters are low. The most appropriate image for this at Inverloch is in June or October 2019 which would be suitable for the project given the availability of measured water levels at Inverloch from late 2019. The imagery can be processed to a 2m grid resolution and to a depth of approximately 3m below sea level. Costs for bathymetric and topographic data (to define the level of sandbars and beach) are in the order of $14,000.00 ex GST and thus also comparable with physical survey.

However, the level of accuracy of the vertical data produced by satellite reanalysis is insufficient for the project with a mean error reported as 0.5-1.5m. The horizontal error is also quite large at 1-5m depending on access to Ground Control Points. Given an error of this magnitude, and a depth limitation of 3m below water level (not MSL), the satellite derived bathymetry is not considered an appropriate tool to infill the entrance data gap.

A-3-2 Beach Profiles

Beach profiles to validate storm bite models can be collected by a local surveyor. The 5 beach profiles along Venus Bay will be surveyed prior to and following a storm event to establish the storm bite. Coastal modelling will be validated to these beach profiles.

Beach profiles are nominally located as shown in Figure 13 to allow for speedy access by survey crew. Survey will be collected from 20m landward of the vegetation line to as low as conditions allow. Costs have been provided in to collect follow up beach profiles to assess recovery rates after the storm event, if time allows.

TABLE 13 BEACH PROFILE COSTS

Survey	Cost (ex GST)
Pre-storm	$ 1,500.00
Post-storm	$ 1,500.00
Beach recovery	$ 1,500.00

FIGURE 13 VENUS BAY BEACH PROFILES

A-3-3 Spectral Wave Climate Analysis

Given the calibrated wave modeling data being provided by the University of Melbourne and the VCMP (see Section A-3-5), this is not considered a significant data gap and is no longer required to be filled.

A-3-4 Present Day Sea Level

The Australian Height Datum was established based on approximate mean sea level based on tidal measurements around Australia in 1966-68. Further information regarding AHD can be reviewed here:

https://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/ahdgm/ahd

A number of different methodologies have been considered to establish the 2020 mean sea level relative to AHD which include consideration of a wide range of information such as:

- Satellite derived mean sea level measurements;
- Estimates of global mean sea level rise since 1970;
- Survey accuracy of AHD and LiDAR;
- Locally measured mean sea level rise;
- Tectonic plate displacement; and so on.

All of these have in build uncertainties and margins of error which lead to further complication of precisely what level mean sea level is in 2020. For this reason, a simplified method is proposed:

1. Locally measured water levels at Williamstown indicate an average increase in mean sea level of 2mm/y since 1966. (A measured increase of 2.5mm/y at Stony Point since 1993 is in line with data which indicates an acceleration of the rate of sea level rise since 1990.)
2. 2mm/y between 1966 and 2020 = 2mm/y x 54y = 108mm increase
3. **Mean sea level at Inverloch in 2020 is approximately 0.1m AHD**

A-3-5 Global Model Review

The University of Melbourne, as part of the VCMP, has recently completed a downscaled (300m resolution) wind-wave hindcast model as part of the VCMP which covers the Study Area. This model uses ERA5 winds from Copernicus**,** the European Union's Earth observation program instead of global forecast winds (CSFR) which are used in CAWCR and Wave Watch III applications. The use of hindcast winds such as ERA5 leads to an increased level of accuracy and the issue with global model configuration and step change in storminess described in the main body of this report is removed.

The University of Melbourne is providing this 40-year wave hindcast to the project which will be used to drive sediment transport modelling along the open coast, and as a boundary for the localized entrance model. This dataset has undergone significant calibration and verification, including comparison of spectral properties at the Inverloch wave buoy. Works are part of PhD studies completed by the University of Melbourne and peer reviewed papers and thesis references will be provided in the Inverloch Regional CHA references as they become available.

A-3-6 Heritage Data Gaps

The Bunurong Land Council Aboriginal Corporation (BLCAC) have endeavoured to provide GIS data layers from the Aboriginal Cultural Heritage Register and Information System (ACHRIS) database. Additional ACHRIS layers for Anderson Inlet and Venus Bay may need to be sourced directly from Aboriginal Victoria. DELWP is presently following up with Gippsland Cultural Heritage staff.

Significant colonial heritage studies including historical research and survey have not been undertaken at Inverloch. Whilst there is likely to be unknown sites within the Study Area, there is no further known historical sites to be used or considered within the study.

