

Sheltered Waters

FEMA Coastal Flood Hazard Analysis and Mapping Guidelines Focused Study Report

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Acronyms

ACES	Automated Coastal Engineering Systems
CTP	Coordinating Technical Partners
DFIRM	Digital Flood Insurance Rate Map
FIS	Flood Insurance Study
FIT	Flood Information Tool
MAS	Mapping Activity Statement
NFIP	National Flood Insurance Program

1 INTRODUCTION

This report provides recommendations for a program leading to improvement of the current FEMA Guidelines related to Sheltered Waters Flood Hazards and develops preliminary time estimates to accomplish these improvements. One sheltered water category was developed at the December 2003 Workshop. This category was labeled “Critical” for the Pacific and Non-Open Coast and “Helpful” for the Atlantic and Gulf Coast.

This was the only focused study category initially established with one related topic; however, the nature of this focused study cuts across many other focused studies, as indicated by the number of ratings in the Non-Open Coast column of the original focused study table. Therefore, this single category has been subdivided into additional topics (needs). The topics either provide detail for recommendations not captured under other focused studies or provide recommendations to refine open coast guidance prepared by other focused study groups, for application to sheltered water studies. The topics were further refined during the February 2004 Workshop. The original topics are shown below.

Sheltered Waters Topics and Priorities					
Topic Number	Topic	Topic Description	Priority		
			Atlantic / Gulf Coast	Pacific Coast	Non-Open Coast
6a	Definitions and Classification	Provide definitions and develop a classification method for sheltered water studies as a framework for an approach	H	C	C
6b	Historical Information	Prepare guidance for reconstructing historic sheltered water flood conditions to validate flood study results	H	C	C
6c	Peer Input	Seek peer input on new sheltered water guidelines needs [Deleted during Workshop 2]	--	--	--
6d	1% Annual Chance Flood Elevations	Prepare guidance for defining the 1-percent-chance flood event in sheltered water areas	H	C	C
6e	Stillwater Elevations and Tidal Currents	Prepare guidance for estimating stillwater elevations and currents in sheltered water areas	H	C	C
6f	Coastal Structures	Prepare guidance for evaluating coastal flood protection structures in sheltered water [Moved to Topic 21a during Workshop 2]	--	--	--
6g	Hazard Zones	Prepare guidance for identifying flood insurance risk zones in sheltered water [Moved to Topic 17 during Workshop 2]	--	--	--
6h	Interrelationships	Coordinate the preparation of sheltered water guidelines with other Map Modernization objectives and multi-hazard planning initiatives	H	C	C

Key: C = critical; A = available; I = important; H = helpful

The preparation of guidance for many of the above topics will be coordinated with other appropriate focused study groups because of the interrelationship of these topics with similar topics found in other focused studies. The purpose of addressing these topics here in the Sheltered Waters Focused Study is to document aspects of the work that may have more relevance to sheltered water flood studies, as opposed to open coast studies.

1.1 SHELTERED WATERS FOCUSED STUDY GROUP AND APPROACH

The Sheltered Waters Focused Study group consisted of: Jeff Johnson, David Divoky, Darryl Hatheway, Ron Noble, and Kevin Coulton who served as Team Leader for this effort.

To provide structure to the team efforts and to avoid unnecessary duplication of work, the following approach was used: the Team Leader developed background material, reviewed available information, and developed draft write-ups, which were then distributed to the Team. All Team Members contributed information of which they were uniquely aware, critiqued and contributed to the draft write ups and accomplished specific components of the overall effort leading to this report.

1.2 CURRENT FEMA GUIDANCE ON SHELTERED WATER FLOOD HAZARDS

Sheltered waters are water bodies with shorelines that are not subjected to the direct action of undiminished ocean waves. Although similar processes contribute to flooding in sheltered water shorelines as along open coastlines, such as wave setup, runup, and overtopping, there are several aspects of sheltered water flood hazards not addressed in the current FEMA Guidelines. For example, wind-generated waves are highly dependent on the shape and orientation of the surrounding terrain to prevailing wind directions (Figure 1).

Wave generation and transformation in sheltered waters are typically limited by an open water fetch distance, complex bathymetry, and often the presence of structures. See the Storm Wave Characteristics Focus Study Report for more information about seas in sheltered waters.

