APPENDIX 11

ADDITIONAL MODEL CALIBRATION – ORANGE TEST VELOCITY

This Appendix provides technical details of the additional model calibration on velocity in the Haven undertaken by Mott MacDonald. The following summary details model performance and calibration results in terms of replicating the observed velocity values from survey data.

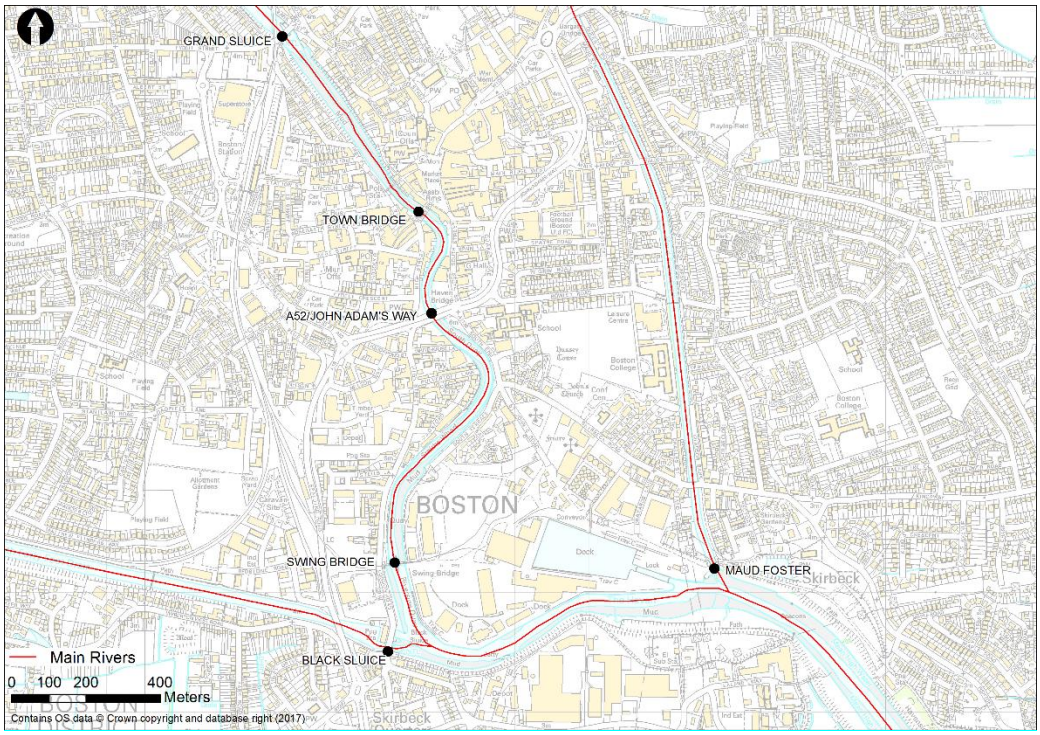
1 Calibration of 2D hydraulic model of the Haven to 28th October 2011 Observations (Orange Test)

Velocity measurement taken on 28th October 2011

1.1 One measure of flow behaviour which was used for calibration is water velocity. By taking measurements of the real world velocity, data is generated which can be used to draw comparisons with model results for velocity. This reveals the accuracy/validity of the model, or suggests tuning of the model is required for a better match.

1.2 In order to determine the flow pattern and the magnitude of the velocity in the Haven, on 28 October 2011 CH2M undertook a standard velocity test using an orange within the peak velocity path at the Swing Bridge on the Haven. This was during an ebb tide when the highest velocity would occur during a typical tide cycle. The location of the Swing Bridge observation is shown in Figure A11-21.3 below.

Figure A11-1 Key Locations in the Haven



1.3 The velocity (speed) data from the orange test was determined by implementing the following methodology:

1.3.1 An orange was thrown into the current at the measurement location every 5 minutes when there was no boat passing;

1.3.2 The time was measured for that orange to reach the end of the segment, and;

1.3.3 The time taken to travel the segment was divided by the distance travelled to observe the velocity (speed)

1.4 From the Swing Bridge superstructure, the red and green lines indicated in Figure A11-21.3 below indicate the path the orange travels, upstream and downstream segments respectively.

