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DEVELOPING BETTER PREDICTIONS FOR EXTREME WATER LEVELS

WEBSITE USER GUIDE

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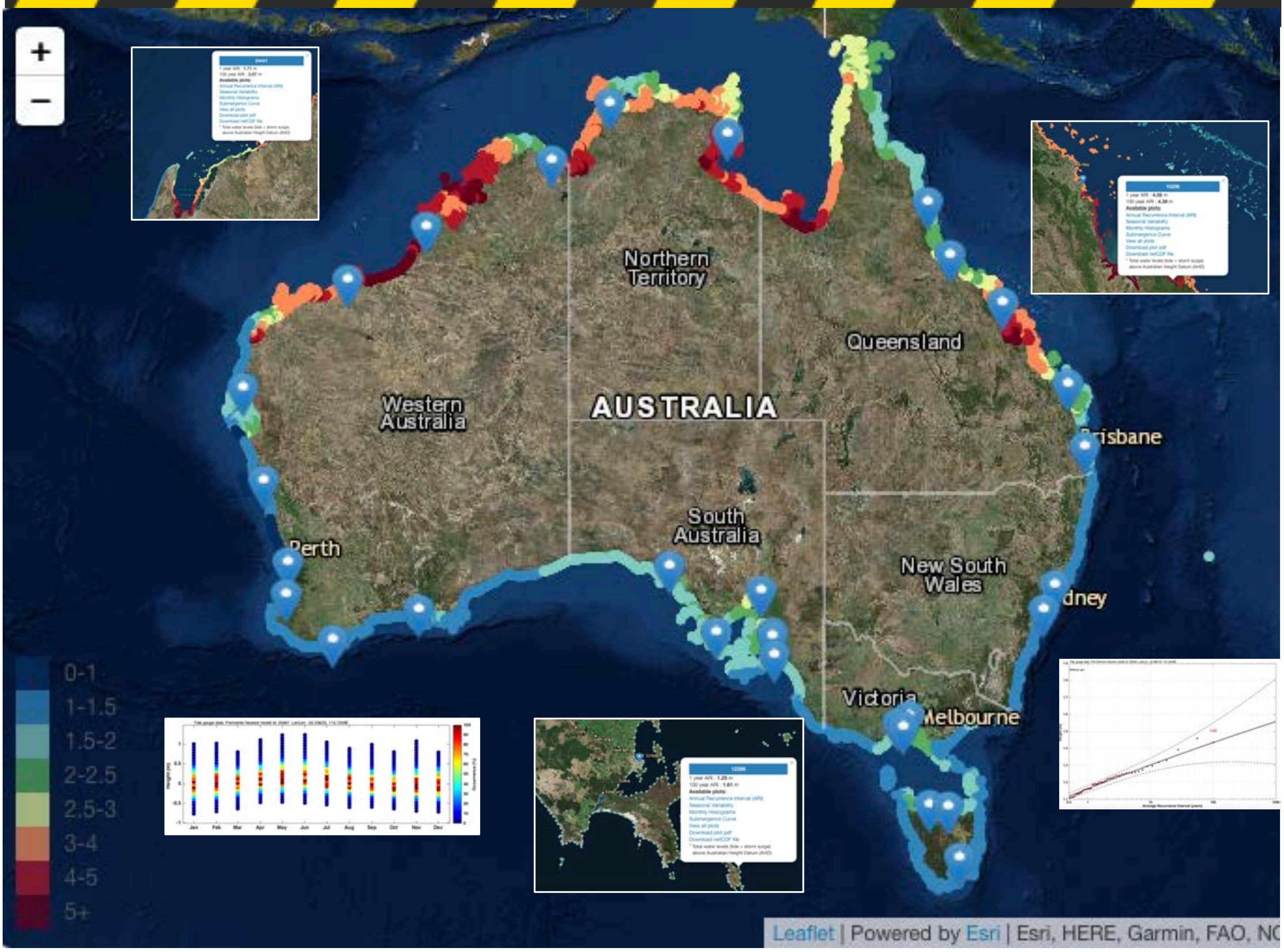

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Cover: Australian extreme sea levels website screenshot showing predicted present day 100 year Average Recurrence Interval water levels.

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INTRODUCTION

The major hazard in coastal regions is inundation through extreme water levels generated in the ocean through different mechanisms such as storm surges and tsunamis or through a combination of effects such as a relatively small storm surge coinciding with high astronomical tides. With rising in sea level, given water levels will be exceeded more and more frequently as progressively less severe storm conditions are required to achieve that water level.

Therefore, it is critical that the exceedance probabilities of extreme water levels are accurately evaluated to inform flood and erosion risk-based management and for future planning. To address this concern, this study estimated present day extreme sea level exceedance probabilities due to storm surges, tides and mean sea level around the whole coastline of Australia through the application of a numerical model.

The SCHISM hydrodynamic model, forced by TPXO tides and JRA55 atmospheric reanalysis (wind and air pressure), was successfully applied to produce a 59 year sealevel hindcast (1958-2016) for the entire Australian region. The outputs provide uninterrupted hourly sea level records at <1 km resolution around the Australian coast. Improvements compared to the previous *Haigh et al.* [2014b] dataset included: extending the hindcast by six years including several record storm surge events, higher spatial resolution, improved meteorological forcing, and 3-D hydrodynamic model implementation. Other physical processes, missing from earlier studies, were also examined in detail including: effects of surface gravity waves, continental shelf waves, and meteorological tsunamis.

Extreme value analysis has been applied to the sea level data to predict Average Recurrence Intervals (ARI) at ~1km spacing around the entire Australian coastline including islands. These statistics and relevant plots and time series data have been made available to the public via an interactive web tool (www.ozsealevelx.org), providing a consistent, accessible, up-to-date dataset for use by coastal planners and emergency managers.

This report provides an overview of the website and describes of how to access and interpret the available extreme sea level data.

WEBSITE CONTENT

The major outcome from the BNHCRC extreme sea level project is a website (www.sealevelx.org) (Figure 1) aimed at making the extreme sea level statistics and data easily available to a broad range of end users. The website consist of an interactive map showing the 100 year ARI as coloured dots spaced at 2 km around the coastline, including islands. The user can click on any of these 31479 points (e.g. Figure 2) to access present day 1 and 100 year ARI levels as well as a number of plots showing more details of the extremes, including: ARI curves (Figure 3); seasonal variability (Figure 4); monthly histograms (Figure 5); and submergence curves (Figure 6) showing the percentage of time certain levels are exceeded. Combined pdf files containing all plots are also available for download, and hourly sea level time series data (model) can be downloaded as netCDF files by clicking on the link provided (Figure 7). Equivalent plots are also available at select tide gauge sites (blue markers) so that the user can compare the statistics derived from the model with those based on observations (Figure 8).

