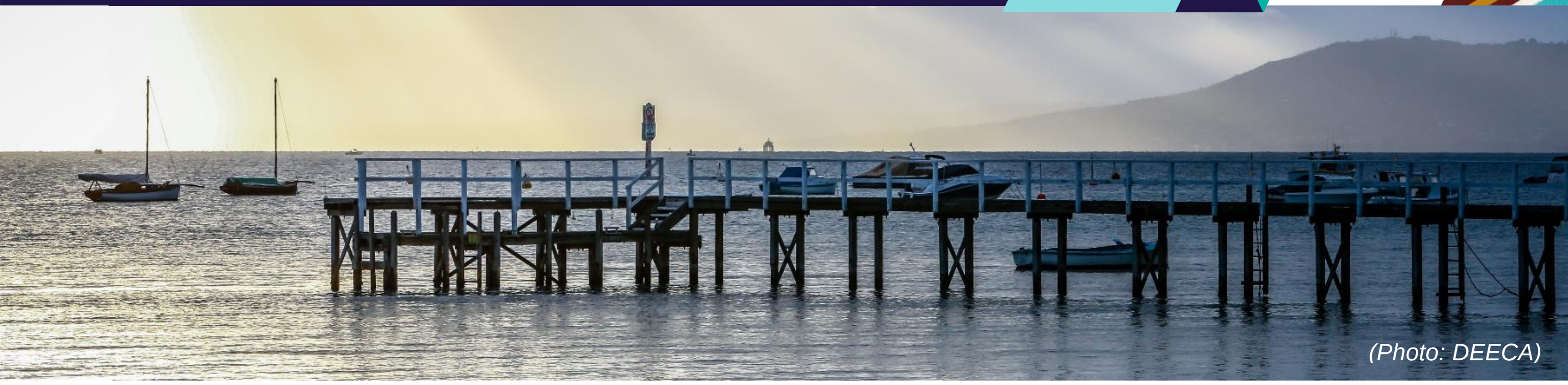
Port Phillip Bay Coastal Hazard Assessment

Summary #3: Coastal modelling

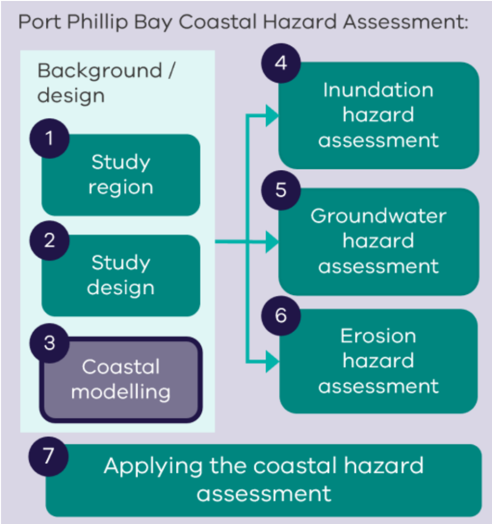


(Photo: DEECA)

Overview

The Port Phillip Bay Coastal Hazard Assessment (PPBCHA) looks at likely coastal hazards around the Bay. Hazards include flooding, erosion and changes in groundwater. We explore these hazards for current and future climate and sea level scenarios. Results will help land managers and the community to consider climate change in future planning.

This summary provides an overview of the computer modelling completed for this assessment. This is the third in a series of summaries providing an overview of the PPBCHA technical work.



In this summary:

We can use computer models to understand natural coastal processes and how these may change in the future.

We can combine models with coastal observations and measurements to improve our understanding.

Improving our understanding of coastal processes and hazards

It is important to improve our understanding of coastal processes and expected changes in climate. This allows us to be better informed to make decisions and plan for the future. Making decisions based on evidence and the best-available science provides more certainty. Monitoring and modelling also continue to increase our understanding over time.

There are a range of ways in which we are improving our understanding. The Port Phillip Bay Coastal Hazard Assessment (PPBCHA) is just one.

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Monitoring

Monitoring can include wind, water levels, waves, climate patterns, and shoreline changes.

Through examining trends, fluctuations, or seasonality, this data helps us understand more about the changes we see on our coast. This can include how environmental processes are linked and/or drive change.

We use data collected from buoys, gauges, weather stations, site visits, and field, aerial or drone surveys.

Modelling

A model can be a physical, computer, or conceptual model. They simply represent real-world processes. We can use models to test what changes we might see in the future under different scenarios. Models rely on good quality monitoring data.

What is a coastal model?

Models come in many shapes, sizes, and types. A coastal model is a simplified and scaled-down representation of the real world. We can use them to better understand complex natural systems. We can also test adaptation actions in a model, before implementing these in real life.

