Appendix K – Modelling Review Memorandum

Memorandum

29 November 2018

To	Melbourne Water Corporation (Lauren Mittiga, Keith Boniface, Rob Considine)		
Copy to			
From	Greg Finlayson; Ryan Brotchie	Tel	
Subject	Review of modelling assumptions	Job no.	3136555

1 Introduction

Flooding issues at Fishermans Bend may arise from three separate sources: *coastal flooding* from Port Phillip Bay, *riverine (fluvial) flooding* from the Lower Yarra River, and *surface (pluvial) flooding* from local rainfall events overwhelming the urban drainage system.

Over the past five years, various studies have been undertaken examining the impact of and responses to flooding at Fishermans Bend, with the most recent being the *Baseline Drainage Plan* (GHD for Melbourne Water, 2018). These studies have had different scopes, data sources and fundamental assumptions relating to flooding. It was therefore considered prudent to undertake an internal review of the modelling assumptions used to date relating to flooding from these different sources, particularly focussing on coastal and riverine flooding. This technical review, undertaken by GHD's Maritime and Coastal team, is contained in **Attachment A** to this memorandum.

The purpose of this memorandum is to provide context to the key findings from this review and discuss the implications of these findings for Melbourne Water (and stakeholders).

2 Modelling Review

GHD's internal review of the modelling conducted for the *Fishermans Bend Baseline Drainage Plan* to date, focusing on the tailwater conditions, the treatment of sea level rise and the implications for the height of the levee.

The review found that modelling for the Baseline Drainage Plan (GHD 2018) uses a time varying tail-water level peaking at 2.25m AHD (from Water Technology 2017), which combines a 1% AEP extreme water level event in Port Phillip Bay with sea level rise of 0.8m, in line with the current planning requirements for sea level rise. The modelling only considers elevated water levels in Port Phillip Bay and local rainfall, not flood flows in the Yarra River.

Key discussion points form the review are presented below.

3 Sea Level Rise

The review found that although current planning requirements and practice are to plan for a sea level rise of 0.8m by 2100, this is only one scenario, and it is important to acknowledge that (i) 0.8m may

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be reached some time before or after 2100, and (ii) 0.8m is not an end point – that sea levels will continue to rise beyond this. Best practice planning should consider a range of scenarios acknowledging the uncertainty in level and timing of sea level rise.

Recommendation:

An adaptive pathways approach is used in the design of the levee. This approach, for example, would commit to providing protection up to 0.8m sea level rise by year 2100. However, the initial works could be delayed or staged over time. Additionally, options to construct an even higher levee to protect against levels above 0.8 sea level rise should be kept open (e.g. contingency/flexible options are actively considered). Whilst not committing to a levee of this height, this might require preparatory actions to be taken now and incorporated into designs (e.g. setting aside land, flexibility in design such as stronger foundations, and modifiable urban design) to ensure the option can be taken in the future if needed.

4 Yarra River Flood Flows

The review found that modelling only considers elevated water levels in Port Phillip Bay and local rainfall, not flood flows in the Yarra River. This is ok for most of the site as water levels in the lower Yarra below Wurundjeri Way are principally determined by the Bay level and river flow has a very minor influence.

However, upstream of Wurundjeri Way the river levels appear to be flow-dominated during flood events and are higher than the Bay level. *It is important to note the current Melbourne Water designated flood level is lower than 2.25m AHD, and so in modelling to date the 2.25m AHD tailwater condition has been assumed to be appropriate. However GHD is aware of a flood study underway for the Lower Yarra that is underway, for which preliminary results indicate that flood flows in the lower Yarra may be up to 3.3m AHD.*

It is plausible that the designated Melbourne Water flood level for the Lower Yarra will be revised in the future. Hence it is **likely that the levee will need to be higher in this area and may need to extend further upstream** than the current model boundary at Clarendon St to protect the eastern most precinct. This also of course has implications for planning controls and the setting of the LSIO.

It is also important to note that unlike the coastal flooding under sea level rise, the riverine flood risk is a present one and so the levee in this section may need to be constructed sooner.

Recommendation:

Melbourne Water's designated flood level may change in the near term, which has implications for Fishermans Bend, including the extent and height of the levee, and planning controls.

GHD therefore suggest the strategy explicitly states the uncertainty related to this input, and includes an agreed approach to manage the levee design and planning controls once the final Yarra River flood level is determined.