Figure A11-21.3: Location of Extracted Results at Swing Bridge

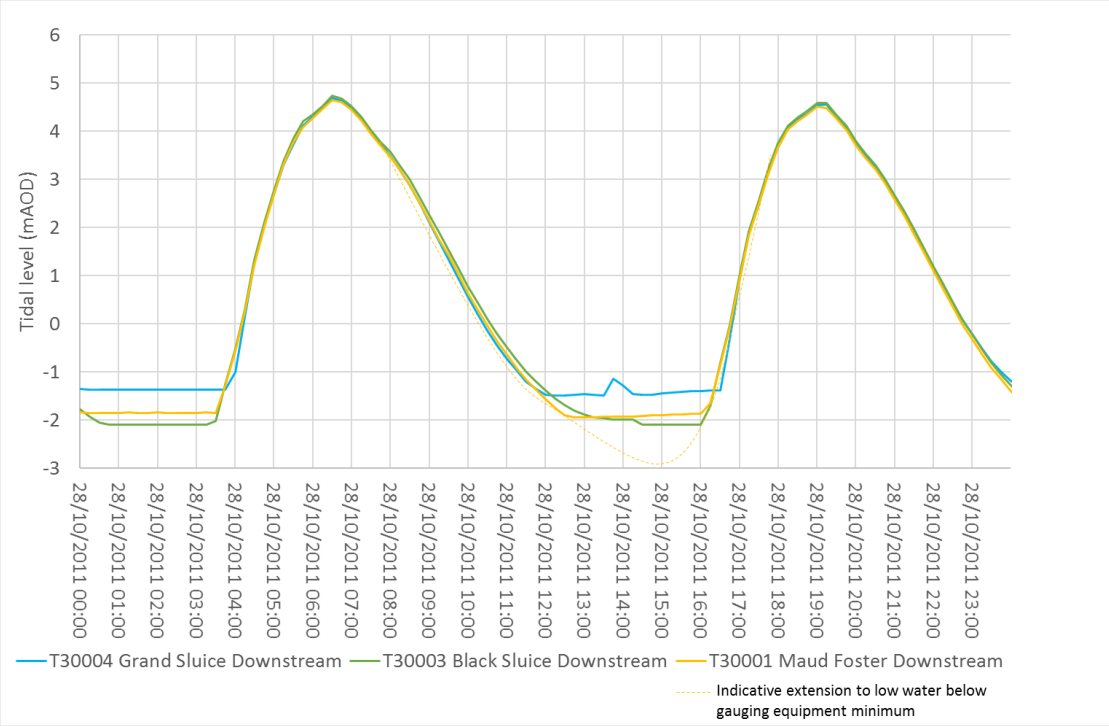
Plate G-1: Location of orange test.

1.5 The recorded tide information at Grand Sluice, Black Sluice and at Maud Foster provides tide levels for the duration of the 'Orange test' measurements. This data represents the conditions in the Haven throughout the measured velocity results. The plot in figure A11-3 below indicates the change in water level over time at the three locations.

1.6 It can be seen in the water level gauge readings that toward the bottom of the tidal level scale readings cease to be logged and the curve is flat (non-continuous). This is a result of the water