Coastal models can be physical (real life), numerical (computer-based) or a combination. They can also be simple ‘conceptual’ models. These are where we combine known concepts in a diagram, to represent and better understand a system. Models can also be quite complex. Complex models combine lots of mathematical equations to simulate natural processes.

A ***physical coastal model*** is often a scaled-down replica of the coastal environment. They can be quite simple, like a wave tank or flume, or very complicated, representing an entire bay or estuary. As a large, complex system, building and running a physical model of Port Phillip Bay would be very expensive and was not used in the PPBCHA.

A wave tank is a simple physical model (Photo: Alluvium)

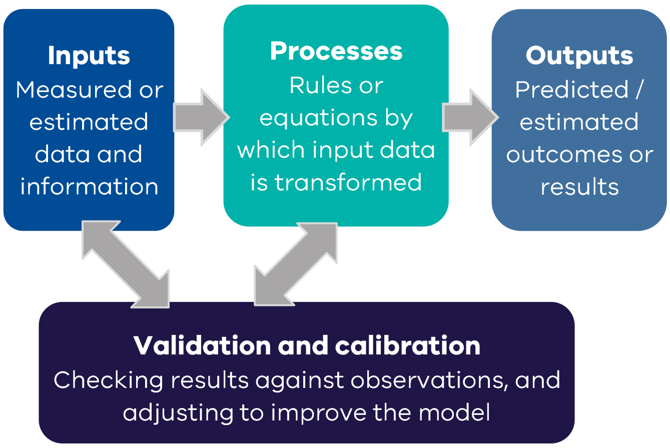
As technology advances, we are now able to ‘build’ digital models of our coastal and ocean environments. They can simulate a range of conditions (scenarios) for larger areas. For large regional-scale investigations like the PPBCHA, we now use computer models.

A ***computer- based (or numerical) coastal model*** simulates coastal processes. These include waves, water levels, currents, and sand movement. These models use mathematical calculations to represent complex physical processes.

They have:

- **Inputs** – based on measured or estimated data.
- **Processes** – rules and equations applied to the inputs.
- **Outputs** – estimated results, produced when the model is ‘run’.

They are also ‘validated’ and ‘calibrated’ against real-world observations. This ensures they are best-representing real-world processes.



Using computer-based models

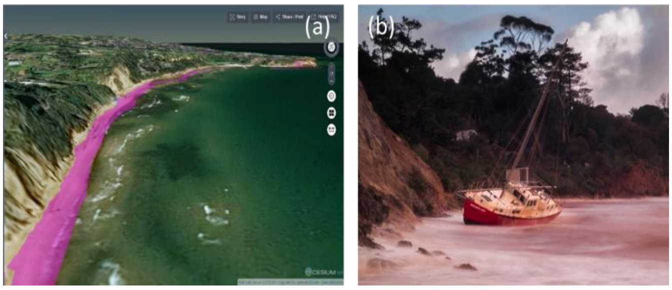
Why do we use them?

We use computer-based models to understand how coastal environments might change. This could be mapping possible inundation or erosion areas (as or ‘extents’. A model can be set up to represent different conditions or ‘scenarios’. These can be past or future conditions, including extreme storm events and rising sea levels. We can also model possible management options (e.g. changes to the landscape or adding/removing engineering structures).

We use models to replicate weather conditions and changes we have already experienced. This makes sure it is representative of the environment. We also use them to understand events that we have never seen before, including larger storms and higher sea levels.

How accurate are computer-based models?

We compare coastal model outputs with past measurements and other models to 'validate' the model. We make adjustments to 'calibrate' the model to make results more accurate. It takes time and a good understanding of coastal processes to develop and check models. This includes checking both the setup and input data, to ensure we get quality modelling results.



Model outputs (a) compared to past observations (b).

The coastal models we build use extensive scientific knowledge and research. But they can only provide a simplified representation of the real world. There are some uncertainties in model results. However, overall, computer models help improve our understanding and fill knowledge gaps.

(Photo: Phill Wizerbowski)

Modelling for the PPBCHA

Many different natural processes act together to drive coastal hazards. **Summary #1: The study region** highlights some of these drivers.

To estimate coastal hazards for the Bay, we need to combine data, analyses and models of a variety of coastal processes and conditions.

The PPBCHA uses a range of different models; some existing and some developed for this assessment. Many models and methods link together, providing key inputs and outputs to inform later parts of the assessment.