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5 Levee Freeboard

The major proposed asset to provide protection against coastal flooding under future sea level rise and Yarra River Flooding is a levee along the Northern boundary of Fishermans Bend.

In addition to the recommendations above, which have implications for the height and extent of the levee, another specific technical finding from the review was: *The proposed levee alignment on the river bank will require increased freeboard due to vessel wake and local increases in water level where flood flows meet obstructions such as bridge abutments.*

The Baseline Drainage Plan doesn't currently allow for freeboard. The DELWP Levee Management Guidelines provide a starting rule of 600mm freeboard for public urban levees, but they do note the freeboard may be increased/decreased depending on conditions & knowledge. It appears that it is MWC's responsibility to set this requirement. Figure 01 over page shows the difference in extent/height of the levee with and without the freeboard allowance.

Recommendation:

That 600mm freeboard be allowed for the levee at Fishermans unless Melbourne Water provide clear guidance as to why freeboard should be reduced.

6 Uncertainties in Levee Design and Cost

The function of the levee is to protect against the possible flooding from the Bay and the Yarra. Several uncertainties arise when considering the points raised in this memo, together with other practical on-ground issues in Fishermans Bend. These include:

Levee Uncertainty	Comment
Height	In the area subject to flooding from the Bay, there may be a need to allow a freeboard addition, to cope with both uncertainty, and local effects. In the area subject to flooding from the Yarra, the design level is under review.
Extent	An increase in levee height will have a corresponding increase in extent.
Timing	In the area subject to flooding from the Bay, the levee may be delayed or staged (assuming preparatory actions are taken to keep future options open) as sea level rise occurs over time. In the area subject to flooding from the Yarra, a levee may be required immediately.
Location	The levee may need to run through private land, and public land which is not under the control of

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	Melbourne Water or the Councils. Therefore the exact location and nature of the levee is not fixed. This could have implications for design and cost if the architectural elements of the levee are substantive. There may also be questions related to the impact the levee might have on the current activities on that land (for example in the port area).
Urban Design / Form	There are opportunities to design the levee into the streetscape/urban form to enhance the liveability of Fishermans Bend. Ideas to achieve this goal have been discussed in various workshops, but given the wide range of unknowns, no fixed position has been reached and specific concepts have yet been explored. This would have implications for land take and cost.

Recommendation:

Given the above points, GHD suggest that the strategy explicitly notes the uncertainty related to the levee design and cost, and includes flexible measures to adjust the scope, budget and funding into the future. Further work will likely be required following this strategy relating to the planning of the levee.

7 Conclusion

We seek advice from Melbourne Water on how to proceed on each of the points raised, and whether the contents of this summary memorandum and the attached technical memorandum should be included in our report on the flood management strategy.

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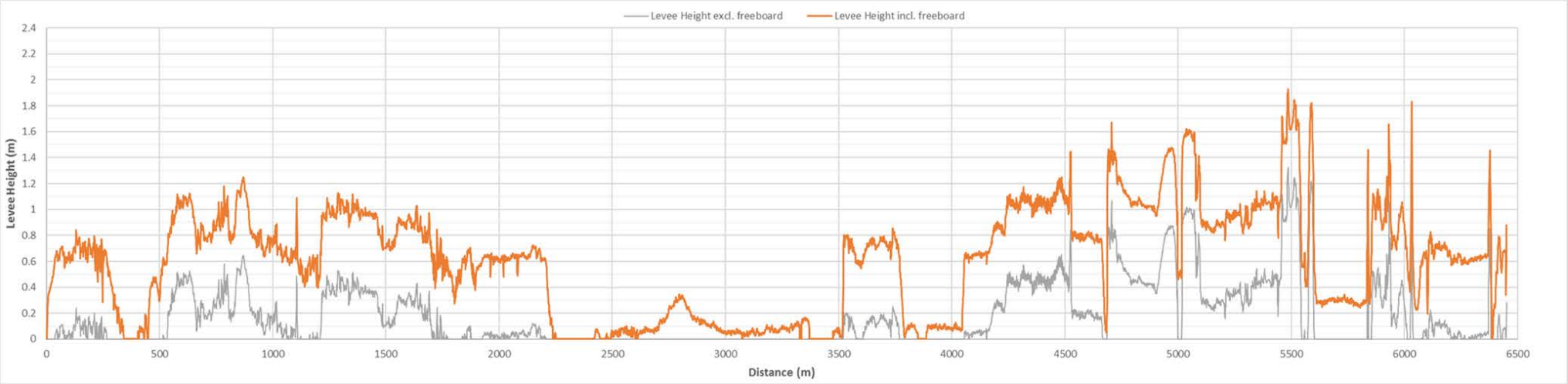
Figure 1: Change to extent and height of levee from adding Freeboard to the levee profile *(grey line represents the assumed levee extent/height in the Baseline Drainage Plan, GHD 2018, and the orange line represents adding 600mm freeboard).*



