13 HYDRAULIC MODELLING

13.1 Hydraulic Modelling Software

The two-dimensional hydrodynamic modelling software XP-SWMM2D is internally coupled with the TUFLOW numerical engine. This enables fully dynamic modelling of stormwater systems and rivers/creeks in 1d, 2d or combined 1d/2d models. The modelled stormwater systems can also include floodplains, ponds, basins, culverts, bridges and underground drainage such as pit and pipe networks. The models may be used for the analysis or design of existing or proposed drainage networks.

The software accurately models backwater effects, flow reversal, surcharging, pressure flow and tidal outfalls and interconnected ponds. The model allows for looped networks, multiple outfalls and accounts for storage in conduits.

The two-dimensional analysis programs such as XP-SWMM2D use the topography in conjunction with continuity and momentum equations to assess the true direction of floodwater as it travels across the floodplain.

Two-dimensional modelling offers significant advantages over the 1D model technique for the reasons outlined below:

- Accurate representation of overland flowpaths based on the topography (DTM), avoiding conceptualization specific to 1D models.
- Accurate representation of the complex distribution of flows in the network of flowpaths, which can vary with storm magnitude.
- More accurate determination of the active part of the floodplain and the delineation of the extent of the floodway zones. In 2D modelling the velocity is allowed to vary laterally across the floodplain.
- More accurate determination of the floodplain storage zones.
- Assessment of impact of major developments, buildings or vegetation along active flowpaths on flooding behaviour.
- Assessment of impact of existing and proposed levees on flooding behaviour in terms of flood levels, flow and velocity distribution.
- Demonstrates the role of flow structures, bridges, culverts, embankments and levees in the distribution of flows across the floodplain by animations of floods across the floodplain.
- Enhanced graphical presentation particularly useful in presentation of results to the Flood Plain Management Committee or in public meetings.
- Ability to include the rainfall-runoff process directly included into the hydraulic modelling.
- Use of dynamic elevation shapes that can change over time for breaching of levees and sandbars with impacts on the 2d model domain.

13.2 XP-SWMM2D Model Setup

13.2.1 Model Configuration

2D Domain

The geometry of the 2D model was established by constructing a uniform grid of square elements based on the Digital Terrain Model (DTM) created from the obtained topographic survey data. The key considerations in establishing a 2D hydraulic model relates to the selection of an appropriate grid element size. The grid size affects the resolution, or degree of accuracy, of the representation of the physical properties of the study area. Selection of the grid element size depends on the size of the computer model and its resulting run times, as selecting a very fine grid element size will result in both a higher resolution and longer model run times.

In determining the element size for the 2D model, the above issues were considered, in conjunction with the final objectives of the study. Given the relatively large size of the study area, run times of the model were still of an acceptable length for a grid element size of 25m. This element size over the study area provided a good definition of the available topography of the floodplain required for modelling. The corresponding time step used to stabilise the model and produce reasonable results was 1 second.

1D Domain

Although considered to provide a good resolution for the general floodplain within the project site, the 25m element size could not provide a good definition of the rivers within the 2D model. Consequently, a dynamically nested one-dimensional (1D) network including the rivers and bridges was embedded into the 2D model to improve the definition of the associated water flows.

The 1D river network was based on the river bed cross-sections from either the ground/bathymetric survey, DTM or interpolations. An earlier assessment of the DTM prepared from the Council's LiDAR survey had confirmed that the DTM provided a good representation of the river bed geometry upstream of the zone of tidal influence, as the river bed in this area was relatively dry during the LiDAR survey, and as such was used for extraction of required cross-sections for modelling.

The DTM representation of downstream river sections (within the zone of tidal influence) was less accurate and could not be applied without significant adjustments. Modelling of the river bed based on applying the cross-sectional data to the length of the river between the surveyed cross-sections provided inadequate results with large vertical drops at the section ends. To increase the resolution of the 1D network in this area and smooth differences in cross-sectional shape and depth at transitions between adjoining river segments, lengths of the river between the surveyed cross-sections were additionally interpolated utilising HEC-RAS modelling software. Where required, these cross-sections were manually adjusted to assure that the width of the section matches the river extents. This approach provided satisfactory definition of the river bed required for input in the model and avoided additional costly bathymetric survey.