A-4 Low Priority Gaps

A-4-1 Surface Sediment Collection – Sand Bars

Sediments are to be collected at the points located at the red dots in Figure 9 where possible. Sampling of beach sediments at the eastern extent of the study site may be limited by access.

Samples on the sand bars at the entrance in Figure 9 noted by green stars will be collected during survey of the entrance, detailed above in Section A-3-1, with the use of the amphibious vehicle. The cost of the sediment sampling is incorporated into the cost of the survey.

A-4-2 Surface Sediment Collection – Anderson Inlet

Samples along the shore of Anderson Inlet inaccessible by road noted in Figure 9 will be collected during survey of the entrance, detailed above in Section A-3-1, with the use of the amphibious vehicle. The cost of the additional sediment sampling is incorporated into the cost of the survey.

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

APPENDIX B
NEW DATA COLLECTED

B-1 New Data

This Appendix has been added to detail new data which becomes available following the completion of the Data Assimilation and Gap Analysis. This Appendix will be updated as data becomes available, with a summary of the data and dates received noted in Table 14.

TABLE 14 NEW DATA COLLATED

Section	Dataset	Summary	Date
B-1-1	Shoreline Analysis – GeoScience Australia	Analyses of satellite imagery to establish long term recession rates	April 2021
B-1-2	Seabed Habitat Mapping – Deakin University	Bed classification of the offshore waters in the study area – sediment, reef and mixed	May 2021
Error! Reference source not found.	Vic Roads - Geotech	As constructed and Geotech investigations for works on Bunurong Road, Tarwin River Bridge and Inverloch LSC	May 2021
B-1-4	Beach Profile Survey	Beach profiles at 5 locations along the Venus Bay open coast, collected on 3 occasions between May and June 2021	May – June 2021
B-1-5	Entrance Survey	Bathymetric Survey of the entrance channels, bars and nearshore bed, collected April 2021	May 2021
B-1-6	Anderson Inlet measured water levels	On-going provision of measured water levels at Inverloch Jetty and Tarwin Lower Jetty through the project	December 2021
B-1-7	Tidal Analysis	Tidal analysis and determination of tidal planes by the BoM based on measured and hindcast water levels	September 2021
B-1-8	Coastal LiDAR & Imagery	LiDAR and high-resolution imagery of the coastline between Cape Paterson and Screw Creek	October 2021

B-1-1 Shoreline Analysis

GeoScience Australia has recently released mapping layers showing shoreline erosion around the coast of Australia, based on shoreline position derived from satellite data. A snapshot of the web based mapping data

at Inverloch is provided in Figure 14. The image shows the rate or erosion (red) or accretion (blue) since 1988. Zooming in on the data allows visualization of the individual shorelines, however the satellite which the data is based on is not visible for confirmation of shoreline position. However, the data provides an excellent additional resource and will assist in informing the gap noted in Section 4.2.3 where a lack of aerial imagery, particularly along the open coast prior to 2006 is noted.