Some of the modelled processes include:

Weather and climate	Weather and climate models can be local, regional or global. They model how energy interacts across land, oceans and the atmosphere. They account for global winds, temperatures and greenhouse gases under different emissions scenarios.
Rainfall/ runoff	Rainfall models simulate water falling onto a surface and then 'running off' into rivers, creeks and drains. This is often associated with a storm event.
Evaporation	Evaporation modelling considers water heating up and evaporating into the atmosphere. This is particularly important in groundwater modelling.
Tides	Tides are the rise and fall of sea level. Tides vary from daily cycles to those associated with climate, weather and sun and moon positions. 'Storm tides' are a combination of normal (expected) tides, storm surge, wave setup and runup (defined below).
Storm surge	Storm surge is a local, abnormal rise in sea level above normal (expected) levels. Water levels change due to low air pressure associated with storms.
Waves	Wave models account for the build-up, movement and decline of waves. This considers wind direction, strength and duration. Models allow us to determine wave height and direction.
Hydro-dynamics	'Hydrodynamics' is the study of the flow and movement of water, including forces that drive its motion. Hydrodynamic modelling includes forces generated by tides, wind and waves.
Inundation	Inundation modelling considers where water is or flows to, accounting for many processes. These include rainfall, tides, storm surge, overtopping and wave runup and setup.
Wave overtopping	Overtopping is where water flows over a structure due to wave action. These structures could be seawalls, breakwaters or other engineered protection.
Wave setup and runup	Wave setup is the increase in shoreline water level due to waves breaking. Wave runup is the full elevation/distance reached by waves washing up the shore, including wave setup.
Erosion and shoreline response	Waves, tides and other movements of water cause sediment (sand) to move offshore, onshore or along the shore. This is the shoreline response. Erosion is sand loss and shoreline retreat inland. Accretion is sand gain and shorelines building seaward.

PPBCHA models and analyses contain information on:

- The local landscape. This includes ground and seabed elevation, geology, vegetation and sediments. We capture this data from literature, existing mapping and ground, aerial and underwater surveys.
- Local and regional conditions from various gauges and monitoring stations. This includes water levels, wind, waves, catchment (river) flows and rainfall.
- Past changes to the coast, obtained from historic imagery, reports and news articles, photographs, and drone and/or beach elevation surveys.
- Coastal structures and drainage infrastructure located in and near the coastal zone. We source this from existing data, stakeholder knowledge and surveys.

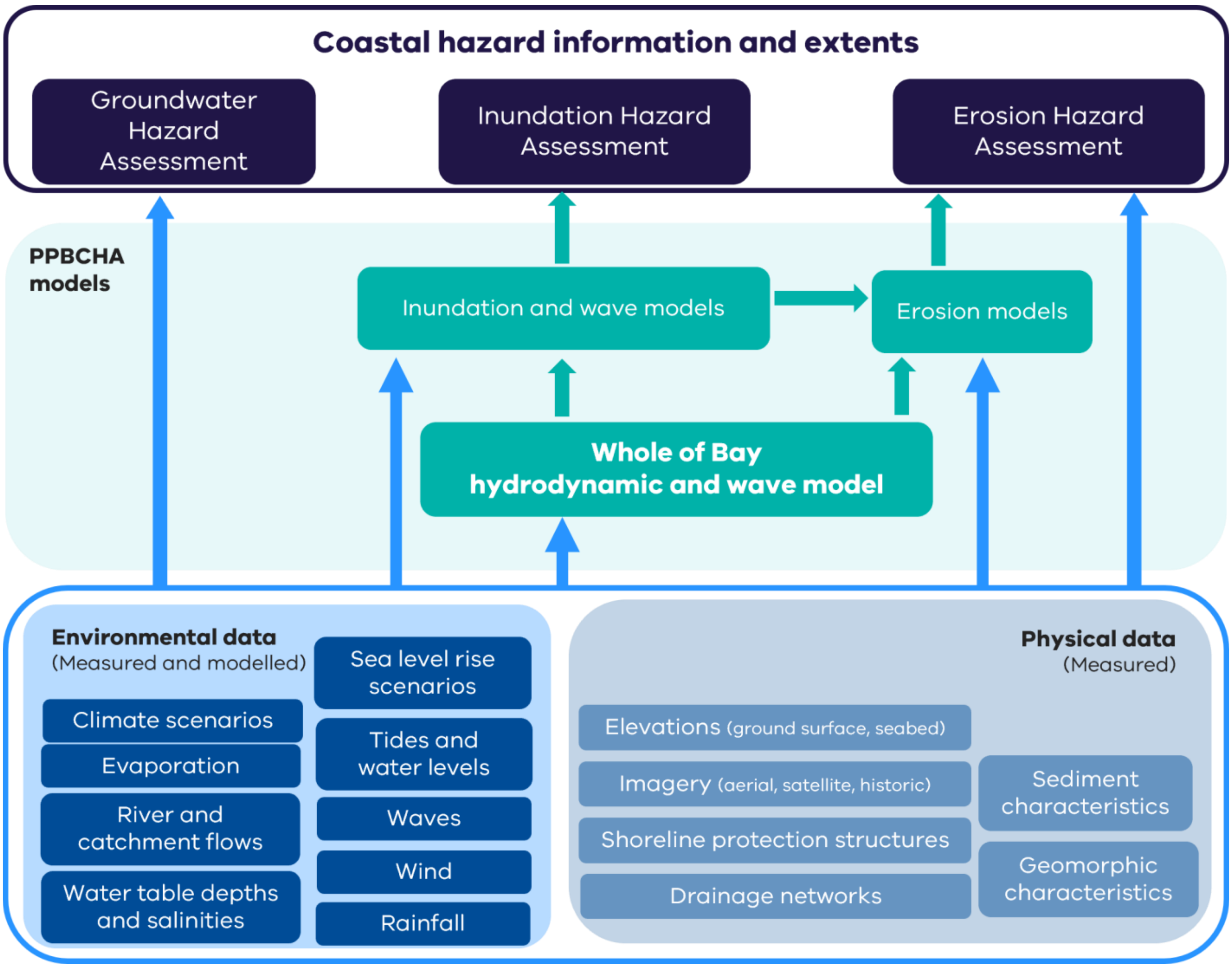
We've outlined the PPBCHA modelling in a workflow:

