1. Overview
2. Report Organization
3. Methods with Examples
4. Recommendations
• NOAA grant to DWR and OST and SIO
  • Needs Assessment (OST)
  • Quick Guide Update (Ford)
  • Future coastal total water levels (SIO)
  • Comprehensive Report (OST/DWR/SIO)

• DWR-OST: Technical Methods Manual (ESA + SIO+TMMC)

• Focus Group
  • Technical Methods Manual Committee (TMMC)
1. Overview – TMM Development and Attributes

Several Drafts, comments, revisions

- Dec 2015 – extensive comments, reorganization
- May 2016 – editorial comments
- July 2016 – final draft
- August 2016 – final report

Collaborative with detailed reviews from Technical Methods Manual Committee as well as the DWR-OST-SIO grant team

Focused on local government informed coastal planning

Distills recent climate change science (SIO future projections) and integrates with contemporary engineering practice (FEMA mapping and coastal hazards quantification)

Quantifies historic and forecast extreme water levels and waves for California (3 regions – South, Central and North)

Methods accommodate information not yet available, with recommendations
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Technical Methods Manual

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3. Methods to Adjust FEMA Maps for Sea Level Rise
4. Examples
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A. An Overview of FEMA Flood Insurance Studies and Flood Insurance Rate Maps
B. Scripps Institution of Oceanography (SIO) Future Waves and Water Levels
   B1. Extreme Value Analysis on Scripps Institute of Oceanography Data
   B2. Extreme Value Analysis on Observed Data
C. Other Sea Level Rise Hazard Mapping Studies and Sources
3. Methods and Examples - Chapter 2 Definitions

Notes:
Wave A induces maximum setup and Wave B induces maximum R' and R
Both maximum elevations and maximum inland extent are mapped

TWL = Total water level = RWL + R
RWL = Reference water level ~ still water level
DWL = Dynamic water level, typically 2% exceedance ~ mean setup (aka “static”) + 2x standard deviation
η = 2% setup at RWL shoreline, wave A
R = runup, including setup, above RWL, wave B typically on projected slope above back shore
Wave setup terms (static (also called steady and average) and dynamic (also called infragravity) and incident wave runup. Adapted from MacArthur, et al, 2007.¹
3. Methods and Examples - Chapter 2 Definitions

Figure 2.3
Typical cross section for TAW runup equation (FEMA, 2015)

Figure 2.4
Plot of the TAW Runup Equations in Non-dimensional Form (FEMA, 2005)
Figure 2.6
2.6a. (top) shows how the components that influence TWL change across the surfzone, and 2.6b shows the Composite Slope Method that is applicable to most California coasts where wave setup from larger waves maximize Total Water Levels (FEMA, 2005)
Figure 2.7
Cumulative distribution of total water level at Ocean Beach, San Francisco comparing SIO GCM (green) and real data (red) calculated with the Stockdon equation and a modified TAW approach with real data (blue).
TMM provides guidance to modify FEMA flood maps for future sea levels.

There are four levels of application that entail a range of effort and information.

The lower levels of application are simpler to apply and the adjustments to the future conditions hazards information are limited.

Higher levels require more effort but greater accuracy. Higher levels require more information and capability.

The levels are:

1. Comparison between FEMA flood limits and future projections.
2. Adjust FEMA V-Zones to include effects of sea level rise.
3. Address other hazard zones and geomorphic processes
4. Apply FEMA methods to SIO or other future conditions outputs.
Level 2: Adjust V-Zones: Adjustment of the V-Zone for future conditions will typically be the most useful application owing to the high hazards and insurance premiums, and restrictive building requirements associated with this zone. Depending on the data available, there are two recommended Level 2 methodologies, identified below and described in Section 3.2:

Level 2.a: Add sea level rise: Add sea level rise to TWL and apply geomorphic adjustment; and,

Level 2.b: Prorate Components: Prorate existing water level by adding future change and prorate wave runup by multiplying by ratio of future change, and sum to get future TWL. Apply geomorphic adjustment.