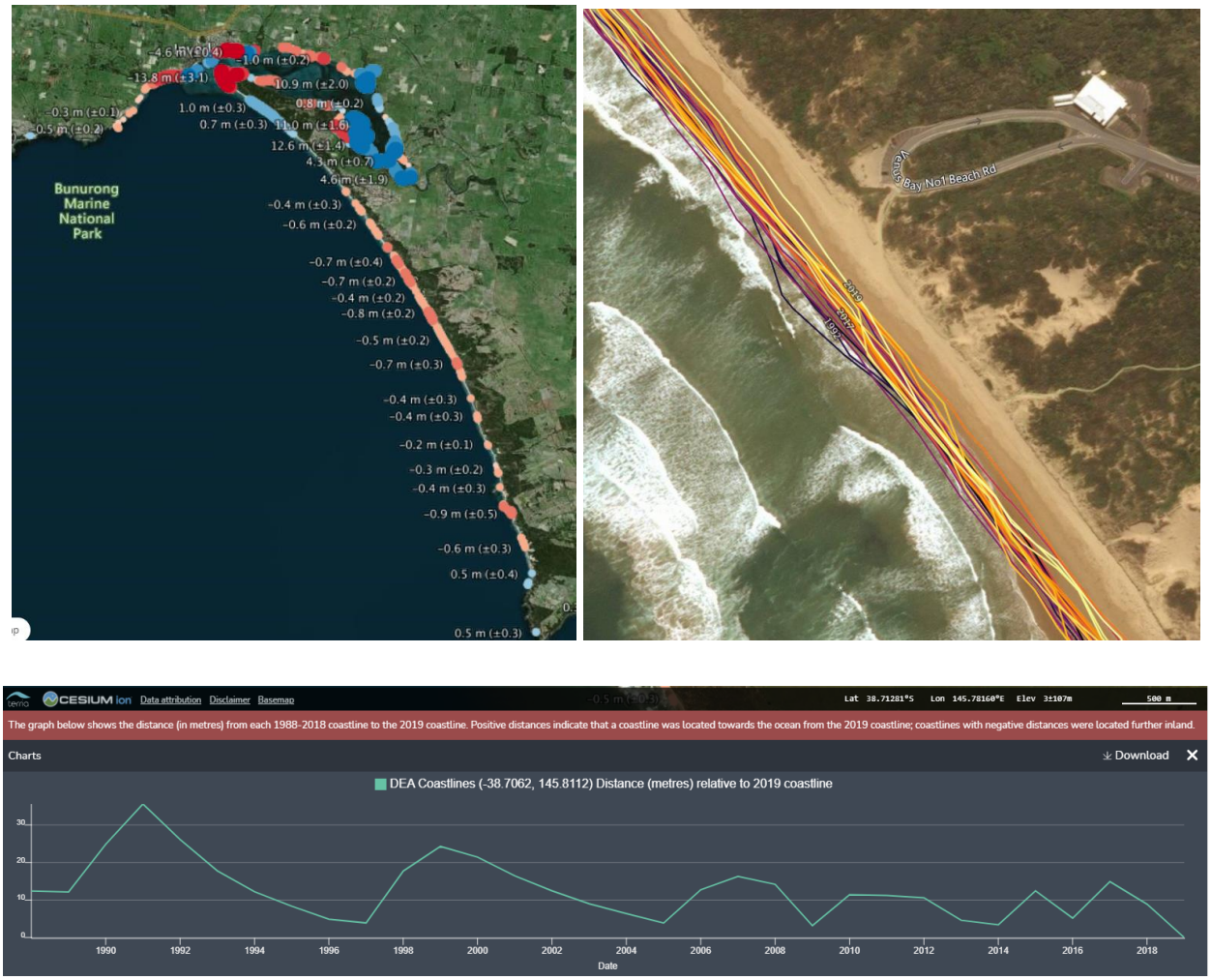


FIGURE 14 GEOSCIENCE AUSTRALIA SATELLITE DERIVED SHORELINE EROSION

B-1-2 Seabed Habitat Mapping

Seabed habitat mapping has been completed offshore of Venus Bay and within Anderson Inlet as part of the Victorian Marine Habitat Mapping Project, funded by the Australian Government through Caring for our Country and the Deakin Central Research Grant Scheme, completed in 2005.

The mapping database provides seafloor structure and biota information for the Study Area and illustrates the mix of sediment and reef in the study area, as shown in Figure 15. This information can be used to surmise information regarding sediment sources and sinks.