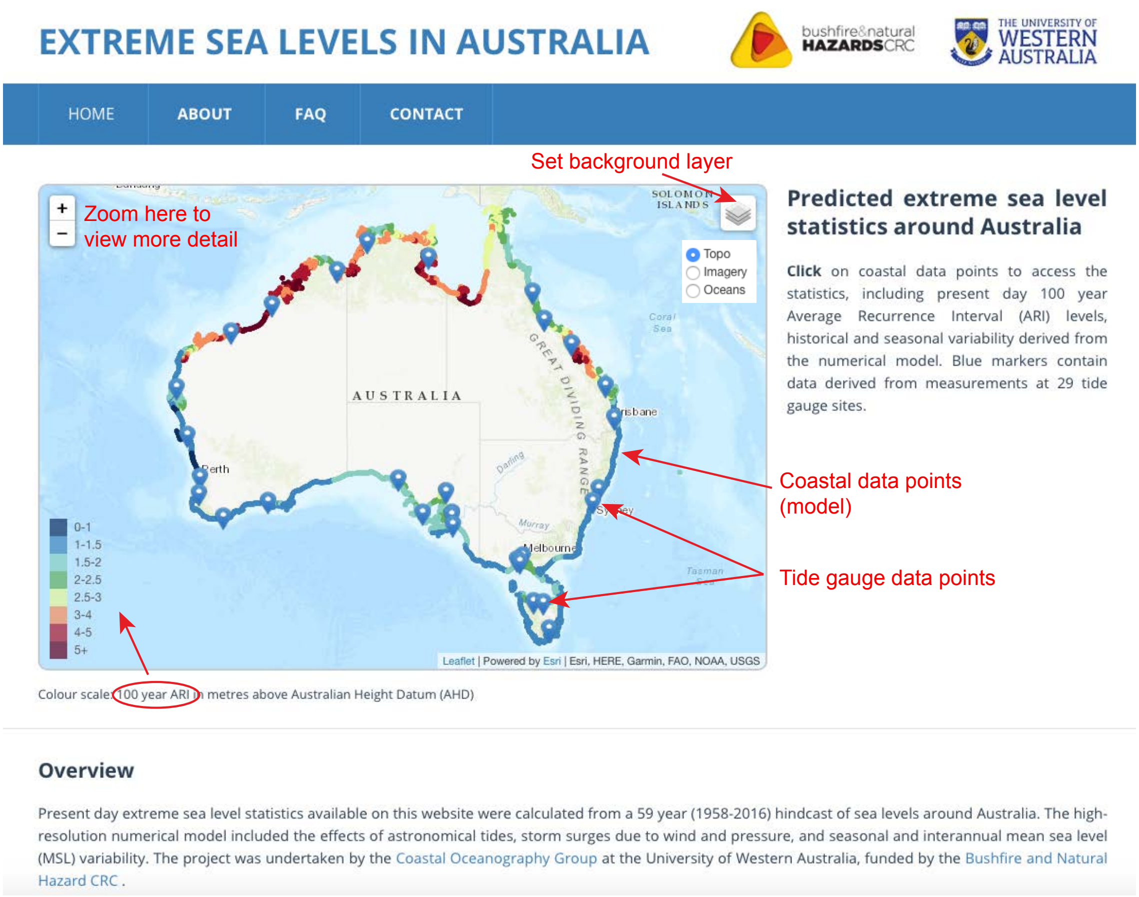

FIGURE 1 SCREEN SHOT OF THE EXTREME SEA LEVEL WEBSITE DEVELOPED DURING THE BNHCRC PROJECT " IMPROVED PREDICTIONS OF EXTREME SEA LEVELS." THE INTERACTIVE MAP ALLOWS FOR THE USER TO EXTRACT EXTREME SEA LEVEL STATISTICS, VIEW PLOTS AND DOWNLOAD TIME SERIES DATA AT 31479 COASTAL DATA POINTS. MAIN FEATURES ARE HIGHLIGHTED WITH RED TEXT.

POP-UP WINDOW

For each of the 31479 coastal data points the user can click on the coloured data points spaced at 2 km intervals around the coast to access the extreme sea level statistics and relevant plots derived from the SCHISM numerical model (e.g. Figure 2). Blue text indicates hyperlinks to view and download plots and data.

