Long-term Morphology Modeling of Barrier Island Tidal Inlets

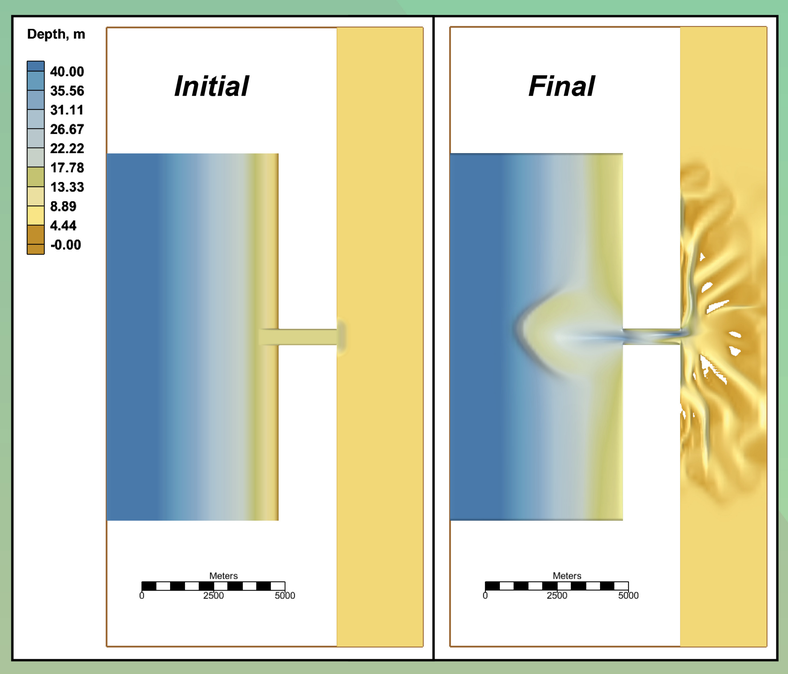
Richard Styles[1], Mitchell Brown[1], Katherine Brutsché[1], Honghai Li[1], Tanya Beck[1], and Alejandro Sanchez[2]

[1]U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory (USACE-ERDC-CHL), [2]Hydrologic Engineering Center (HEC), Institute for Water Resources

INTRODUCTION

The primary focus of this study is to validate the Coastal Modeling System (CMS) for long-term applications through simulations of tidal inlet formation, evolution and maintenance. A wide range of conditions are chosen to test the breadth of model applicability including varying waves, tide and inlet geomorphic characteristics. The model is run for an effective 100 years using a morphology acceleration factor of 10 with 10 years of forcing. The resulting morphological state is gauged in terms of inlet stability theory.