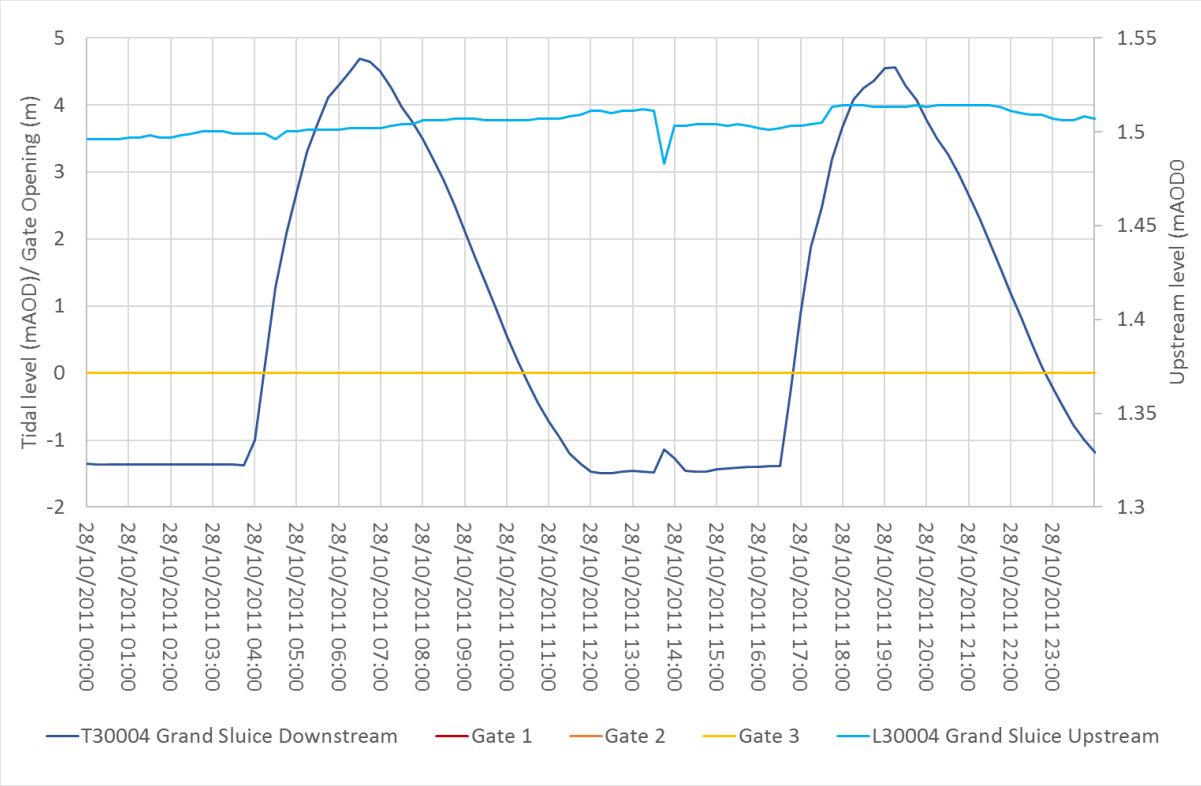
level dropping below the bottom of the gauge reading limit. The dashed line in Figure A11-3 is inferred information only, indicative of the profile extension below this minimum gauge level.

Figure A11-3 Gauge data for water levels in the Haven on 28/10/2011



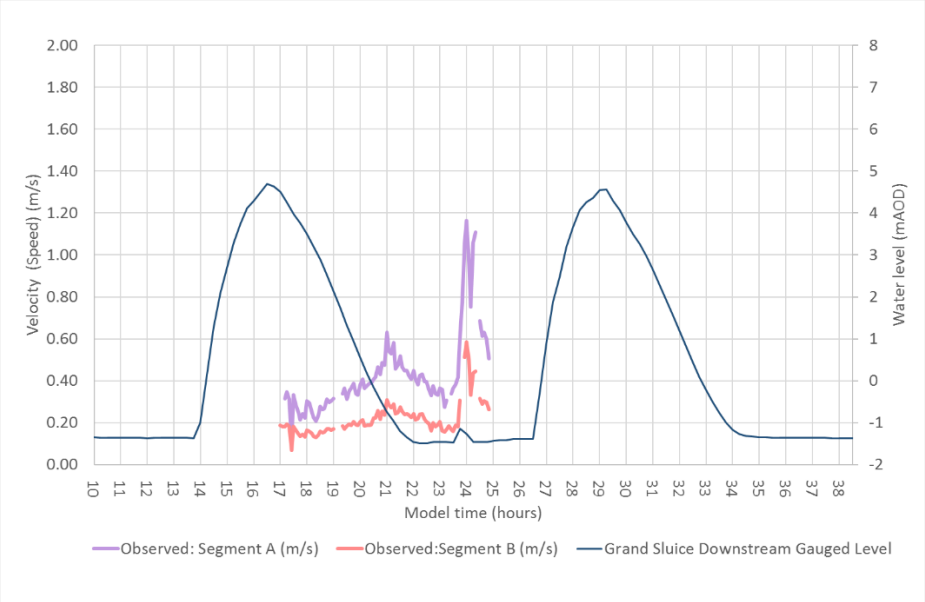
1.7 The corresponding records for the tide level and gate opening width at Grand Sluice provides tide levels and gate opening widths for the duration of the 'Orange test' measurements. The plot in figure A11-41.7 below indicates the change in water level over time at Maud Foster, and a constant gate opening width of zero metres, i.e. closed.