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Appendix A – Technical modelling review

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Memorandum

31 October 2018

To	GHD Project Team		
Copy to	Melbourne Water		
From	Christian Taylor	Tel	+61 3 8687 8856
Subject	Review of modelling and implications for levee	Job no.	3135713

1 Summary

Flood levels at Fishermans Bend are principally driven by water levels within Port Phillip Bay. As such, GHD's maritime and coastal team have conducted a review of the modelling conducted for the Baseline Drainage Plan to date, focusing on the tailwater conditions, the treatment of sea level rise and the implications for the height of the levee.

Issues identified by the review are:

- Current planning requirements and practice are to plan for a sea level rise of 0.8m by 2100. This is however only one scenario, and by no means an end point for sea level rise. Best practice planning should consider a range of scenarios acknowledging that this level may be reached some time before or after 2100, and that sea level will continue to rise beyond this point.
- Modelling for the Baseline Drainage uses a time varying tail-water level peaking at 2.25m AHD (from Water Technology 2017), which combines a 1% AEP extreme water level event in Port Phillip with sea level rise of 0.8m, in line with the current planning requirements for sea level rise.
- Modelling for the Baseline Drainage Plan to date only considers elevated water levels in the Bay and rainfall, not flood flows in the Yarra River. This is ok for most of the site as water levels the lower Yarra below Wurundjeri Way are principally determined by the Bay level and river flow has a very minor influence. However, upstream of Wurundjeri Way the river levels are flow-dominated during flood events and are higher than the Bay level. Hence the levee will need to be higher in this area and may need to extend further upstream than the current model boundary at Clarendon St to protect the eastern most precinct.
- The proposed levee alignment on the river bank will require increased freeboard due to vessel wake and local increases in water level where flood flows meet obstructions such as bridge abutments.

2 Documents Reviewed

- *Victorian Coastal Strategy* (VCS) (Victorian Coastal Council (VCC), 2014);
- *The Effect of Climate Change on Extreme Sea Levels in Port Phillip Bay* (CSIRO, 2009);

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- *Planning for Sea Level Rise Guidelines* (Melbourne Water, 2017);
- *Derivation of Victorian Sea Level Planning Allowances* (Hunter, 2013)
- *Information for Australian Impact and Adaptation Planning in response to Sea-level Rise* (McInnes et al, 2015);
- *Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering* (National Committee on Coastal and Ocean Engineering (NCCOE), 2017);
- *Coastal Engineering Guidelines for Working with the Australian Coast in an Ecologically Sustainable Way* (NCCOE, 2017)
- *Climate Change Adaptation Guidelines in Coastal Management and Planning, Engineers Australia* (NCCOE, 2012).
- *Port Phillip Flood Modelling* (Water Technology for Melbourne Water, Draft, Dec 2017)
- *Fishermans Bend Baseline Drainage Plan* (GHD for Melbourne Water, Draft Aug 2018)
- *Yarra River Flood Mapping project – Modelling Assumptions & Implications* (Memo from GHD to Melbourne Water dated 29 March 2018)
- *Adaptive Pathways Planning Guidelines* (GHD for Melbourne Water 2018)

3 Prediction of Sea Level Rise

The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for assessing the science related to climate change, including sea level rise. The IPCC have currently produced five assessment reports which cover the full scientific, technical and socio-economic assessment of climate change. The IPCC assessment reports are considered to be the most comprehensive scientific reports about climate change produced worldwide, and are used extensively in Australian guidelines and reports, including the following which are relevant to determining an appropriate allowance for sea level rise at Fishermans Bend:

The *Fifth Assessment Report* (IPCC, 2013), provides global mean sea level projections for four Representative Concentration Pathways (RCPs). The RCPs were developed to represent possible future emissions and concentration scenarios, focusing on the concentrations of greenhouse gases until 2100. The sea level rise projections in IPCC (2013) range from 0.26 to 0.82 m by 2100.