IDEALIZED INLET – HUMBOLDT INLET, CALIFORNIA

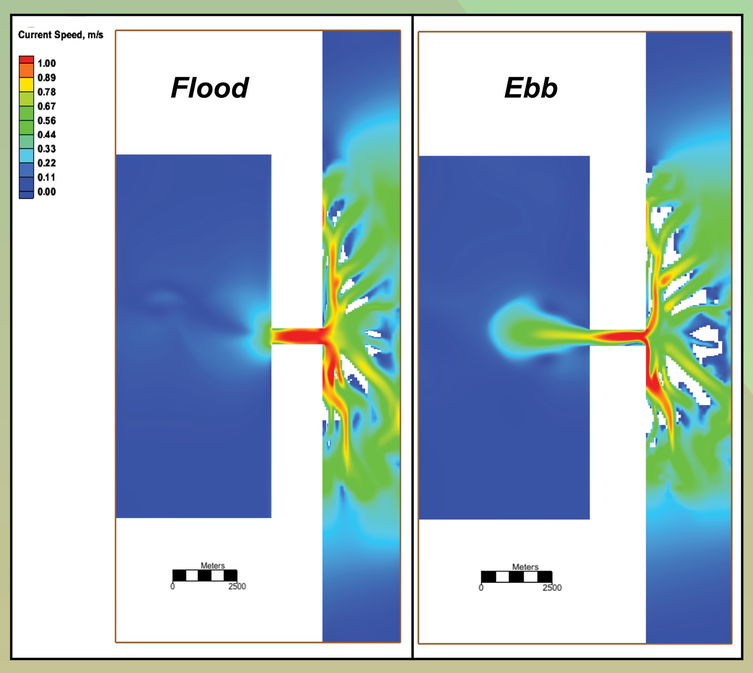


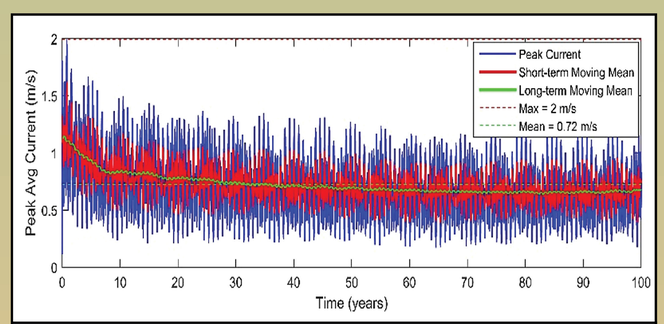
Final inlet characteristics

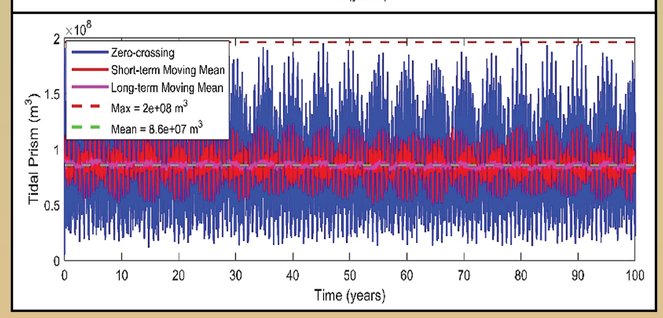
- The ebb shoal main lobe is nearly symmetric with respect to the along-shore direction.
- There are two nearly symmetric marginal flood channels on either side of the lobe.
- The inlet channel shallows in the middle and then shifts towards the positive y-axis before exiting into the bay.
- The bay contains a series of incised tidal channels distributed into random, elongated fingers.

Spatial current magnitude distribution near the end of the simulation during maximum flood and maximum ebb are shown to the right.

- Flood currents enter primarily through the marginal flood channels and strengthen in the inlet throat and follow the deeper bay channels. Tidal flats have developed in the bay forming linear bars between the channels.
- Ebb currents are consistently strong within the bay channels and converge at the inlet.

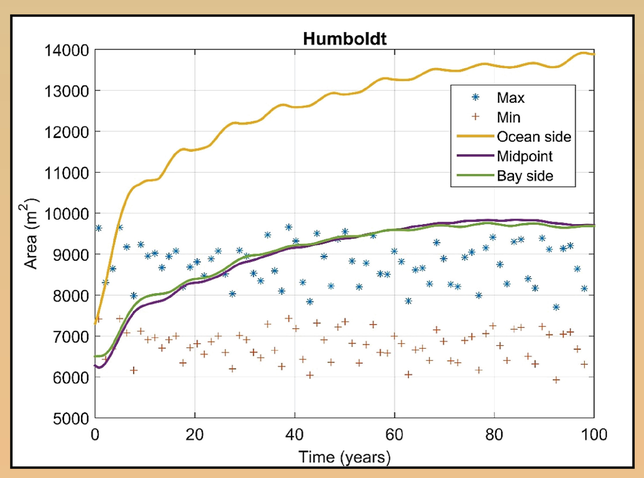




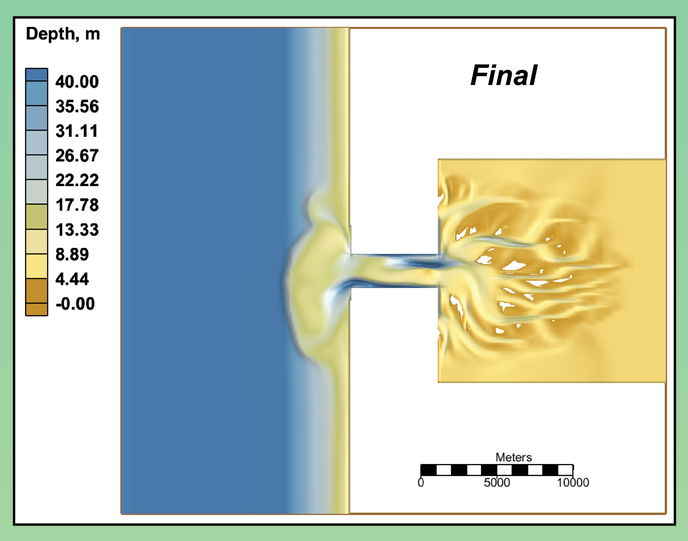


- The tidal current in the inlet throat decays over the first ~50 years and then is fairly uniform with a ~1 m/s maximum amplitude (Upper). Peak current amplitude, which drives sediment transport, is likewise fairly uniform after 50 years.
- In addition to tidal variations, the tidal prism amplitude envelope is fairly uniform with a slight initial increase as the inlet throat cross-sectional area increases (Lower).

- At simulation start, the cross-sectional area grows as the channel deepens. The CMS-predicted cross-sectional area at the midpoint and bay approaches the upper edge of the envelope, which encompasses the highest spring tide conditions including the greatest seasonal variability.
- The cross sectional area at the ocean side over-predicts but this is not the narrowest cross-section in the inlet throat, which is used to define the O'Brien formula.