Figure A11-41.7 Gauged Water levels and gate opening at Grand Sluice on 28/10/2011



1.8 The plot in Figure A11-51.3 below indicates both the water level and the observed velocity, over time. The following velocity trends can be seen: i) Velocities reach a peak when the water level is drawn down as water leaves the Haven out towards the sea, and; ii) Velocities are at a minimum as the tide changes from flood to ebb, when slack water occurs.

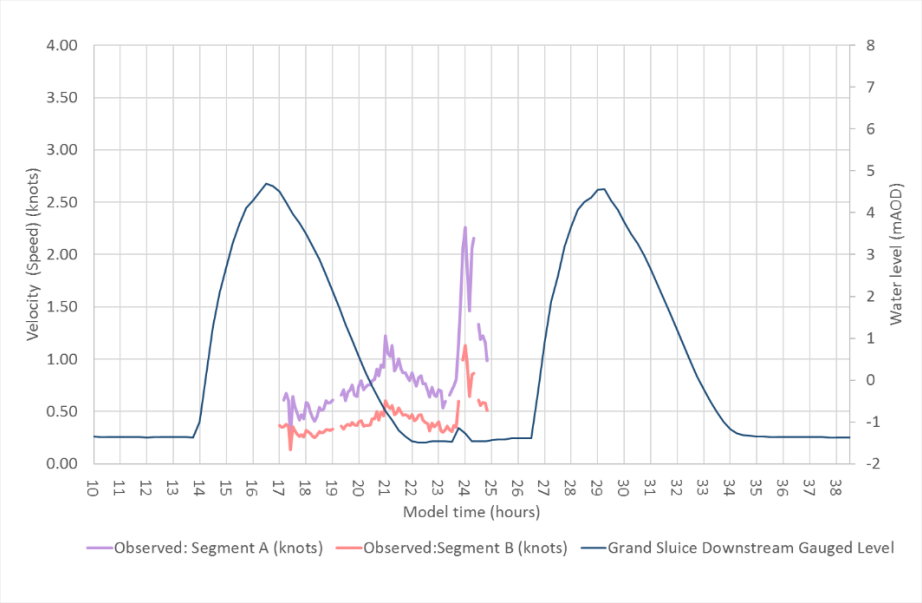
Figure A11-51.3 Observed Velocity (speed) and Grand Sluice Level 28/10/2011



1.9 The same plot is shown below in Figure A11-61.9 with the velocity scale converted to knots. The observed velocity was recorded between 0.1m/s-1.16m/s as stated in Table G-1 of Phase 1 Hydraulic Modelling Report that provided the underlying evidence for the Boston Barrier PAR

(CH2MHILL, 2013). However, the previous PAR study incorrectly converted the observed velocities from metres per second to knots to estimate knots more than three times larger than they should have been. The observations have been corrected by the TWAO based on the standard conversion factor of 1m/s:1.94384 knots. As a result, the maximum velocity in knots reduces from 7.8 knots down to 2.3 knots.