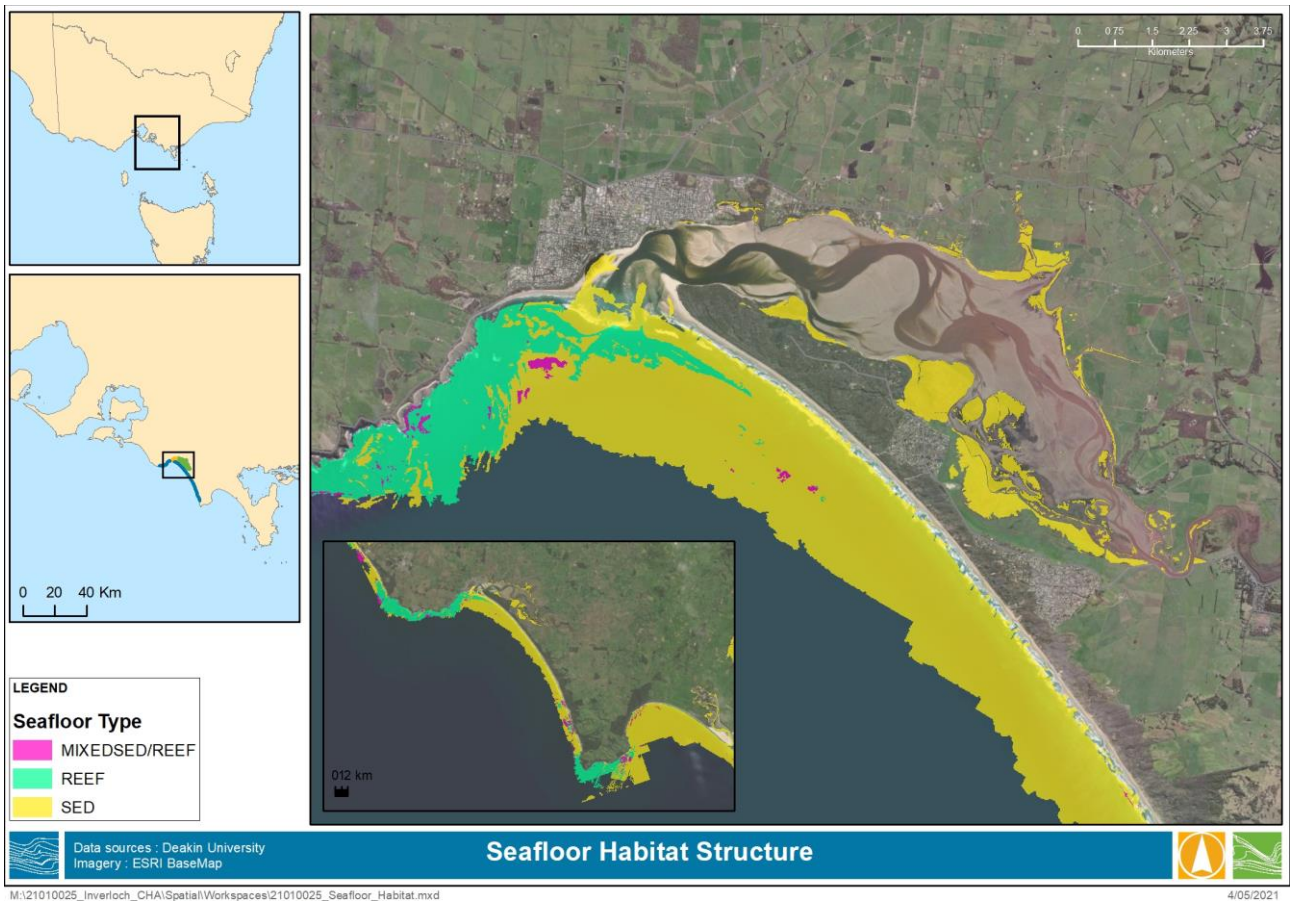


FIGURE 15 SEABED STRUCTURE

B-1-3 Beach Profile Survey

Beach profiles were captured along the Venus Bay open coastline to fill data gap identified during the analysis phase. Beach profiles were captured prior to and after a low level storm event in May 2021 and again in mid June 2021 following a larger storm. The measured wave data and timing of the beach profile surveys, and the change in beach profile where erosion was noted, are presented in Figure 16 and Figure 17.