A sheltering effect typically reduces wave energy and flood potential compared to open coast areas; however, wave runup and overtopping along sheltered water shorelines may present additional hazards from wave-cast debris and backshore flooding because insured buildings are often located closer to the shoreline than along the open coast. Hazard evaluations for these and other characteristics of sheltered waters require special methods not available in the Guidelines.

The existing Guidelines (FEMA, 2003) are generally written to provide guidance for coastal flood studies along the open coasts of the Atlantic Ocean and Gulf of Mexico. Several references to sheltered water areas are made in these Guidelines, but detailed guidance is not provided. The Great Lakes are very large sheltered water bodies and guidelines (Great Lakes *G&S* in *Appendix D*) are provided for flood studies; however, these guidelines are very specific to the storm meteorology and physiography of the Great Lakes and are assumed to not be applicable to Pacific Ocean sheltered water areas.

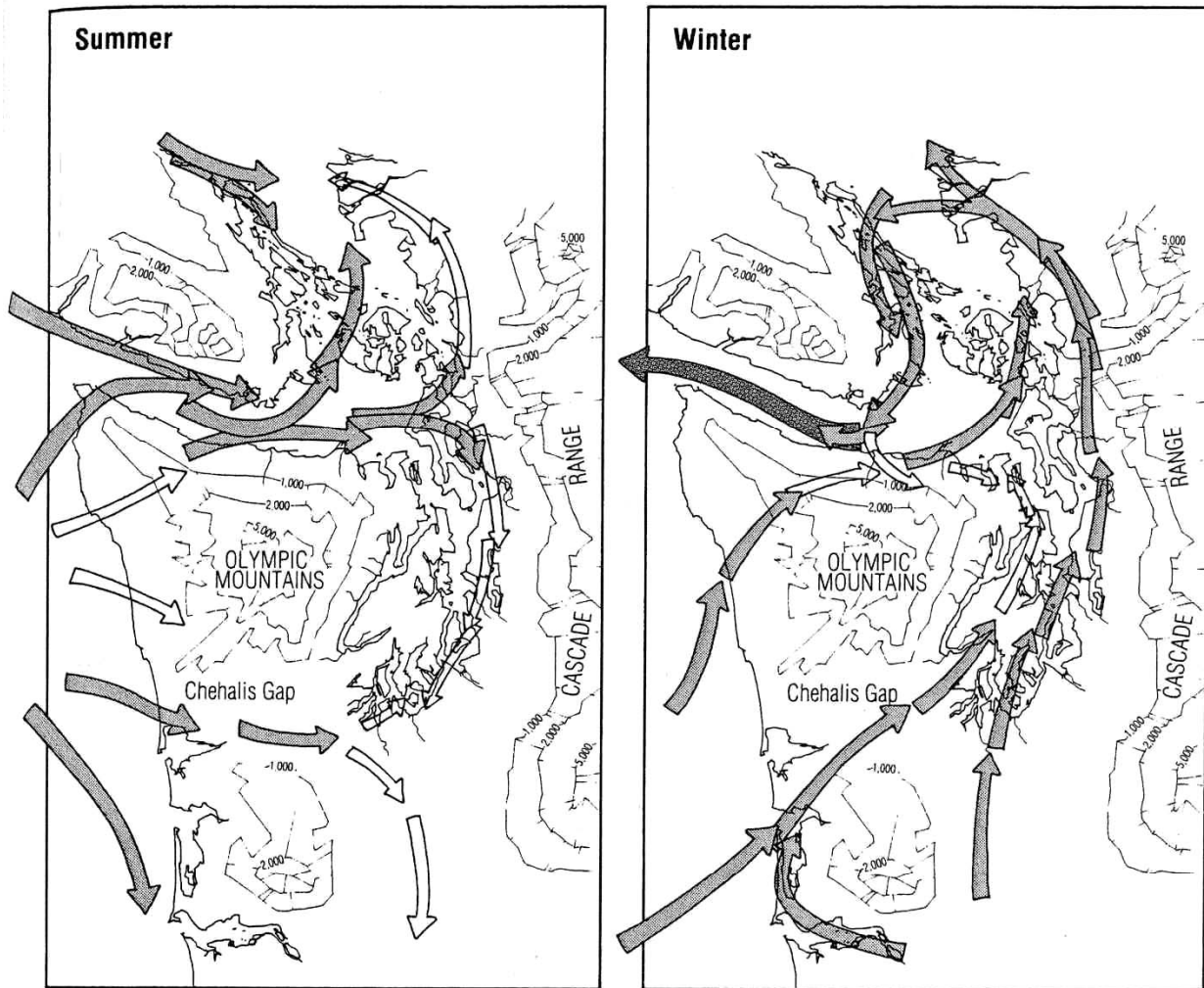


Figure 6.1 Seasonal patterns of the winds over western Washington. Land topography is the dominant influence on wind speed and direction over Puget Sound.