“Geomorphic adjustment” is the change in shore geometry resulting from sea level rise, primarily due to waves breaking on the shore at a higher elevation, and associated erosion and sediment transport.
3. TMM Organization - Chapter 3 Methods – 2a

Eq (1) \[ TWL_{\text{future}}(t) = TWL_{\text{existing}} + SLR(t) * F(\text{Morphology, time}) \]

With a Morphology Function

\[ F(\text{Morphology, time}) = 1 \text{ for erodible backshores (can use Stockdon runup eq with landward migrated shore Figure 3.2)} \]

\[ F(\text{Morphology, time}) = 1 \text{ to 4, with a default of 2, for static (erosion resistant) backshores (can use modified TAW methodology with landward overtopping extent Figure 3.4).} \]

This formulation is similar to that developed for the FEMA Pilot Study (Baker-AECOM, 2016; Vandever et al., 2016), which uses the term Amplification Factor instead of Morphology Function.

**TABLE 3.1**
**MORPHOLOGY FUNCTION SUMMARY**

<table>
<thead>
<tr>
<th>Backshore</th>
<th>Waves</th>
<th>Morphology Function (MF) values, ( \Delta TWL = (MF) \ast SLR )</th>
<th>Explanation and simplifying assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erodible</td>
<td></td>
<td>1.0</td>
<td>Shore adjusts to sea level rise, runup does not change</td>
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<td>Erosion resistant</td>
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Eq. (6) \[ TWL_{\text{future}} = SWL_{\text{FEMA}} + \{RWL_{\text{future}} - RWL_{\text{existing}}\} + R_{\text{FEMA}} \times \{R_{\text{future}} / R_{\text{existing}}\} \]

Where \( \{RWL_{\text{future}} - RWL_{\text{existing}}\} \) = increase in reference water level predicted based on climate projections

And \( \{R_{\text{future}} / R_{\text{existing}}\} \) = relative increase in wave runup predicted based on climate projections

Eq. (7) \[ R_{\text{FEMA}} = TWL_{\text{FEMA}} - SWL_{\text{FEMA}} \]

RECOMMENDATIONS: existing and future studies should provide these parameters. In the meantime:

Select \( SWL_{\text{FEMA}} \) from FEMA FIS backup, from SIO data (Appendix B1), from other source(s) (Appendix B2)

Solve for \( R_{\text{FEMA}} \) or attain from FEMA FIS backup

Attain \( \{R_{\text{future}} / R_{\text{existing}}\} \) from SIO (Appendix B1) or other Future Conditions forecast

Attain \( \{RWL_{\text{future}} - RWL_{\text{existing}}\} \) from SIO (Appendix B1) or other Future Conditions Forecast (can be simplified to = Sea-level Rise)

Consider Morphology Response (shore recession and runup amplification) if not included in \( \{R_{\text{future}} / R_{\text{existing}}\} \)
3. Methods and Examples - Chapter 3 Methods

Figure 3.6
Expanded inland extent of wave action due to increased overtopping for a range of negative freeboard of $ΔR_{\text{future}}/ΔR_{\text{existing}}$ between 1.1 and 3 and $Y_{\text{existing}}$ between 5 and 100 feet.

Figure 3.5
Bore Propagation Driven by Wave Runup above the Shore Elevation
3. Methods and Examples

Figure 3.7

Landward extent of wave runup for Bay (dashed; T=5s) and Open Coast (solid; T=15s) conditions using the Cox and Machemehl and Composite Slope models.
Eq (2) \[ \text{Shore Recession} = \text{SR} = a \times \frac{s}{m} \] where

\[ s = \text{sea level rise} \]
\[ m = \text{shore face slope} \]
\[ a = \text{dune reduction factor} = \frac{\text{shore face depth}}{(\text{effective dune height} + \text{shore face depth})} \]

Figure 3.2 plots typical values of \( \frac{\text{SR}}{s} \) using a shore face depth of 40 feet. Effective dune height is the height of the backshore above the beach, multiplied times the percent of the material that is beach sand: The minimum practical value of “\( a \)" recommended in this analysis is 0.67 based on a dune height equal to the shore face depth and a beach sand content of 50% by volume.