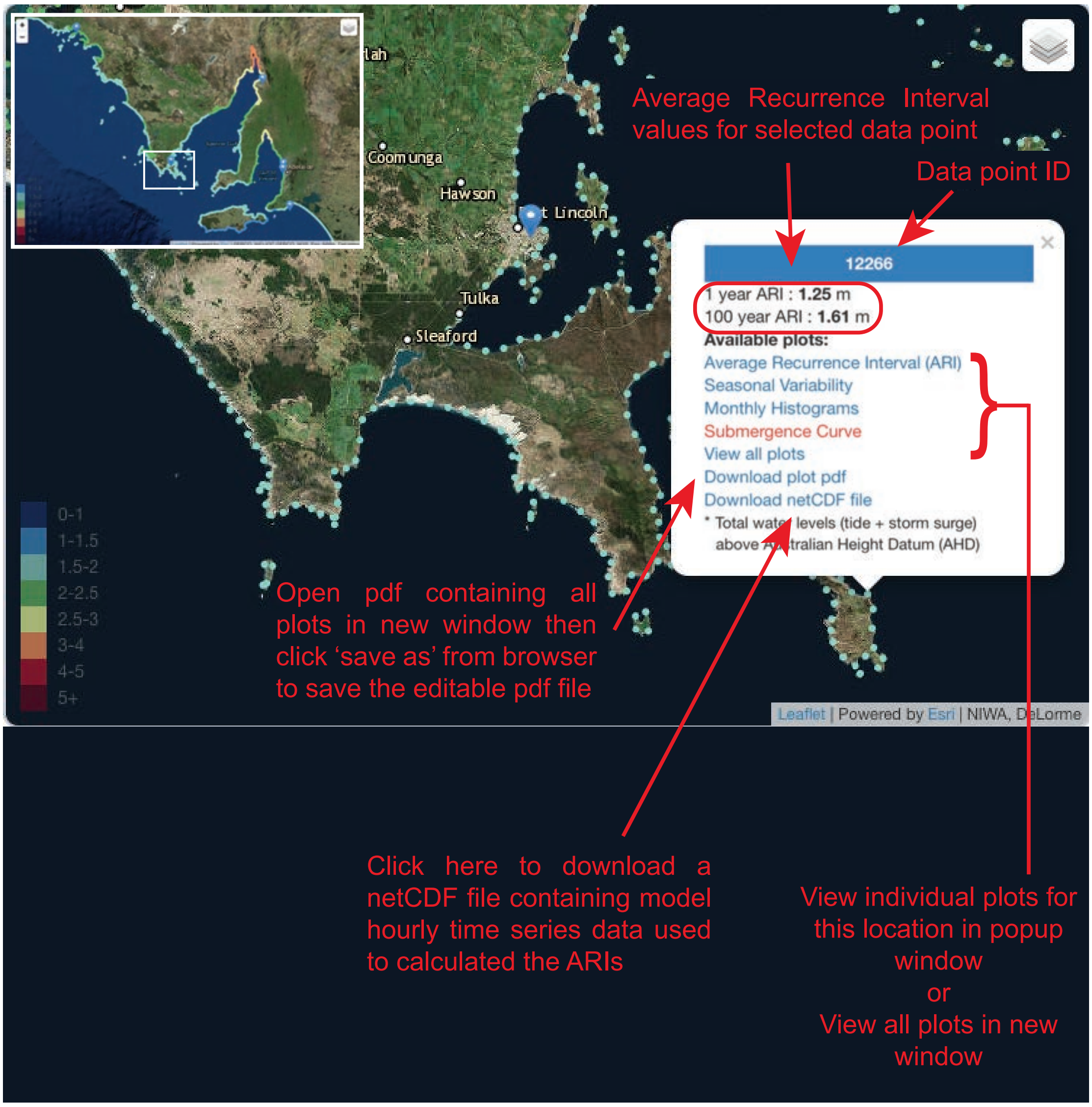

FIGURE 2. EXAMPLE ZOOM VIEW OF SOUTH AUSTRALIA SHOWING THE INTERACTIVE MAP AND POP UP WINDOW THAT APPEARDS WHEN THE USER CLICKS ON COASTAL DATA POINTS.

AVAILABLE PLOTS

Average Recurrence Interval Curves

The Average Recurrence Interval (ARI) curve with 95% confidence intervals (dashed lines) shown below indicate the highest total (tide+surge+MSL) water levels as a functon of ARI (return period) in years based on numerical model results (Figure 3). The dots indicate the annual highest predicted water levels after the Mean Sea Level trend was removed, which were used to calculate the curves. The spread of the 95% confidence intervals depends on the variability of the source data and the length of the series used, with lower confidence at longer ARIs. Red triangles indicate ARIs derived from synthetic tropical cyclone simulations [*Haigh et al.*, 2014a] and may better represent extreme sea level probabilities due to tropical cyclones. These values are only plotted when they exceed the ARIs in the Australia SCHISM model.

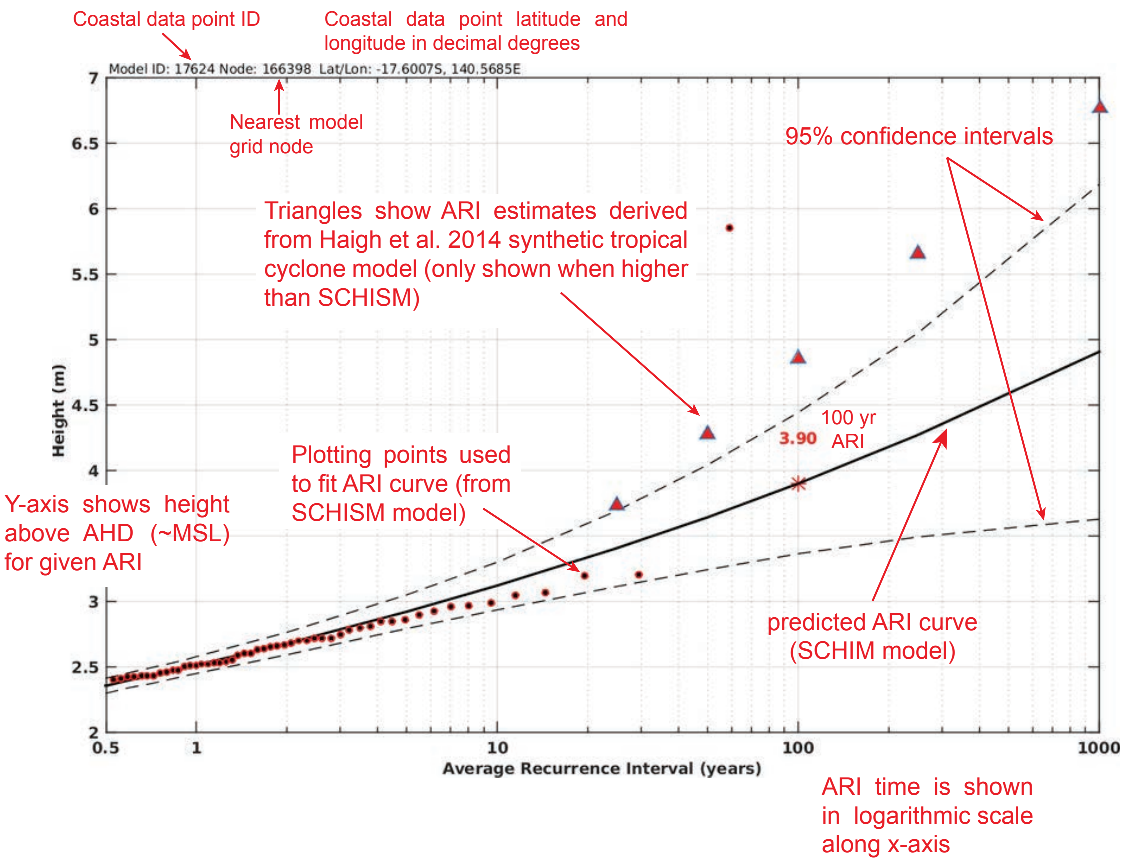

FIGURE 3. EXAMPLE PLOT OF ARI CURVE AVAILABLE (SHOWN FOR SITE NEAR KARUMBA, NT) FOR EACH COASTAL DATA POINT ON UWA/BNHCRC EXTREME SEA LEVEL WEBSITE.

Seasonal variability

Monthly indicator of likelihood sea level will occur (relative to AHD). Based on numerical model predictions of number of hours sea levels at given heights between 1958-2016 (Figure 4).