Environmental data
Measured and modelled

Physical data
Measured

PPBCHA models
Processes input data and information to create outputs. We also use some of the input data to calibrate and validate models.

Coastal hazard information and extents
Data or information produced by the models.



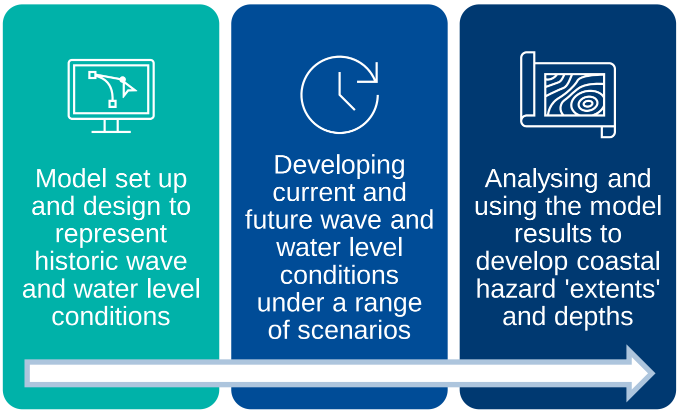
A bay-wide model

Essential to this assessment is a combined hydrodynamic and wave model of Port Phillip Bay. This model simulates water levels due to tides, weather and waves. It provides important information on the coastal processes of the Bay. It also informs other analyses and modelling for the Port Phillip Bay Coastal Hazard Assessment.

Hydrodynamics is the study of flow and movement of water, including forces that drive its motion.

Including this model, the PPBCHA has many other models, processes, inputs and outputs. The diagram above details how the hydrodynamic and wave model informs other parts of the PPBCHA.

Put simply, the PPBCHA modelling process includes:



Model set up and design

The hydrodynamic and wave model covers all of Port Phillip Bay. It extends offshore, including the surrounding ocean and coasts and the Bass Strait. A larger model area accounts for ocean conditions outside Port Phillip Heads. These include swells that influence coastal processes within the Bay.

Model grids

Model grids are important to how numerical models work. Grids spatially organise and represent the modelled study area. We also divide the grid up into smaller grid cells, which hold input data at spatial locations.

Models use data grids to arrange and find the information needed for their calculations. Grids also calculate and store the results of model equations. Models can have many grids that link together.

When we develop a model, we choose the design, number of grids and grid cell sizes based on:

- the input data available
- the information and detail we need to get from the analysis
- the computer processing power available.