Figure A11-61.9 Observed Velocity (speed) and Grand Sluice Level 28/10/2011



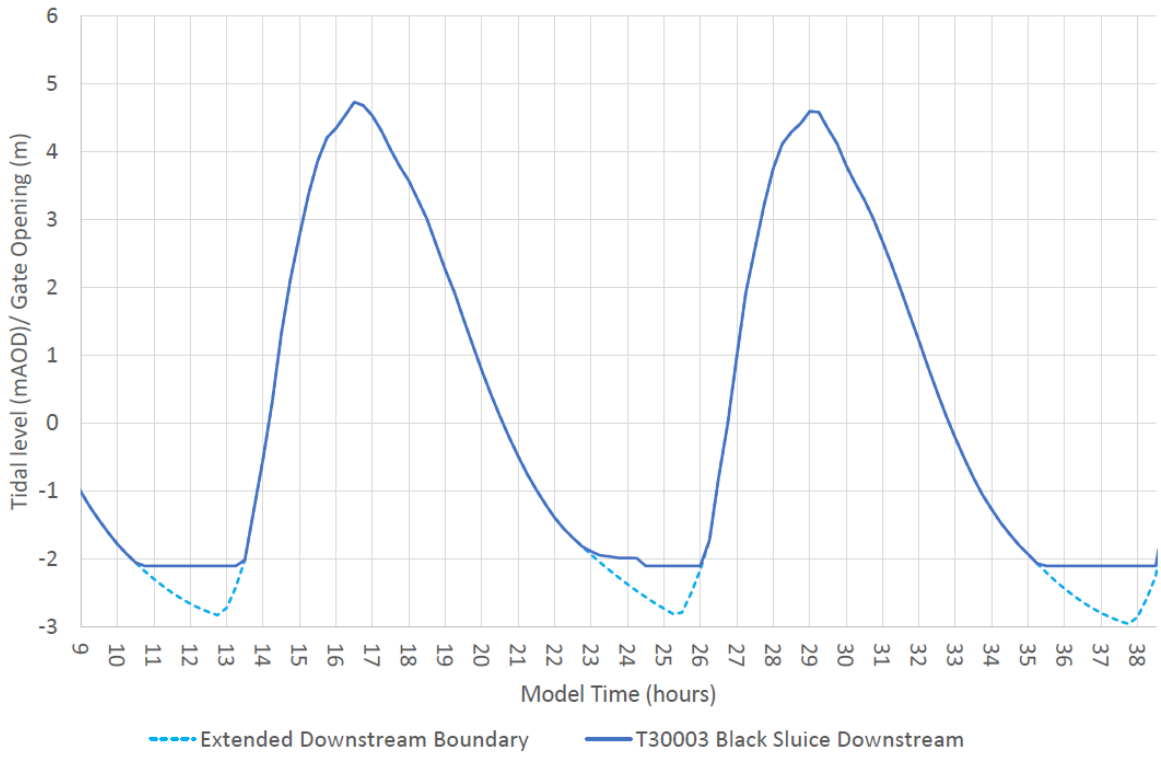
1.10 The highest velocities observed coincide with a sudden increase in the water level at Grand Sluice during the low water period. However, the Grand Sluice records indicate that the sluice gates were 0% open. There is no supplementary evidence to support why there was a sudden increase in water level corresponding with a sudden increase in velocity.

Model configuration

1.11 The model was configured with upstream flows taken from the gauged data at Grand Sluice and Black Sluice, and downstream tidal boundary based on the tidal water level data from Maud Foster.

1.12 The tidal information was extended for low water levels as discussed earlier. This accounts for the situation where the gauged water level information is incomplete due to water levels below the recording range of the gauge equipment. Figure A11-7 below indicates the extension of the water level curve to the elevations below the bottom of the equipment.

Figure A11-7 Extension of water level plots below base of gauge equipment



1.13 The model has considered two scenarios to replicate the velocity profile observed:

(a) Model configuration based on the quality assured gauge records from the Environment Agency (i.e. no flow at 28/10/2011 13:45 or 23.75 hours model time)