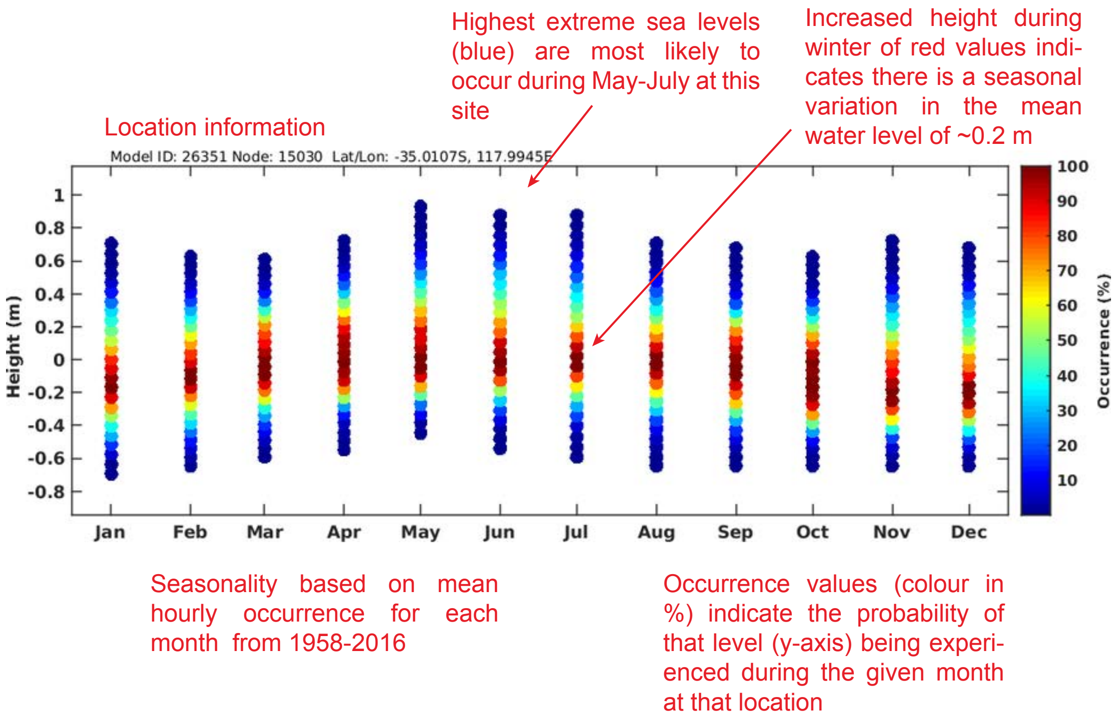

FIGURE 4. EXAMPLE PLOT OF SEASONAL VARIABILITY AND LIKELYHOOD OF OCCURRENCE AVAILABLE FOR EACH COASTAL DATA POINT ON UWA/BNHCRC EXTREME SEA LEVEL WEBSITE.

Monthly Histograms

Monthly histogram plots (Figure 5) show total counts of years where ARI levels were exceeded during each month between 1958-2016 in the SCHISM model. The plot gives an indication when extreme sea levels are likely to occur based on historical events. For the example shown below (Figure 5) sea levels for ARIs between 5-10 years (moderate extremes) have occurred during February, March, and April, whilst the largest event for this site (the 100 year ARI) occurred during December. This was due to a single tropical cyclone passing near the site. This can give an idea of how common it is for given ARIs to occur during a given month. For example, during April, the 5-year ARI was exceeded on average 10 times, the 10 year ARI 3 times, but the 50 or 100 year ARI was not exceeded during April. Total counts of events are likely higher than given values, since this plot shows monthly occurrence rather than counts of individual events.

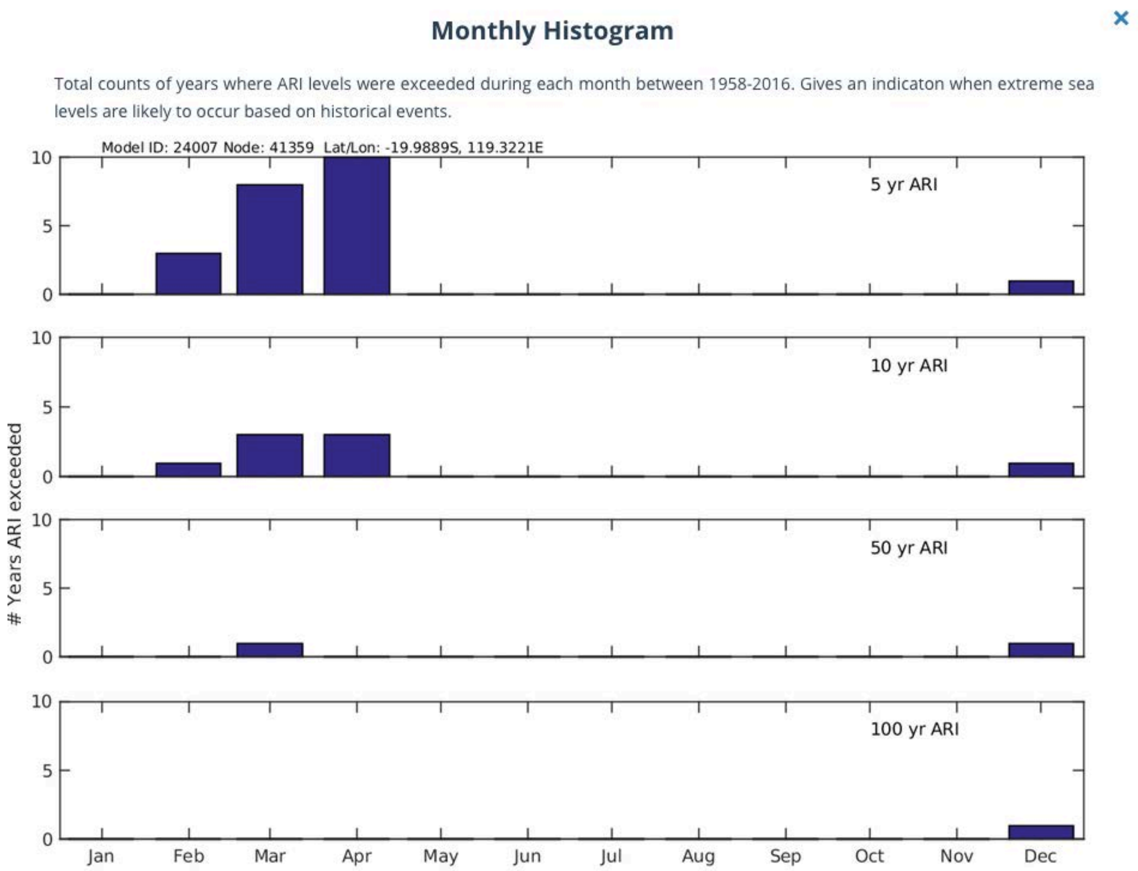

FIGURE 5. HISTOGRAM AVAILABLE ON THE UWA/BNHCRC WEBSITE INDICATING WHEN ARI LEVELS WERE EXCEEDED BETWEEN 1958-2016 IN THE SCHISM NUMERICAL MODEL SEALEVEL HINDCAST.

Submergence curves

Submergence curve (blue line) shows the percent of time (x-axis) sea levels are above given heights (y-axis) based on hourly time series from SCHISM model for most recent tidal epoch (1992-2011)(Figure 6). The form factor calculated from the tidal constituents is given for each location, and definitions for appropriate levels are given in (Table 1). Form Factor >0.5 indicates diurnal tide (one high and low tide per day). Form Factor <0.5 indicates semi-diurnal tide (two high and low tides per day). Note that these values have not been adjusted to fit nearest tide gauge data, whereas the ARI values derived from the model time series have been adjusted for the 1 year ARI levels – this explains some times low estimates of HWL and HAT. An estimate of the bias can be made by looking at ARI values < 1 year in ARI plots.