Figure 1. Seasonal wind patterns in Puget Sound, Washington
(Figure from Downing, 1983)

The following listing provides a brief description of portions of the existing guidelines relevant to the topic of Sheltered Waters flood studies. These items are expanded on in subsequent sections of this report.

- ④ Section D.1.2.4 – “Methods by which barriers, inlets and rivers have been treated” are required in documentation of the hydrodynamic storm surge model. However, no guidance is provided for methods to consider modeling for sheltered waters.
- ④ Section D.2.2.7 – The “analysis of restricted fetches” in “sheltered coastal sites” is addressed in the existing guidelines and the ACES software is referred to; however, more specific guidance can be provided on how to apply this software to fetch-limited conditions.
- ④ Section D.2.5.5 – “Wave runup in special situations” addresses wave runup and overtopping on shoreline barriers where overtopping flows discharge across landward-dipping or level backshore slopes to a “bay, river, or backwater”. These situations are prevalent in sheltered water areas. No additional guidance is provided.

The natural processes that result in flooding in sheltered water areas are complex and not adequately addressed in the current guidelines. Sheltered water areas often have unique flood hazards, due to the effects of fluvial drainages and modified tidal and surge hydrology, and relatively strong currents. Wave-cast debris from extreme wave runup and overtopping can be especially problematic, owing to the proximity to sources of such materials in many estuaries. Other unique flood-related characteristics include the complex geometry of the embayments, lack of coincident peak storm surge with peak winds, shallow water and restricted wind fetches for wave growth, and non-sandy shoreline types with special erosion and scour hazards. These unique flood hazards are not adequately addressed in the current guidelines for sheltered water bodies.

New guidelines are needed to inform and guide Mapping Partners in the preparation of coastal flood insurance studies and flood hazard maps in sheltered water areas of the coastal floodplain.

1.3 SUGGESTED IMPROVEMENTS

Flood hazards in sheltered waters are caused by physical processes that are also responsible for open coast flooding (e.g., tidal surge, wave runup and overtopping); however, the sheltering effect of high elevation upland terrain on wind wave development and the localized shallow water bathymetry influence on the inland propagation of ocean swell and waves may create flood hazards unique to sheltered water areas.

At a basic level, definitions and descriptions of the physical conditions and physical processes associated with flood hazards in sheltered water areas need to be clearly described to Mapping Partners (and the public) through the guidelines. This information should be documented in the

guidelines in a manner that establishes a framework for standardized, repeatable, and defensible flood study methods.

Given the lack of guidance for performing sheltered waters flood studies, Mapping Partners have developed methods to meet the needs of these unique studies over the years. Therefore, a concerted effort should be made to compile, review, and compare past methods that have been employed and approved by FEMA, and may be suitable for documentation in the new Guidelines.

It is proposed that new guidelines for sheltered water areas be developed as a separate section of the Guidelines to accompany the Pacific Ocean, Gulf of Mexico/Atlantic Ocean, and Great Lakes sections. This Sheltered Waters section would consist of methods unique to physical processes influenced by these sheltering effects. Cross-references would be provided to other sections of the guidelines to either instruct Mapping Partners on where and how to import parameters for use in the unique sheltered water methods or to export findings for use in subsequent methods to define final flood hazards.

An interim approach is to include a description of sheltered waters in the Pacific Coast Guidelines, which is to be written in Phase 2 of this project. It is anticipated that this section would also be useful for flood studies in other regions.

2 CRITICAL TOPICS

A series of focused study topics were identified to support the original Sheltered Waters issues in Topic 6, which was identified as being a critical need in Workshop 1. Following Workshop 1 eight critical topics were identified, but as of Workshop 2 three topics from this focused study report were either removed entirely or included in another Category and Topic. The remaining five Sheltered Water topics are discussed in the following sections of this report.