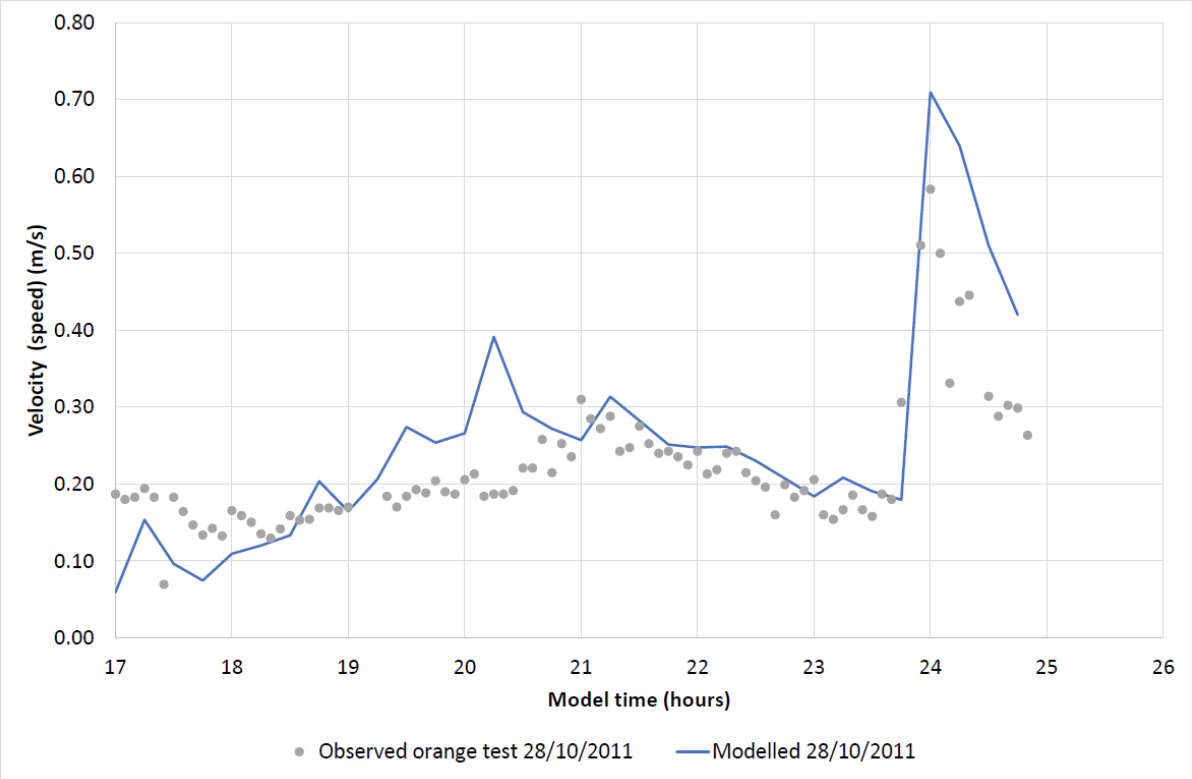
(b) Model configuration based on the observation of a large spike in the river flow at 24hours. Configuration was made using the quality assured gauge records from the Environment Agency, supplemented with a synthesized flow to replicate the apparent sudden increase in downstream water levels (i.e. a flow of approximately 26 m^3/s at 28/10/2011 13:45 or 23.75 hours model time).

1.14 Velocity results from the model simulations were obtained at the locations of each of the segments where orange velocity observations were made. The modelled and observed velocities were plotted against one another.

Model Results

1.15 In both cases with and without a Grand Sluice release, the modelled velocities at Swing Bridge are broadly comparable in terms of magnitude and time-profile with the observed velocities. (Figure A11-8).

Figure A11-8 Modelled Velocity compared with measured data



1.16 It is seen on the graph above, prior to the 24 hour mark, the observations (and modelled flow) indicate a consistent velocity profile. At the 24 hour mark a significant increase in river flow velocity was observed with a higher flow passing the Swing Bridge observation location.

1.17 The source of the sudden release of flow at Grand Sluice is not documented. The Port of Boston advice to mariners does warn of sudden releases from the Grand Sluice lock gate. This would be consistent with the sudden decrease in water level upstream and increase in water level downstream and 0m sluice gate opening seen in Figure A11-4. However, without visual observations or historic boat movements on 28/10/2011 we cannot confirm the source of the apparent sudden release of flow.

1.18 A synthetic release of flow at Grand Sluice replicated the sudden spike in velocities observed on 28/10/2011. This was achieved in the model by producing a supplemented flow at Grand Sluice to create the increase in river flow as observed from Swing Bridge during the Orange Test. However, velocities are slightly overestimated by approximately 0.1m/s at the spike due to the uncertainty on the exact size of the flow release.

<u>Conclusion</u>

1.19 After calibration of the model to gauged water level information, the comparison of the modelled velocity with the observations of the 'orange test' validate the model performance. The model broadly reproduced the observed velocities prior to the sudden increase detailed above. By supplementing the release of flow from Grand Sluice with the additional flow volume, the model replicated the spike in velocities at Swing Bridge.