The most recent IPCC report *Global Warming of 1.5°C* (IPCC, 2018) focuses on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways. While sea level rise is discussed in this special report, results from the Fifth Assessment Report (IPCC, 2013) regarding sea level rise have not been updated. IPCC, 2018 contains the following information regarding sea level rise:

- *"Given the long timescales involved to reach equilibrium in a warmer world, sea level rise will likely continue for millennia even if warming is limited to 2°C."*

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- *"While it is virtually certain that sea level will continue to rise well beyond 2100, the amount of rise depends on future cumulative emissions (Church et al., 2013) as well as their profile over time (Bouttes et al., 2013; Mengel et 23 al., 2018)."*
- *"The impacts of storms are amplified by sea level rise (Section 3.4.5) with substantial challenges today and in the future for cities, delta, and small islands in particular (Section 3.4.5.2 - 3.4.5.4) as well as coastlines and ecosystems (Section 3.4.5.5 – 3.4.5.7)."*

Sea level projections differ across the globe due to, amongst other things *"shifting surface winds, the expansion of warming ocean water, and the addition of melting ice"* IPCC (2013). Regional variation is described in *Information for Australian Impact and Adaptation Planning in response to Sea-level Rise* (McInnes et al, 2015),

McInnes et al (2015) contains the following information regarding sea level rise in Australia:

- *"Projections of sea-level rise (SLR) for 2090 for the Australian coast-line are similar to the global mean sea-level projections. The global and regional projections are almost independent of the Representative Concentration Pathways (RCPs) for greenhouse gas emissions chosen for the first decades of the 21st century, but they begin to diverge significantly from about 2050. For the business-as-usual scenario (RCP8.5), the rates increase steadily through the 21st century, reaching almost 12 mm/yr by 2100 at all locations. For the intermediate scenarios of RCP 6.0 and RCP 4.5, the rates stabilise in about 2090 and 2060 at about 7-8 and 6 mm/yr, respectively. For the strong mitigation scenario (RCP 2.6, requiring significant and urgent mitigation of greenhouse gas emissions), the rate of rise stabilises much earlier than the other scenarios and then reduces slightly to about 4 mm/yr".*
- *"At the end of the 21st century, global and regional sea level is projected to continue rising in all scenarios, with the rate in the high emission RCP8.5 scenario equivalent to the average rate experienced during the deglaciation of the Earth following the last glacial maximum, and much larger than the late 20th century rate."*
- *"Global mean and Australian sea levels are projected to increase beyond 2100, with thermal expansion contributions (proportional to the degree of warming) continuing for many centuries." "Avoiding the larger rises associated with the higher emission scenarios and large sea-level commitments beyond 2100 requires significant and urgent mitigation of global greenhouse gas emissions".*
- *"The greater uncertainty in sea level projections towards the end of the 21st Century compared to those for 2030 implies that flexible strategies are needed for adaptation. The 'adaptation pathways' approach affords this flexibility by characterising different adaptation strategies in terms of adaptation tipping points. This approach favours flexible and reversible options and keeping options open to maximise the benefit of future adaption strategies."*

McInnes et al (2015) also provides updated sea level rise projections for a number of locations in Australia. The locations closest to Fishermans Bend are Stony Point, which has a range of 0.38 to 0.81 m by 2090, and Williamstown, for which sea level rise projections are shown in Figure 2 below.

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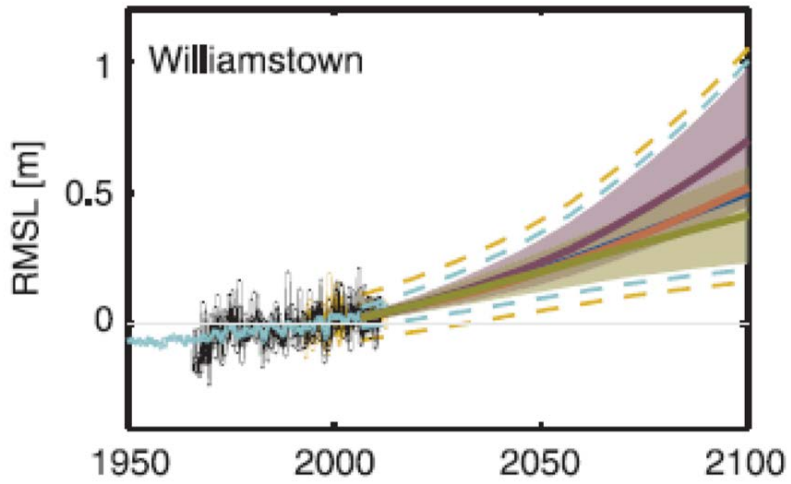