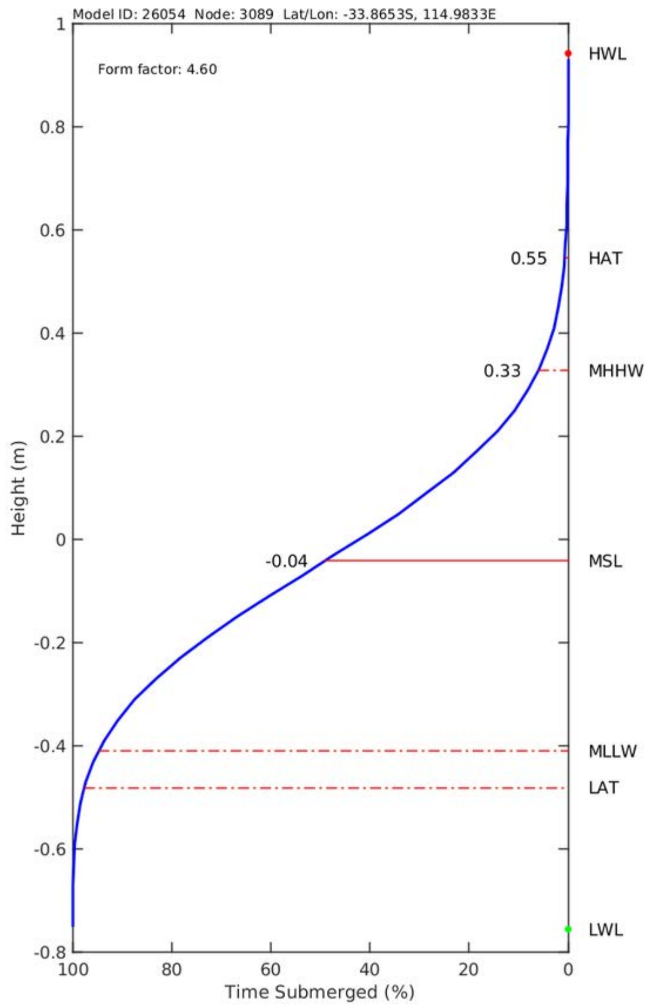

FIGURE 6. EXAMPLE SUBMERGENCE CURVE PLOT AVAILABLE FOR EACH COASTAL DATA POINT ON UWA/BNHCRC EXTREME SEA LEVEL WEBSITE. THE CURVE APPROXIMATES THE PERCENTAGE OF TIME THE SEA LEVEL WILL BE ABOVE VARIOUS LEVELS BASED ON NUMERICAL MODEL RESULTS.

TABLE 1. LEGEND FOR INTERPRETATION OF SUBMERGENCE CURVE PLOTS

Diurnal regions		Semi-diurnal regions (Form factor < 0.5)	
HWL	Highest total water level	HWL	Highest total water level
HAT	Highest Astronomical Tide	HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide	LAT	Lowest Astronomical Tide
LWL	Lowest total water level	LWL	Lowest total water level
AHD	Australian Height Datum	AHD	Australian Height Datum
MHHW	Mean Higher High Water	MHWS	Mean High Water Springs
MLHW	Mean Lower High Water	MHWN	Mean High Water Neaps
MLLW	Mean Lower Low Water	MLWN	Mean Low Water Neaps
		MLWS	Mean Low Water Springs

DATA DOWNLOAD OPTION FOR MODEL TIME SERIES

Hourly time series data from the SCHISM numerical model can be downloaded as netCDF files for each of the 31479 coastal data points. The data are relative to model mean sea level and have been adjusted to include the seasonal signal from AVISO satellite altimeter data. Since 1993 the seasonal signal was added directly and prior to that a mean seasonal signal was added based on the satellite data. This resulted in the best estimate of total sea level but may introduce a bias in deriving trends in the data. For this reason it is not recommended to use these data to determine tends in extremes. Please contact the data administrators if the raw model data are required. An example plot of total adjusted (black- the data available through direct download), total raw model (cyan), tide (blue), and non-tidal residual surge (red) are shown in Figure 7.

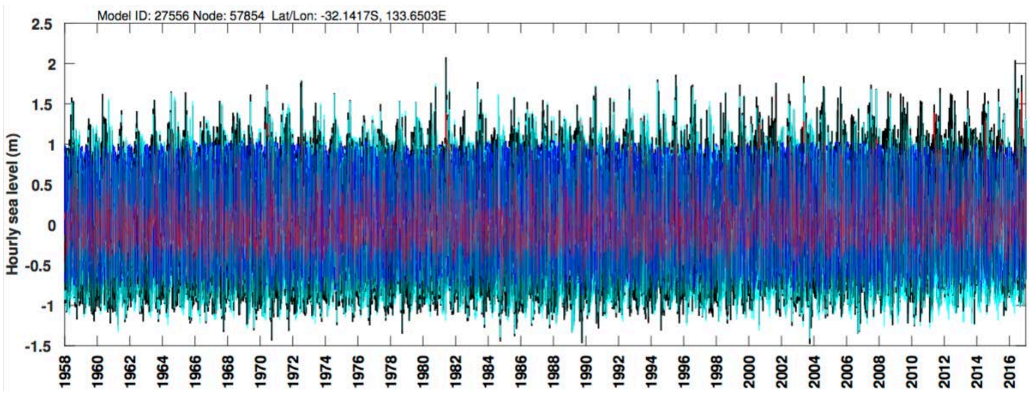

FIGURE 7. EXAMPLE TIME SERIES HOURLY DATA AVAILABLE FOR DOWNLOAD AT EACH COASTAL DATA POINT FROM THE UWA/BNHCRC WEBSITE. HERE, TIDAL ANALYSIS HAS BEEN PERFORMED ON THE DATA AND PLOTTED ARE: MSL ADJUSTED TOTAL WATER LEVELS (BLACK), PREDICTED TIDES (DARK BLUE), AND NON-TIDAL RESIDUALS (RED), AND RAW MODEL DATA (CYAN).

COMPARISON WITH TIDE GAUGE DATA

Clicking on any of the 28 blue markers at available tide gauge sites (Figure 8, Fort Denison, Sydney) allows the user to access the same plots and data as for the other coastal data points, but these values and plots are derived from the observed tide gauge data. Therefore, these locations provide important information for interpreting surrounding numerical model data points, which may have bias in some cases. This allows the user to decide how to interpret the extreme sea level statistics to suit their purposes.