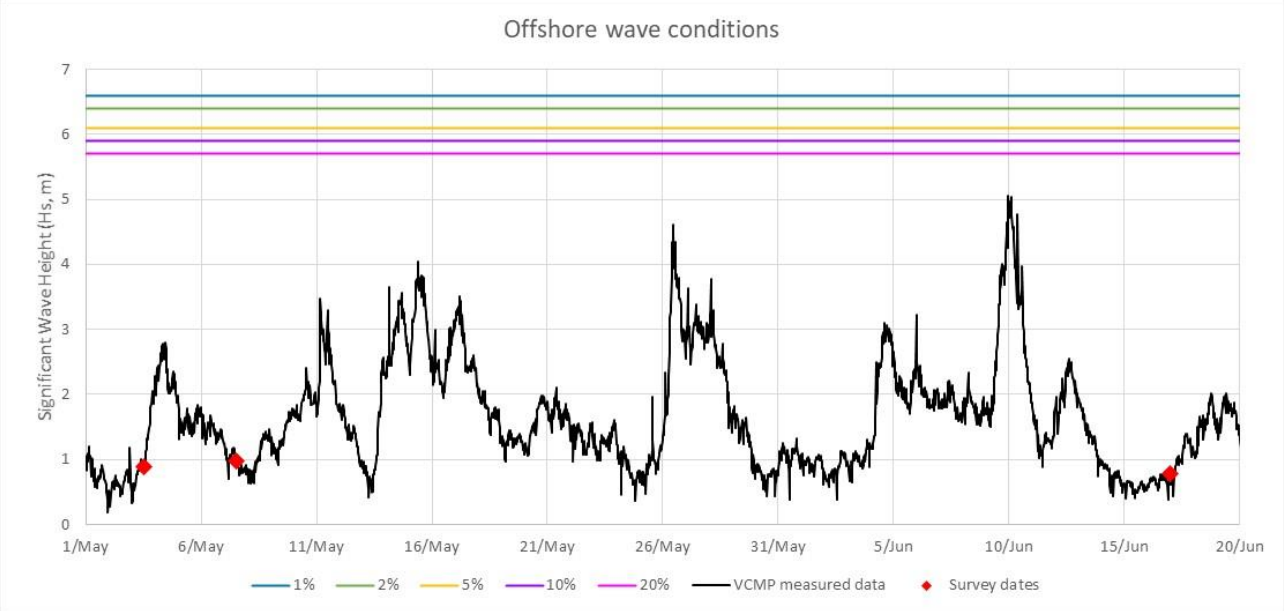


FIGURE 16 OFFSHORE MEASURED WAVE HEIGHT, VENU SBAY, MAY – JUNE 2021

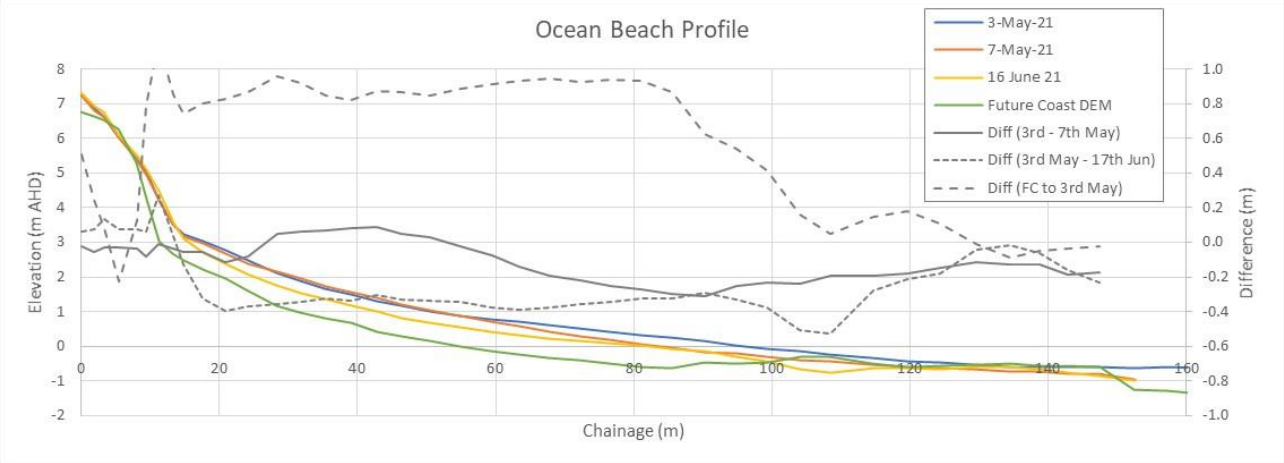


FIGURE 17 VENUS BAY MEASURED BEACH PROFILE, CARPARK NO. 4 PROFILE

B-1-4 Entrance Survey

Coincident survey of the channels, bars and nearshore zone at Surf Beach were undertaken in late April 2021 to fill a medium priority gap identified in the gap analysis. Survey was collected within the entrance and nearshore by Gippsland Ports via survey jetski and across the beaches and channel bars by Farron Group using an amphibious survey vessel. The extensive survey data was used to provide a more complete analysis of sediment volume change since 2008 and used as the bathymetry for numerical modelling of erosion and inundation hazards.

B-1-5 Anderson Inlet Measured Water Levels

Gippsland Ports continued to provide measured water levels within the Study Area at Inverloch Jetty and Tarwin River jetty.

This data included the flood event which occurred in June 2021 which enabled better validation of the Anderson Inlet hydrodynamic model. The increase in water level during the wetter months was also captured by the extended duration of monitoring provided by Gippsland Ports.

B-1-6 Tidal Analysis

This extended record of measured water levels, along with the results of the 40 year hydrodynamic hindcast model, was provided to the Bureau of Meteorology for harmonic analysis to establish tidal planes within the Study Area.