Figure 1 Observed and projected relative sea level change

Figure 1 shows the observed and projected relative sea level change in metres, with the observed sea level records in black, and tide gauge reconstruction in cyan. The 5th to 95th percent uncertainty range of the detrended historical records is shown by the dashed lines plotted above the top and below the bottom of the projections. Multi-model mean projections (thick purple and olive lines) for the RCP8.5 and RCP2.6 emissions scenarios with likely model ranges are shown by the purple and olive shaded regions from 2006 to 2100. Thick dark blue and orange lines represent multi-model mean projections for the RCP 4.5 and 6.0 scenarios, respectively.

4 Planning for Sea Level Rise

Planning for Sea Level Rise Guidelines (MW, 2017) lists the *Victorian Coastal Strategy* (VCS) (Victorian Coastal Council (VCC), 2014) as a key document which was used to provide the strategic basis for MW's guidelines. The VCS references the current Victorian planning benchmarks, which are to plan for sea level rise of not less than 0.8 metres by 2100 and to plan for sea level rise of not less than 0.2 metres by 2040 for urban infill areas. The VCS also references a report that the VCC commissioned titled *Derivation of Victorian Sea Level Planning Allowances* (Hunter, 2013) which suggests *"planning benchmarks for Victoria include to plan for sea level rise of not less than 0.8 metres by 2100. It was also noted that planning for sea level rise of 0.9m by 2100 is a more conservative option"* (VCS, 2014).

Given the level of uncertainty around climate change and the rate of sea level rise, best practice planning for large developments in the coastal zone is to consider how the development performs under a wide range of possible scenarios including more rapid and slower sea level rise than specified in the planning policy. Changes in temperature, wind, rainfall and storm intensity should also be considered but these changes have an even greater level of uncertainty and are often excluded from analysis and not included in the planning guidelines.

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These issues can be dealt with using the 'Adaptive Pathways' approach, developed for the upgrade of the Thames Barrier in the UK. GHD have prepared *Adaptive Pathways Planning Guidelines* for Melbourne Water to aid in the application of this method.

5 Extreme Coastal Water Levels in Port Phillip Bay

The extreme coastal water level experienced at the coast during the passage of a storm event is made up of contributions from a number of different processes, with the predominant components being (as shown in Figure 2):

- Astronomical Tide - which can be predicted with high accuracy
- Storm Surge - includes a number of regional scale processes such as barometric setup, wind setup and the influence of waves and currents on regional water levels. Can be predicted with fair accuracy if good records are available
- Wave Setup – relates to the elevation of water level due to breaking waves pushing water landward in the surf zone. Varies locally with wave breaking conditions and requires detailed modelling to predict.
- Wave Runup – the surging of broken waves up the beach and over structures. Varies locally with wave breaking conditions and shore profile, requires detailed modelling to predict.

These components are often grouped under the concept of 'storm tide' which is the total water level measured above mean sea level (MSL). Note that storm tide is usually predicted for a point seaward of the of the surf zone, or a sheltered location such as a port, and as such generally does not include wave setup or run-up.

Allowances for future sea level rise are not included in storm tide, but are made by increasing MSL.