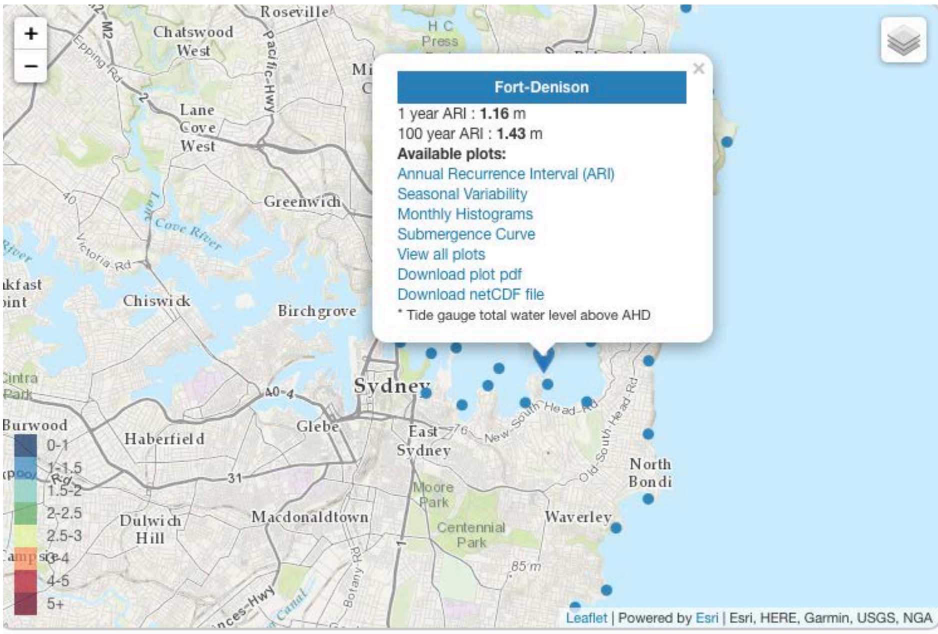

FIGURE 8. EXAMPLE POP-UP TEXT BOX SHOWING EXTREME SEALEVEL STATISTICS BASED ON TIDE GAUGE DATA AT SELECT SITES ENABLING THE USER TO COMPARE MODEL WITH OBSERVATIONS. TIDE GAUGE SITES SHOW A NAME OF THE SITE RATHER THAN COASTAL DATA ID.

ADDITIONAL APPLICATIONS

The ozsealevelx website does not contain information on **inundation**, however, a rough estimate of which populated areas might be inundated by extreme sea levels can be obtained by extracting the relevant water level from http://www.ozsealevelx.org and manually inputting the data to an interactive external web tool http://www.coastalrisk.com.au (not related to UWA/BNHCRC). This method does not take into account the dynamics of storm surge inundation events (e.g. duration of surge, waves, erosion, surface drag effects). Furthermore, the coastalrisk web tool uses a 'bathtub' GIS approach, where inundation simply occurs where land areas are lower than the given water level. Thus hydrologic connectivity between low lying areas and the ocean is NOT considered. Therefore, the user must be cautious when applying this method for a specific purpose. Still, the method described below may still be useful as a first estimate of flood risk from extreme sea level events. Note that the coastalrisk web tool is only available for major population centres. An example of this method is given below for the Adelaide region of South Australia considering a 100-year ARI sea level event.

Potential inundation (Adelaide, SA 100 year ARI 2.4 m)

1. Using a web browser, navigate to www.ozsealevelx.org and use the map to zoom in to Adelaide, SA.
2. Click on a coastal data point of interest (coloured dots) or the blue tide gauge marker to obtain the 100 year ARI water level (Figure 9). Comparing the model values to tide gauge values is useful to get an idea of the accuracy to the ARI if the tide gauge is located nearby. If the tide gauge is far from the area of interest, the model data point will provide the best estimate. Also, the ARI curve plot will give more information, and using the upper confidence interval will give a realistic conservative (upper bound) value.

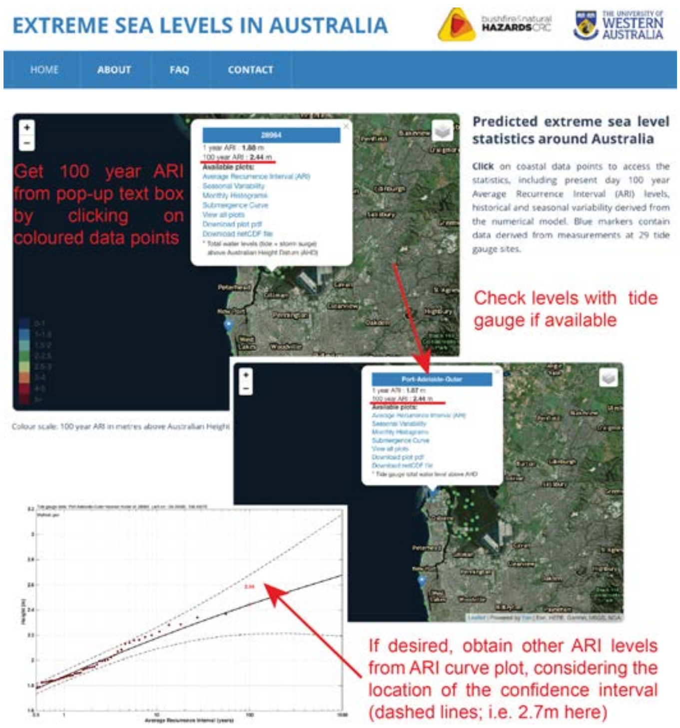

FIGURE 9. EXAMPLE FOR ADELAIDE; EXTRACTING 100 YEAR ARI LEVEL TO BE USED FOR INUNDATION ESTIMATE.

3. Open a new web browser page for http://www.coastalrisk.com.au and accept the terms of use. Use the map controls to navigate to the Adelaide region.

4. On the left hand side of the web page, select 'Manual' control to access a slider that you can drag to the right to input the 100 year ARI (or other ARI), 2.4 m in this case (Figure 10).

5. The map now displays inundated areas with blue colour, and this gives a rough estimate of areas potentially inundated by a sea level 2.4 m above MSL (assumed to be equivalent to AHD) (Figures 10-13).

- Special caution should be given to areas that are not clearly hydrologically connected to the ocean. For example, some areas are surrounded completely by dry land and although they are lower than the sea level, they are very unlikely to be flooded by the ocean (Figure 11).
- Note also that the sea levels may be lower in areas restricted by topography that were not resolved by the SCHISM model (i.e. far up the river) so the inundation visualised in the web tool is likely more than would be realized in such an event (Figure 11).