In the legend, the first number is the inverse of the slope (e.g. 20 indicates a slope of \( \frac{1}{20}=0.05 \)) and the second number is “\( a \).” Note that “\( a \)" does not have a great effect for the steeper slopes.

**Figure 3.2**
Plot of Relative Shore Recession for a Shore Face Depth of 40 Feet and a Range of Reduction Factor “\( a \)” Values Associated with Backshore Sand Contributions
3. Methods and Examples - Chapter 4 Examples

Figure 4.3
Level 2a Example, 3’ of SLR

Location 1: Zone VE elevation increased to 25’ NAVD; Zone VE extent moved 180’ landward.
Location 2: Zone VE elevation increased to 32’ NAVD; Zone VE extent moved 70’ landward

Method 2a results 25’ (+3’ = SLR) and 32’ (+6’ = 2 x SLR)
3. Methods and Examples - Chapter 4 Examples

Method 2b results using prior calculations by ESA (2012) for similar locations, and using SLR = 4.6’ (interim California guidance for high sea level rise scenario) 27’ (vs 22’) and 44’ (vs 26’)

MR / AMP Factor of ~ 1 and ~ 4, respectively

Conclusion: Method 2a default may underestimate TWL for erosion-resistant morphology (MR / AMP of 2 to 3 versus computed 4)
1. FEMA existing conditions studies should include the still water levels (SWL) and wave runup values (R) for each total water level (TWL) used to define high velocity zones (V ZONES). This may require additional work, to calculate and select the SWL and R values most appropriate for the 100-year TWL. Other information, such as the shore profile geometry, equations used, and profile parameters such as slopes should also be provided.

2. Future conditions flood studies should provide the TWL, SWL and R values for mapped or otherwise designated location. Other information, such as the shore profile geometry, equations used, and profile parameters such as slopes should also be provided.

3. Both FEMA existing conditions studies and future conditions studies by FEMA or others should provide guidance on how the study results can be related to future conditions, and existing FEMA maps, respectively.

4. Studies should characterize the existing backshore conditions in terms of the morphology function defined in this Technical Methods Manual. The required information consists of whether the shore is erodible or not, and the type of wave condition driving the hazard (breaking or not, long period swell or short period seas). Table 3.1 (repeated below as Table 5.1) provides an overview of the Morphology Function concept and suggested values. Note that in most cases, the total water level (TWL) increases (ΔTWL) more than the amount of sea level rise (SLR), unless the shore adjusts landward, with the exception being for non-breaking waves. Adaptation measures are not included in this analysis.

5. Coastal erosion should be considered in addition to flooding, along with estimates of the increase in erosion rates with sea level rise.

6. Additional attention needs to be applied to develop specific guidance for quantifying future coastal hazards, building upon the substantial progress made to date by California, NOAA and others. The “gap” to be filled or bridged is between the substantial progress made by science informing policy and educating the public, and the needs at the planning and engineering applications level. While requiring a multi-discipline effort, greater participation by engineers is required to develop practical solutions needed to facilitate informed planning and resilient design.
### TABLE 5.1
MORPHOLOGY FUNCTION RECOMMENDATIONS

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Speaker: Bob Battalio
Professional Civil Engineer (CA, WA, LA, OR, FL)
Coastal Processes training from UC Berkeley, 1985
Chief Engineer, Vice President @ ESA, San Francisco
Engineering Criteria Review Board, BCDC

Practices Coastal Zone Engineering and Management

Vice President, California Shore and Beach Preservation Association (Non profit)
Surfer