The nesting of the 1D network into the 2D domain allowed for a dynamic interaction between the 1D and 2D elements. Provided there was adequate capacity in a specific 1D element, such as a river channel, floodwaters would flow into it from the adjacent overland flowpaths. Wherever the capacity of the 1D network was exceeded, overflow would reverse back onto the flowpath (the 2D domain), providing a full interchange of flows between the 1D and 2D domains.

13.2.2 Classes of Entrances and their Modelling

Rivers influenced by ocean and tidal effects can be categorised into four general categories. These include:

- Class 1 – catchments that drain to a coastal lake
- Class 2 – catchments that drain directly to the ocean via trained or otherwise stable entrances
- Class 3 – catchments that drain directly to the ocean via shoaled entrances, or
- Class 4 – catchments with normally closed or partially blocked entrances.

An inspection of aerial photography indicates that the berm significantly encroaches on the entrance/river outlet indicating that Class 4 may be appropriate. However photography of the flood passing the February 1971 and March 2011 events indicates that these floods passed with a wide opening and that the entrance may be considered to be of Class 3 variety.

The entrance geometry (morphology) can be modelled as a simple fixed entrance condition or more sophisticated dynamic scour condition where the geometry changes over time. In this Flood Study the historic flood events applied a fixed geometry altered against available calibration data. The design flood events applied a dynamically variable geometry, were historic events and aerial photos were used to assist in the development of physical limits of entrance variability.

13.2.3 Boundary Conditions

The hydraulic model is governed by boundary conditions that occur at both the upstream and downstream extent of the model. The upstream boundary condition to the model incorporated the flow data for the modelled storm, including both the historic and design events. The upstream boundary conditions were represented by the hydrographs obtained from the hydrologic model.

The Candelo model primarily included Candelo Creek with hydrographs at the upstream boundary and a rating curve at the downstream boundary in a 1-dimensional, unsteady state model. The Bega/Brogo River model is a larger and more detailed 1d/2d - unsteady flow model with river hydrographs used as inputs at the upstream end, lateral catchment hydrographs at several locations between the upstream end and Mogareeka and a time series of ocean water levels at the downstream end.

Ocean water levels for the modelling of historic flood events data were sourced from OEH as owners of the data. The data was obtained through the Manly Hydraulic Laboratory (MHL) as the organisation responsible for collection and releasing the data. A thorough search of historic water level sites was undertaken for the modelling of the tailwater conditions of the historic flood events. Sites that were searched included:

- local ocean tide sites (particularly Bermagui-Live, Eden-Live) – used for February 2010, March 2011 events
- nearby sites up and down the NSW coastline (where local sites were not available)
- archived sites (particularly Eden-Snug Cove) – used for March 1983 event
- where no water level sites were available as in the case of the February 1971 event, an assumed tailwater level was applied based on the nearest observed levels.

Although the archived site at Eden-Snug Cove was relatively close to the Bega River location this data was not quality coded due to an absence of a recorded datum. An assumed datum was used for the March 1983 dataset from the nearby station at Two-fold Bay near Eden that records present day levels further south of Mogareeka.

The February 1971 was the largest historic flood event with continuous river flow data available and was included in assessment for this study as it was considered to be an important historic flood event, although only an assumed tailwater could be established for it.

13.2.4 Site Specific Analysis of Ocean Levels

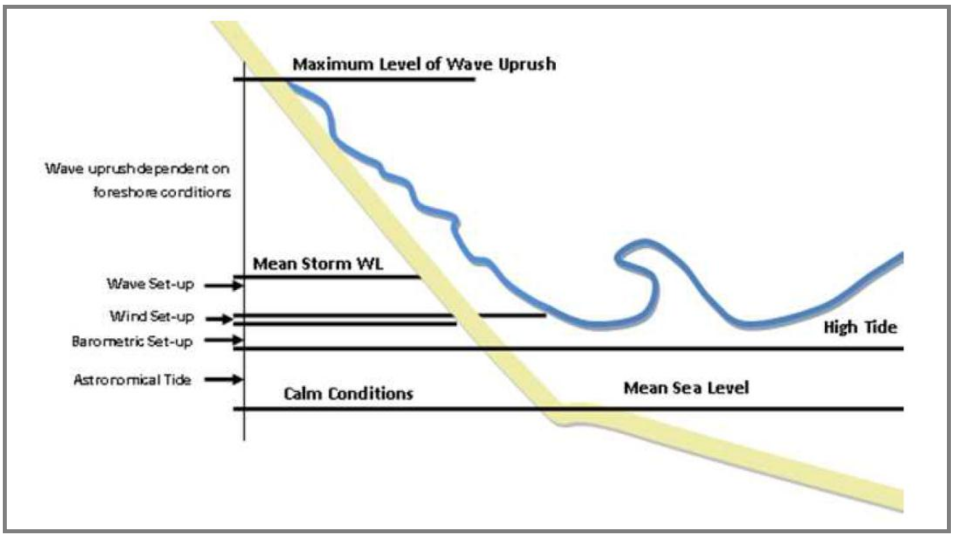
There are three principal options for determination of downstream ocean levels for design flood events, based on the Flood Risk Management Guide (OEH, 2010). These include:

- a conservative assumption for the 1%AEP water level (constant 2.6 mAHD) for a catchment that drains directly to the ocean (i.e. does not drain into an ICOLL or tidal waterway)
- a default dynamic open-ocean water level that varies in time with a dynamic peak of 2.6 mAHD for 1%AEP conditions (Fig 15.3)
- a detailed site-specific analysis of elevated water levels at the ocean boundary at the entrance including components such as tides, storm surge, etc.

Tailwater levels can depend on a number of factors, namely:

- tide,
- tidal anomaly caused by barometric and wind setup (storm surge), and
- wave setup which is caused by wave breaking at the entrance and is dependent on the incident wave climate.

Figure 13.1: Components of Elevated Water Levels on the Coast (Adapted from NSW Government, 1990)



Tidal levels are a result of astronomical forcing and are therefore statistically independent of a storm event. However, wind setup (piling up of wind against the shoreline), barometric setup (increase in water levels as a result of low barometric pressure) and wave setup (increased water level caused by breaking waves) are all statistically related to storms which cause flood events as these events are often caused by the same weather systems. An additional component can include the effects of increased levels associated with sea level rise.

A site specific analysis or a default relationship can be used for setting downstream boundary conditions to the hydraulic model, both of which are sourced from the same OEH guideline. (OEH, 2010). The OEH guidelines recommend site specific analysis to provide refined and more detailed estimates. The default levels provide a simpler more readily available approach that is more conservative. More details on estimating the applicable ocean levels are provided in Section 15.3 and Appendix B.

13.2.5 Surface Roughness

Based on the aerial photographs submitted by Council, the modelling area was categorised into the following major land uses:

- roads
- pasture
- trees
- urban
- creeks

These categories provided a basis for the establishment of the roughness required for modelling. Different surface material types were identified for the setting of Manning's roughness 'n' values for the initial modelling runs, based on the sourced technical literature.

Some of the roughness values were established as a composite roughness value to allow for variations in roughness within the specific land use category. For example, the roughness used for a typical residential (urban block) category represents a composite roughness value that covers a combination of grassed and paved surface treatment, buildings within the block and, in particular, fences.

The adoption of specific roughness values will be further discussed in the later sections of the report.

13.2.6 Modelling of Hydraulic Structures / Bridges

Hydraulic structures were incorporated as 1d elements at the following locations:

- New Princes Highway
- Old Princes Highway (for February 1971 historic event)
- Tarraganda Lane – Bega River
- Tarraganda Lane – Bega River anabranch
- Jellat Jellat weir
- Tathra- Bermagui Bridge at Mogareeka – Bega River
- Bridge at Candelo – Candelo Creek

Where available design drawings were used to represent the cross-section shape of the structure at the time of the historic flood. For more recent events and for design events the recently updated survey of the bridges was used to define the shape of each structure. Blockages of structures in historic events were incorporated by increasing roughness coefficients to reduce the conveyance capacity of flow through the bridge, and piers were also included.

13.2.7 Princes Highway Upgrade

The design of the upgrade was undertaken by GHD and "issued for construction" (RTA, 2011). As required by the NSW Floodplain Development Manual, this would require a comparison of flooding under post-upgrade and pre-upgrade conditions to confirm any potential increase in flood levels (or afflux) and flow hazard within the study area. The scope of this study was to provide flood results for pre-upgrade conditions.

13.3 Candelo Creek Model

The Candelo Creek was modelled using a 1 dimensional, unsteady flow model. The surveyed cross-sections were used to set up the entire hydraulic model opposed to using a 2d model based on a DEM (Digital Elevation Model). This approach was utilised as there was no DEM available for the Candelo area. A plan view of the cross section layout used for modelling is shown below.

Figure 13.2: Layout at Candelo Creek