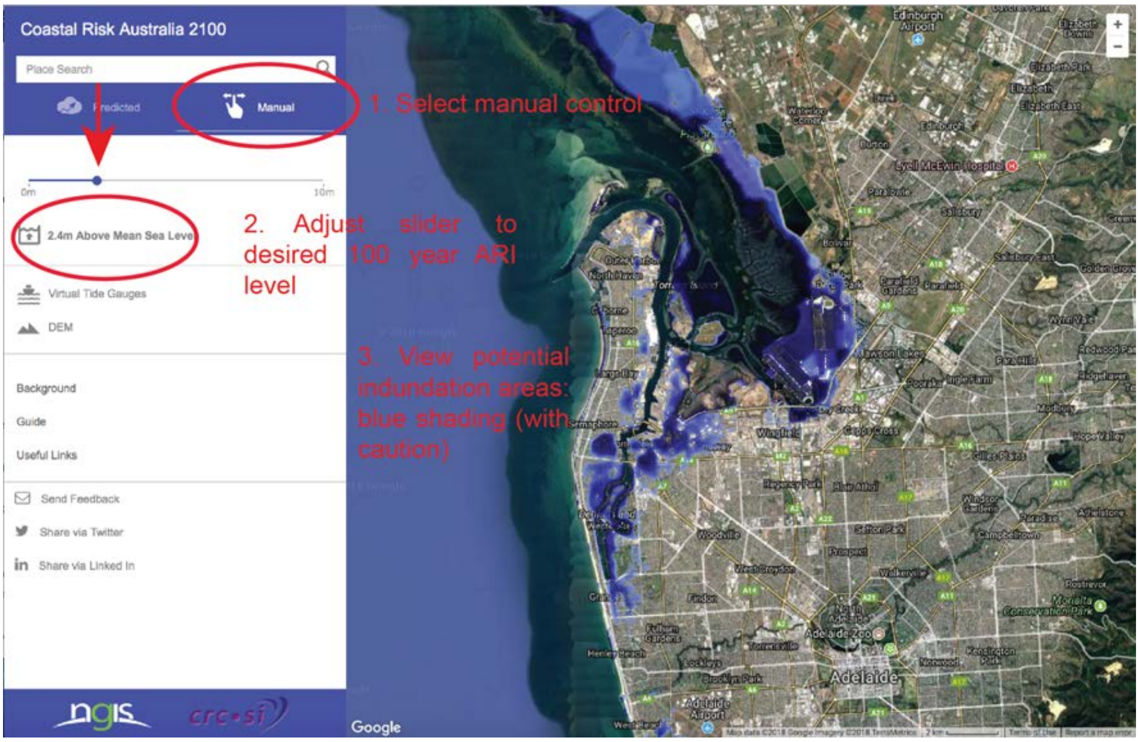

FIGURE 10. EXAMPLE OF HOW TO VISUALISE POTENTIAL INUNDATION FOR 100 YR ARI FOR ADELAIDE REGION USING EXTERNAL INTERACTIVE WEB TOOL: HTTP://WWW.COASTALRISK.COM.AU .

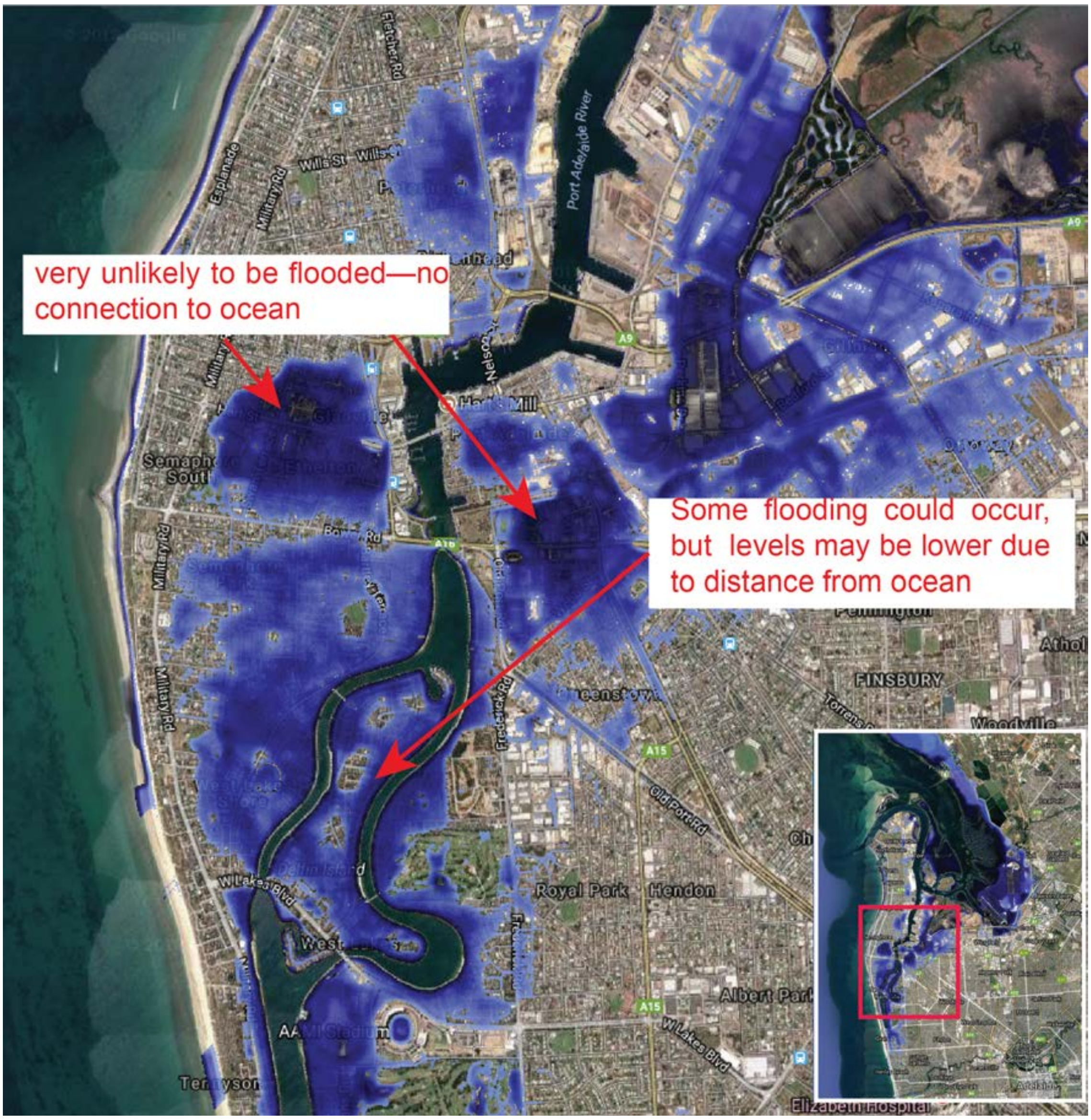

FIGURE 11. ZOOM VIEW OF POTENTIAL INUNDATION IN CENTRAL ADELAIDE FOR 100 YR ARI (2.4 M) EVENT, SHOWING AREAS WHERE THE BATHTUB METHOD MAY CAUSE ERRORS AND SHOULD BE INTERPRETED WITH CAUTION.