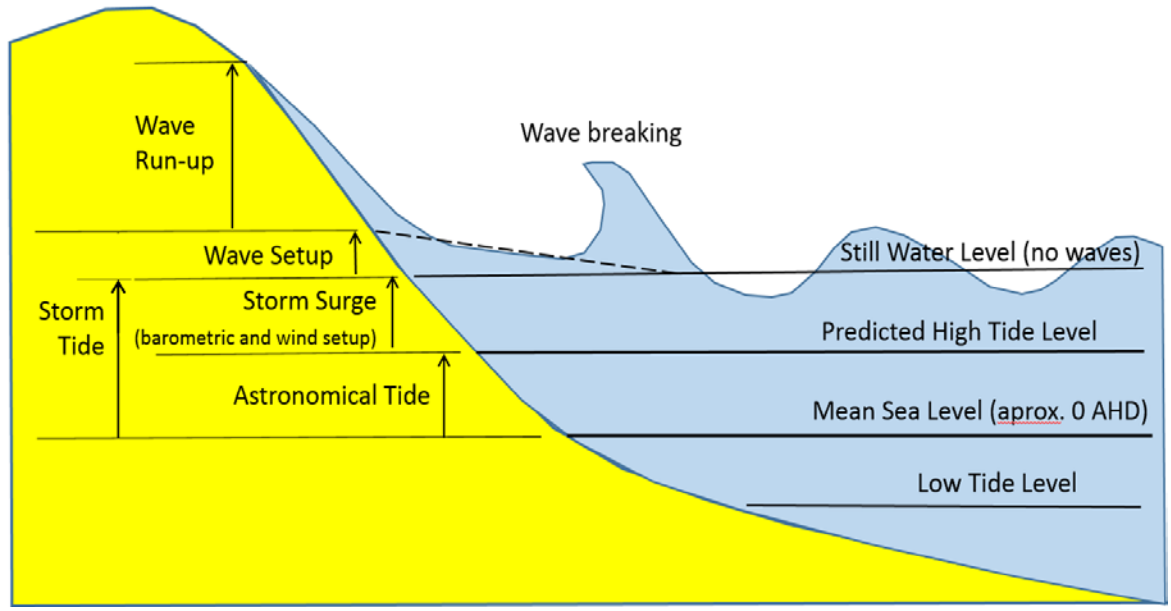

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Figure 2 Components of extreme coastal water levels

Melbourne Water's (MW) 1% AEP (Annual Exceedance Probability) flood levels within Port Phillip Bay include a projected sea level rise of 0.8 m by 2100 (*Planning for Sea Level Rise Guidelines*, MW, 2017). Under these guidelines the flood levels applicable to Fishermans Bend for a 1% AEP flood level are 1.8 m AHD by 2040 and 2.4 m AHD by 2100. In addition to setting flood levels, MW also recommends that floor levels for new developments are set 0.6 m above the design flood level.

The Effect of Climate Change on Extreme Sea Levels in Port Phillip Bay (CSIRO, 2009) calculated a 1% AEP flood level for St Kilda of 2.28 m AHD by 2100 under climate change scenario 2[1].

While the allowance for sea level rise is the same, MW's 2100 levels are higher than CSIRO's because of differing calculation of the 1% AEP storm tide. MW includes some allowance for wave effects, where CSIRO does not, and MW also takes a more conservative approach or including outliers in the analysis of historical tide gauge records.

The *Port Phillip Flood Modelling* study (Water Technology 2017) involved modelling propagation of tides and storm surges from Bass Strait into Port Phillip, combined with wind and waves effects (includes some wave setup but not wave runup) within Port Phillip, to produce time-series of water levels at coastal locations around the Bay for the 10% and 1% AEP events. Sea level rise of 0.8m was added to the storm tide to give a peak water levels for the 1% AEP event in 2100 of 2.25m AHD at St Kilda and 2.23m AHD at Williamstown.

[1] IPCC 2007 A1F1 scenario in combination with 'high' wind speed scenario

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6 Fishermans Bend Baseline Modelling

The Fishermans Bend baseline flood modelling includes flooding of the site from elevated coastal water levels in Port Phillip and the Yarra River, as well as from rainfall falling on the site. Yarra catchment floods elevating levels in the river are not considered.

The Water Technology (2017) time series for St Kilda (peak 1% AEP level of 2.25m AHD in 2100) has been used as both the Bay and the River water level in the model. The peak level is similar to the CSIRO (2009) level and slightly lower than the MW (2017) level. However, the WT (2017) analysis is more sophisticated and includes all the relevant processes therefore a lower level of conservatism is justified. Further, most of the flooding of the site comes from the river, which is sheltered from wave action, so inclusion of allowances for wave action (as per MW 2017) is not required.

The chief advantage of the WT (2017) storm tide levels is that, unlike all other predicted levels, they are time-varying, meaning that modelling of coastal inundation is more realistic. The peak of the storm tide only occurs for a couple of hours and this limits the quantity of water that enters the site.

As most flooding of the site is via the Yarra it may be more appropriate to use the predicted Williamstown timeseries rather than the St Kilda time series as a tail water level, although using the St Kilda time series is slightly more conservative.