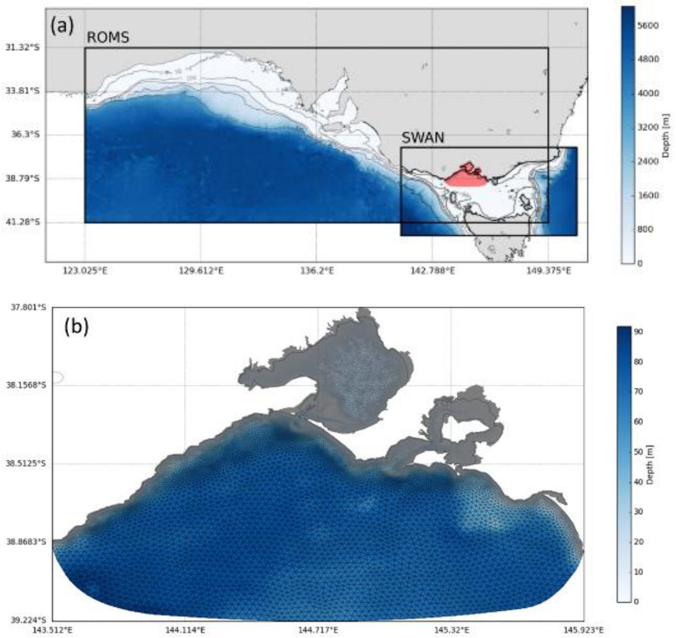
Large, regional-scale models have long computer processing times. They need lots of memory and data storage space to run. It's important to consider the total number of grid cells when designing models.

The Port Phillip Bay model grid

For PPBCHA, the combined hydrodynamic and wave model uses grids that have varying grid cell sizes. We include bigger (coarser) grid cells in offshore areas and smaller (finer) grid cells in areas closer to shore. This means we get more detailed information in the areas we are most interested in. The model grids also extend from the shoreline to the 3 m AHD land elevation contour.

AHD is the Australian Height Datum. It is an official benchmark for Australian elevation measurements.

This approach allowed for efficient model processing time and more manageable output data sets. Below are examples of the PPBCHA model grids.



The model grid for broader Bass Strait (top) and the Port Phillip Bay region (bottom)

Modelling for a range of scenarios

The Bay-wide combined hydrodynamic and wave model produces an extensive modelled data set. This includes water levels and waves under many different conditions.

To set up the model, we first ran model simulations of past coastal processes. Available tide and wave data records were used to check (calibrate) and verify the model outputs and refine the model setup. Once the models were generating values that reasonably replicated real-life coastal processes, we could use this setup to run new scenarios and timeframes.

We used the model to simulate a longer historic period (over three decades). Different sea level rise scenarios were then also run for these same historic periods. This provided the basis for estimating future wave and water level conditions for Port Phillip Bay.

The total amount of data generated by all these model runs was more than 20 Terabytes.

A baseline for present day

We use complex statistical analysis to analyse and interpret the model results. This includes determining patterns and trends in waves and water levels. We look at both typical conditions and extremes to establish a 'baseline'. We then use this baseline to represent the present-day conditions (0.0 m sea level rise scenario).

The future under a changing climate

With present-day conditions as a foundation, we then explore future conditions under climate change and sea level rise. Using the model, we can examine the possible effects of sea level rise. This looks at the effects on tides, and extreme water levels and waves (due to storms).

Modelled effects of sea level rise:	
Tides	• Daily tidal ranges (difference between high and low tide) inside the Bay will increase with sea level rise. • This increase varies at different locations. • Intertidal zones (the area between high and low tide) will increase in some areas. • Bigger tidal currents may increase shoreline erosion in some areas.
Extreme sea levels	• Extreme water levels within the Bay will increase with sea level rise. • There is a link between increasing extreme sea levels and increases in tides. • Sea level rise does not appear to significantly change the way storm surges behave (dynamics).
Waves	• Wave energy and wave heights moderately increase with sea level rise inside the Bay. • Rising sea levels increase water depth in some parts of the Bay. Deeper water makes the Bay's water surface area larger. Waves heights are linked to water surface areas that winds can blow across (called 'fetch'). This means slightly larger waves are expected for some wind conditions. • Increasing water depths through Port Phillip Heads may also allow more ocean wave energy (swell) into Port Phillip Bay.

(Doug Grant Reserve, Altona, Photo: Alluvium)

Using model outputs to determine coastal hazards

Water levels and waves drive many of the coastal hazards on our shorelines. Therefore, outputs of the Bay-wide hydrodynamic and wave model inform many parts of the PPBCHA.

We use the modelled waves and water levels as key inputs into extra modelling and analyses specific to each of our different hazard assessments. This additional work explores how water levels (tides) and waves interact with the Bay's shorelines and coastal areas.

Further summaries provide detail on how we calculate these coastal hazards:

- **Summary #4: Inundation hazard assessment**
- **Summary #5: Groundwater hazard assessment**
- **Summary #6: Erosion hazard assessment**

(Photo: Alluvium)

We acknowledge Victorian Traditional Owners and their Elders past and present as the original custodians of Victoria's land and waters and commit to genuinely partnering with them and Victoria's Aboriginal community to progress their aspirations.

Accessibility

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