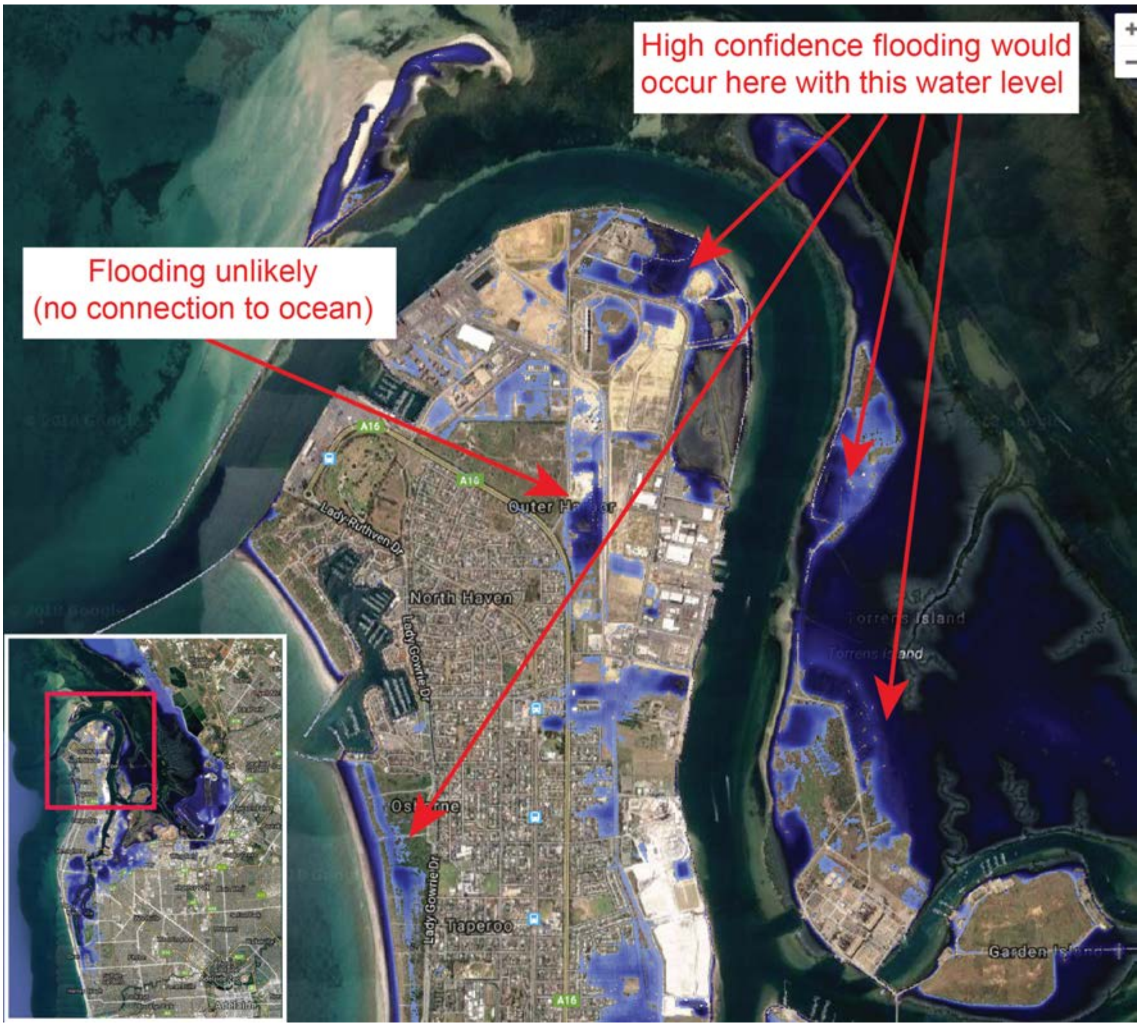

FIGURE 12. ZOOM VIEW OF POTENTIAL INUNDATION IN AROUND NORTH HAVEN AND OUTER HARBOUR FOR 100 YR ARI (2.4 M) EVENT, SHOWING AREAS WHERE THE BATHTUB METHOD MAY CAUSE ERRORS AND SHOULD BE INTERPRETED WITH CAUTION, AND AREAS WHERE CONFIDENCE IS HIGH.

FIGURE 13. ZOOM VIEW OF POTENTIAL INUNDATION IN GREEN FIELDS AREA OF ADELAIDE FOR 100 YR ARI (2.4 M) EVENT, SHOWING LOW-LYING AREAS WHERE INUNDATION IS LIKELY FOR THIS WATER LEVEL.

Other possible applications of the ozsealevelx.org website

1. Using a web browser, navigate to www.ozsealevelx.org and use the map to zoom in to Adelaide, SA.

Example utilization scenarios

1) Emergency planners in coastal town need to plan evacuation routes but lack engineering and modeling resoutrces
    a. Emergency manager uses UWA Extreme sea level web portal to click on a map to get the best estimate of 1 in 100 year water for the location of interest.
    b. They are also given the historical context for this water level (e.g. a plot of dates of events when this water level was exceeded in the past).
    c. The time of year when this water level is most likely to occur is also given.
    d. For a first guess as to areas likely to be inundated from this event they are prompted to visit the Coastal Risk Australia web tool (http://coastalrisk.com.au) with an explanation on how they can manually input this water level see a map of estimated inundation.
    e. If they require more detailed inundation analyses they (or a consultant) can follow web links to download UWA hydrodynamic model data to force an inundation model.

2) Emergency personnel are confronted with a real time storm surge forecast (by BoM soon to be released) of 1.5 m. What does this mean?

1) A quick review of extreme water level statistics by clicking on a map available on the UWA sea level web site indicates that this is a 1/10 year event. They decide only minimal preparation is necessary.
   Or

2) The same quick check reveals that it is a 1/100 year event and emergency planning must begin

* All content, information, data, technology and other material found or accessed on the http://www.ozsealevelx.org website are made available for informational purposes only. The user assumes all risk associated with use, possession or reliance on content.

REFERENCES

Haigh, I., L. MacPherson, M. Mason, E. M. S. Wijeratne, C. Pattiaratchi, R. Crompton, and S. George (2014a), Estimating present day extreme water level exceedance probabilities around the coastline of Australia: tropical cyclone-induced storm surges, *Clim Dyn*, *42*(1-2), 139-157, doi:10.1007/s00382-012-1653-0.

Haigh, I., E. M. S. Wijeratne, L. MacPherson, C. Pattiaratchi, M. Mason, R. Crompton, and S. George (2014b), Estimating present day extreme water level exceedance probabilities around the coastline of Australia: tides, extra-tropical storm surges and mean sea level, *Clim Dyn*, *42*(1-2), 121-138, doi:10.1007/s00382-012-1652-1.