Yarra River 1% AEP flood profiles given in *Yarra River Flood Mapping project – Modelling Assumptions & Implications* (Memo from GHD to Melbourne Water dated 29 March 2018) clearly show that for the river below Wurundjeri Way are principally determined by the bay level and river flow has a very minor influence (refer Figure 3). However, upstream of Wurundjeri Way the river levels are flow-dominated during flood events and are higher than the Bay level (refer Figure 3). As flood flows are not included in the current modelling it will be underpredicting flood levels in the eastern-most part of the site which floods from the Yarra upstream of Wurundjeri Way.

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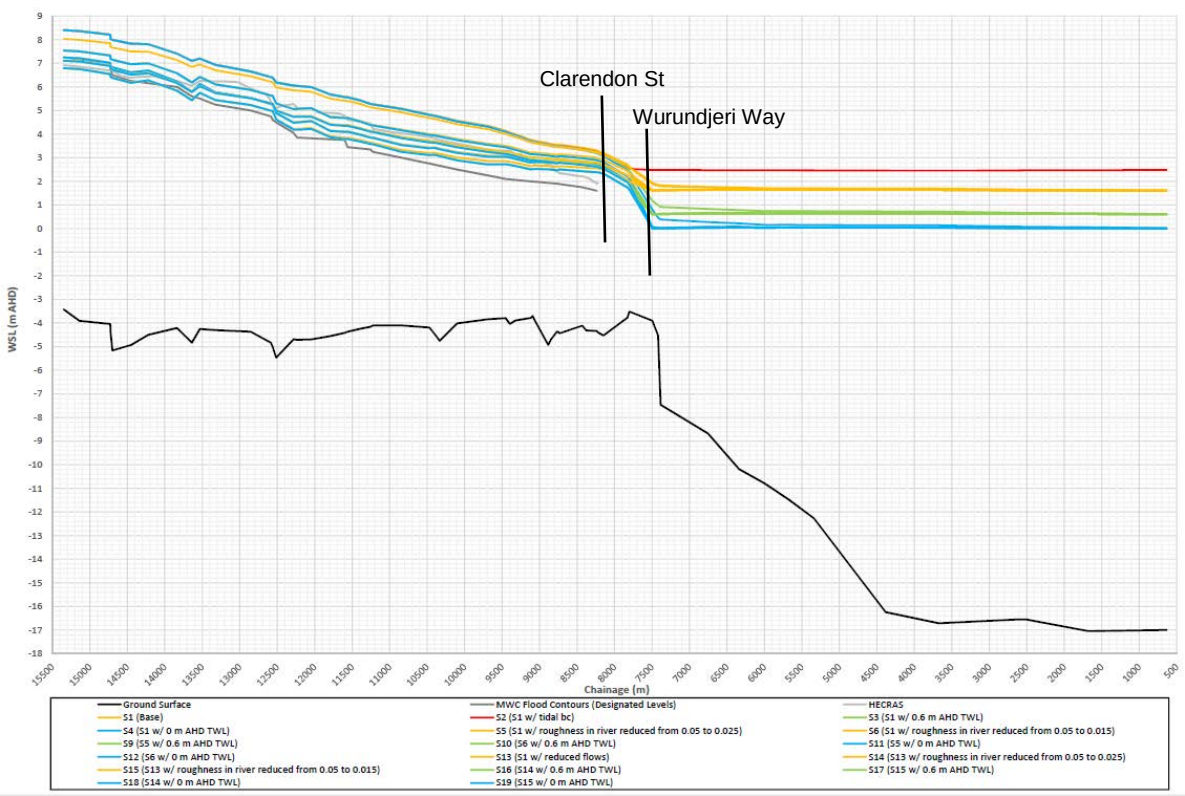

Figure 3 Modelled flood profiles for the Lower Yarra from *Yarra River Flood Mapping project* (GHD 2018, Draft)

7 Implications for the levee

The implications for the proposed levee at Fishermans Bend are:

- Due to the effect of flooding from the Yarra during catchment flood events, the levee will need to be higher in the area upstream of Wurundjeri Way and may need to extend further upstream than the current model boundary at Clarendon St to protect the eastern most precinct.
- The proposed levee alignment on the river bank will require increased freeboard due to vessel wake and local increases in water level where flood flows meet obstructions such as bridge abutments.

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Regards

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