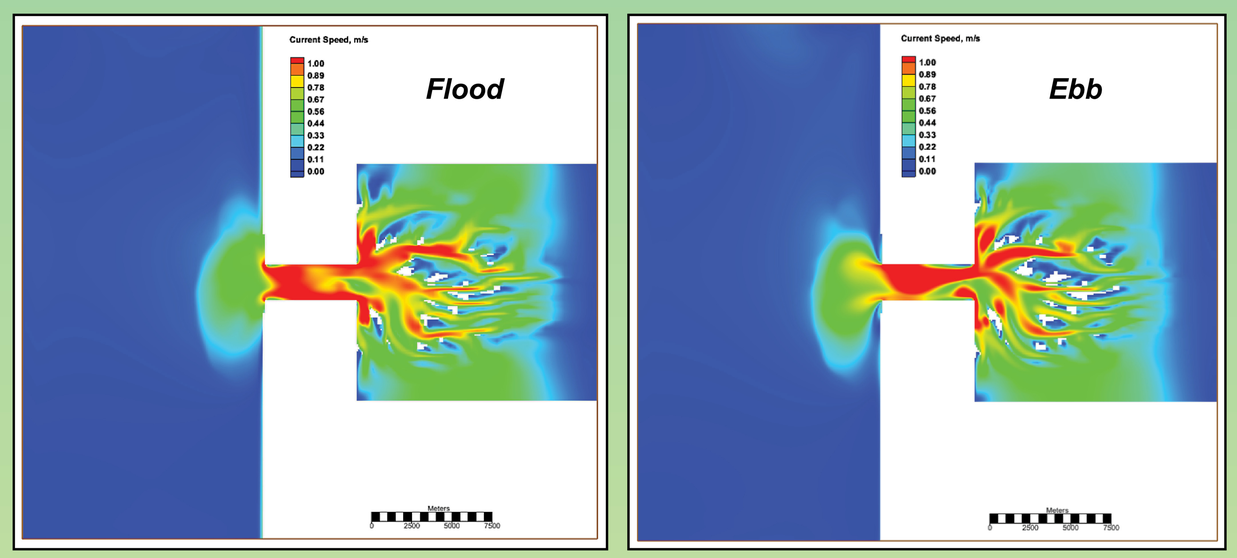


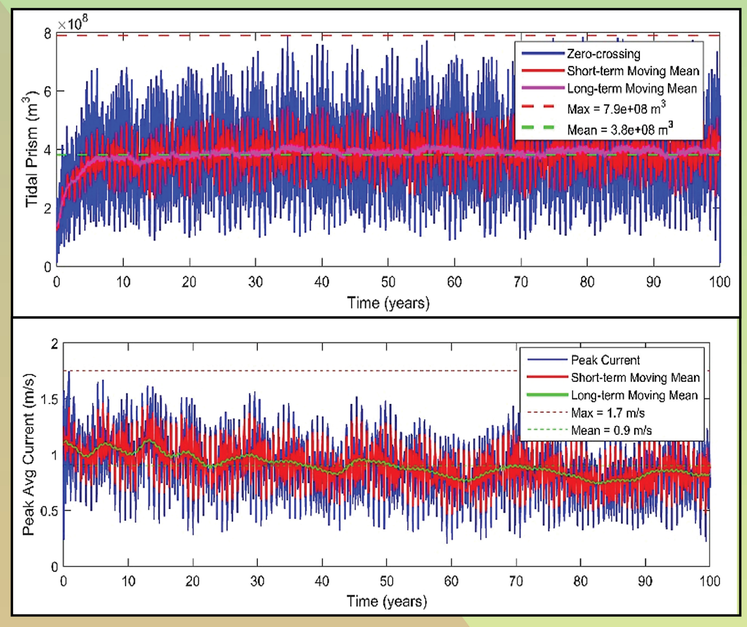
IDEALIZED INLET – GRAYS HARBOR, WASHINGTON



Final inlet characteristics

- The ebb shoal main lobe is skewed and elongated in the positive y-direction due to wave-generated longshore transport.
- There are two marginal flood channels on either side of the lobe with the south channel serving as the main ebb channel.
- The inlet channel forms a pair of alternating scour holes on opposite ends of the inlet with a shallower region in the middle
- The bay has evolved into a series of incised tidal channels in random patterns of elongated fingers.





- Tidal current time series in the inlet throat show a decrease in the amplitude envelope during the simulation (Upper). Peak current amplitude, which drives sediment transport, decreases due to deepening.
- In addition to tidal variations, the tidal prism increases for the first 35 years and then asymptotically reaches an equilibrium within the tidal force envelope which is consistent with the reported tidal prism for this inlet. (Lower).

- At simulation start, the cross-sectional area grows as the channel deepens. The CMS-predicted cross-sectional area at the midpoint and bay approaches the upper half of the envelope, which represents the highest spring tide conditions.
- The cross sectional area at either end of the inlet is in closer agreement with the highest tidal range while the midpoint approaches the average spring tide conditions.

SUMMARY

This study investigated the use of CMS as an engineering tool to predict the long-term morphological evolution of barrier island tidal inlets and was motivated by the need to develop an effective way to model the effects of relative sea level rise in support of the USACE Civil Works mission. The study had three major goals:

- Demonstrate the numerical stability of CMS for simulation periods up to 100 years
- Demonstrate the feasibility of carrying out long-term simulations in the context of engineering applications
- Verify that CMS's hydrodynamic, wave, and morphological algorithms reproduce the known generic characteristics of inlets on climatological time scales.