The BoM completed the harmonic analysis based on data received prior to and post the winter months and an increase in tidal planes at Tarwin Lower was noted. The increase in tidal planes is a result of the higher baseflow elevating the water level during the wetter months.

Given this fluctuation in the tidal levels at Tarwin Lower, the lack of extreme event water level data, and the vulnerability of the area to inundation, it is recommended that measurement of tidal water levels at Tarwin Lower continues.

B-1-7 Coastal LiDAR and Imagery

High resolution imagery, LiDAR derived digital elevation models (DEMs) and pano-spheres of the coastline from Cape Paterson to Screw Creek were collected on behalf of the Department of Transport and the Inverloch Region CHA during August 2021. Whilst the data was originally designed to be collected in conjunction with the entrance survey captured in April 2021, the COVID-19 restrictions in place at the time delayed collection of data.

The LiDAR data provided additional surface elevations to allow for volumetric analysis of change since 2008 along the coastline, and to allow a baseline for coastal recession hazard to be set along the Inverloch shoreline. Section A-2-1 identifies the level of HAT as a suitable location for the coastal “Baseline” for coastal setback, however analysis of the LiDAR survey and aerial imagery identified significant erosion had already occurred landward of the HAT.

To provide hazard mapping which was logical (i.e. existing erosion was not already landward of the future erosion hazard zone), the coastal Baseline was set to the toe of the existing dune scarp.

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

APPENDIX C
VICTORIA'S RESILIENT COAST FRAMEWORK

Victoria's Resilient Coast – Adapting for 2100+ framework	Purpose	Key questions	Cape to Cape Resilience Project key deliverables	Completion timeline	Document citation	Additional products
STAGE 1 Scoping and preparation	Provide a foundation for adaptation planning aligned to best practice guidance.	• Do we need action? • Who is involved? • Where's the study area? • What is our study scope?	Project plan	Mar-21	DELWP 2021, Inverloch Regional and Strategic Partnership Project Plan, Victoria, March 2021.	Website establishment and content. DELWP & Alluvium. May 2021. Project Update 1 - Introducing the Cape to Cape Resilience Project. DELWP & Alluvium. May 2021 Fact Sheet 1 - Project scene setting, introducing the RaSP. DELWP & Alluvium. May 2021. Project Update 2 - Data gathering, gap analysis, engagement commencement. DELWP & Alluvium. July 2021. Fact Sheet 2 - Coastal adaptation and hazards technical terminology. DELWP & Alluvium. July 2021.
			Engagement plan	Mar - July 2021	Alluvium 2021, Cape to Cape Resilience Project Engagement Plan, Victoria, March 2021.	
STAGE 2 Values, vision and objectives	Ensure adaptation planning is underpinned by regional and place-based values.	• What do we value? • As a region and as a State? • What do we want the future to look like?	Community values study	Oct-21	Alluvium 2021, Cape to Cape Resilience Project Community Values Study - Engagement Report - Values and Experiences, Victoria, October 2021.	Engage Victoria online survey & on-site drop in sessions - Community values and perspectives
			Cultural values assessment	Dec-21	Bunurong Land Council Aboriginal Corporation 2021, BLCAC Cultural Values Assessment: Cape to Cape Project, Victoria, December 2021.	
STAGE 3 Coastal hazard exposure	Assess coastal hazard exposure, including scenarios that enable best practice approaches to assessing current and emerging risk.	• What processes are occurring and how might these change?	Inverloch region coastal hazard assessment	June 21 - Mar 22	Water Technology 2022, Inverloch Region Coastal Hazard Assessment - Report 1 - Project Summary Report, Victoria, June 2022.	Fact Sheet 3 - Understanding coastal landscape context, processes and hazards. DELWP & Alluvium. Oct 2021. Fact Sheet 4 - Understanding coastal hazard modelling. DELWP & Alluvium. Oct 2021. Project Update 3 - Technical work (LiDAR, models, Assessment work), engagement update. DELWP & Alluvium. Nov 2021.
					Water Technology 2022, Inverloch Region Coastal Hazard Assessment - Report 2 - Data Assimilation and Gap Analysis, Victoria, June 2022.	
					Water Technology 2022, Inverloch Region Coastal Hazard Assessment - Report 3 - Technical Methodology , Victoria, June 2022.	
					Rosengren, N. & Miner, T., 2021, Inverloch Region Coastal Hazard Assessment – Coastal Geomorphology, Appendix A in Water Technology 2022c, Inverloch Region Coastal Hazard Assessment Report 3: Technical Methodology, Victoria, 2021.	
					Water Technology 2022, Inverloch Region Coastal Hazard Assessment - Report 4 - Coastal Processes and Erosion Hazards , Victoria, June 2022.	
					Water Technology 2022, Inverloch Region Coastal Hazard Assessment - Report 5 - Inundation Hazards, Victoria, June 2022.	
STAGE 4	Explore place-based coastal hazard vulnerability and risk, to enable strategic	• How might these processes impact what we value?	Coastal hazard asset exposure assessment	April - May 22	Water Technology 2022, Inverloch Region Coastal Hazard Assessment - Report 6 - Coastal Hazard Asset Exposure Assessment, Victoria, June 2022.	Project Update 4 - Technical work update (hazard mapping, values, economics), engagement update. DELWP & Alluvium. April 2022.

Victoria's Resilient Coast – Adapting for 2100+ framework	Purpose	Key questions	Cape to Cape Resilience Project key deliverables	Completion timeline	Document citation	Additional products
Vulnerability and risk	consideration of adaptation needs/priorities.		Coastal hazard risk and vulnerability assessment		Alluvium 2022, Cape to Cape Resilience Project - Asset and Values Risk and Vulnerability Assessment, May 2022.	
			Economic base case		Natural Capital Economics & Alluvium, 2022, Cape to Cape Resilience Project – Economics Assessment, June 2022.	
STAGE 5 Adaptation actions and pathways	identify, assess, consult on and decide which adaptation options and actions are the most appropriate for managing the current and future coastal hazard risks in the study area. This includes a diversity of integrated actions across land management, planning and design, nature based and engineering themes.	• How can we manage and adapt to these impacts?	Adaptation options and preferences	May - June 22	Alluvium 2022, Cape to Cape Resilience Project Adaptation Options - Engagement Report - Adaptation Engagement Outcomes, Victoria, October 2021.	TBC
			Adaptation framework summary paper		Alluvium 2022, Cape to Cape Resilience Project – Adaptation Framework Summary Paper, Victoria, June 2022.	
			Adaptation feasibility modelling		Water Technology 2022, Inverloch Region Coastal Hazard Assessment - Report 7 - Adaptation Assessment, Victoria June 2022	
			Economic assessment & cost benefit analysis		Natural Capital Economics & Alluvium, 2022, Cape to Cape Resilience Project – Economics Assessment, June 2022.	
STAGE 6 Plan and implement	Confirm the plan of action for coastal hazard risk management and adaptation, and commence implementation. This includes priority actions in the adaptation pathways, shared roles and responsibilities, triggers for review and resources/requirements.	• Which options are feasible and suitable, both now and in the future? • How can we plan our response strategically?	Cape to Cape Resilience Plan		Inverloch RaSP Stage 2- TBC 2023	
			Cape to Cape Implementation plan/s		Inverloch RaSP Stage 2-& Partner Agencies TBC 2023 onwards	
STAGE 7 Ongoing monitoring and review	Ensure coastal hazard risk management and adaptation is accompanied by ongoing monitoring and evaluation process that enables effective implementation, learnings and improvement.	• How can our response be adaptive to changing conditions? • How are we tracking in implementing our plan?	Cape to Cape Resilience Plan including implementation, monitoring and evaluation		Inverloch RaSP TBC 2023 onwards	

Melbourne

15 Business Park Drive
Notting Hill VIC 3168
Telephone (03) 8526 0800
Fax (03) 9558 9365

Brisbane

Level 5, 43 Peel Street
South Brisbane QLD 4101
Telephone (07) 3105 1460
Fax (07) 3846 5144

Adelaide

1/198 Greenhill Road
Eastwood SA 5063
Telephone (08) 8378 8000
Fax (08) 8357 8988

Perth

Ground Floor
430 Roberts Road
Subiaco WA 6008
Telephone 08 6555 0105

Geelong

PO Box 436
Geelong VIC 3220
Telephone 0458 015 664

Gippsland

154 Macleod Street
Bairnsdale VIC 3875
Telephone (03) 5152 5833

Wangaratta

First Floor, 40 Rowan Street
Wangaratta VIC 3677
Telephone (03) 5721 2650

Wimmera

PO Box 584
Stawell VIC 3380
Telephone 0438 510 240

www.watertech.com.au

info@watertech.com.au