2.1 CRITICAL TOPIC 6A – PROVIDE DEFINITIONS AND DEVELOP A CLASSIFICATION METHOD FOR SHELTERED WATER STUDIES AS A FRAMEWORK FOR AN APPROACH

2.1.1 Description of the Topic 6a

Definitions for coastal and riverine flood studies are provided in the NFIP regulations (44 CFR 59.1). These definitions are useful as they convey basic concepts related to flood insurance studies and they support the Guidelines and Specifications. “Sheltered waters” is not currently defined in the NFIP regulations or the existing Guidelines. One USACE definition of sheltered waters is “shorelines that are not subjected to the direct action of undiminished ocean waves.” There are likely additional definitions that should be reviewed and considered to clarify the terms used in the pending revised guidelines. Examples of sheltered water bodies may also be

appropriate to present in the guidelines to demonstrate the range of sheltered water conditions that can be encountered in coastal flood studies.

Pacific Coast examples of important sheltered water areas include Puget Sound (WA), San Francisco Bay (CA), and San Diego Bay (CA). Siletz Bay (OR), Humboldt Bay (CA), Morro Bay (CA), and Newport Bay (CA), San Diego Bay (CA) are examples of smaller embayments which may exhibit similar characteristics of sheltered waters.

Gulf of Mexico examples of sheltered water include Galveston Bay (TX), Mobile Bay (AL), Tampa Bay (FL), and Charlotte Harbor, (FL).

Atlantic Ocean examples of sheltered water include Indian River Lagoon (FL), Albermarle and Pamlico Sounds (NC), Chesapeake Bay (MD-VA), Delaware Bay (DE-PA), Long Island Sound (NY-CT), Narragansett Bay (RI), Buzzards Bay (MA), and Cape Cod Bay (MA).

This focused study proposes the use of a classification system as a way to provide a framework for the sheltered waters guidelines. Given the variety of coastal conditions a Mapping Partner could encounter along the shorelines of bays, river deltas, estuaries, etc. and the variety of coastal processes at work in sheltered water resulting in unique flood hazards, a classification system may assist a Mapping Partner to determine relevant issues and available methods for assessing potential flood hazards. Such an approach would benefit Study Contractors working on the open coast as well.

2.1.2 Current FEMA Guidance on the Topic

The following sections from the current FEMA Guidelines (2003) generally address this topic:

- ④ Section D.1 – “General guidance” is primarily oriented to the Atlantic and Gulf Coasts; however, a 1977 technical paper is referenced for Pacific Northwest open coast flood study guidance. No references are provided for sheltered water flood studies in the current Guidelines.
- ④ Section D.1.2.1 – The “geographic setting” of the flood study site is required as part of the engineering report. It is assumed that the general description of the geographic and demographic conditions of the study area are prepared to satisfy this requirement, and then is typically used as text for the FIS narrative report.
- ④ Section D.1.2.4 – “Methods by which barriers, inlets and rivers have been treated” are required in documentation of the hydrodynamic storm surge model.
- ④ Section D.2.1. and Section D.3.1 – “Typical shoreline types” (Table D-1) are provided in guidance for Atlantic and Gulf Coast studies and “basic types of coastal topography” (Table D-14) are provided for Great Lakes studies. No similar specific classification system is provided for Pacific Coast or sheltered water areas.

- ② Section D.2.2. and Section D.2.2.2 – “Upland regions” and “Topographic data” are discussed in these sections in relation to data requirements for coastal flood hazard analyses. The discussion is primarily focused on shore topography and does not encourage a broader view of regional topographic conditions.
- ② Section D.2.2.4 – “Land cover data” are discussed in the current guidelines as related to the immediate shoreline and backshore areas. This information is used to establish shoreline reaches with similar cultural features and define the nature of overland wave obstructions caused by vegetation and buildings.

2.1.3 Alternatives for Improvement

In lieu of changing the NFIP regulations and adding to the definitions provided in 44 CFR 59.1, a new section in Appendix D of the Guidelines for coastal flood study definitions (sheltered water and open coast) should be provided to augment those in 44 CFR 59.1. It is understood that the Guidelines currently has a “Glossary of Flood Hazard Mapping Terms” following the appendices; however, it may be easier for users of the Guidelines to refer to definitions within the technical appendix itself.

There is an opportunity to expand existing guidance for defining the “geographic setting” of the flood study site. Expanded guidance would be provided to assist the Mapping Partner in undertaking a systematic approach to quickly assess a project setting in order to better understand the regional and site specific characteristics of the study site. With this understanding, the Mapping Partner would then be guided to a series of methods to best define flood hazards given the study site characteristics. This approach would be embodied in a classification system.

Classification has been used in a variety of disciplines to order characteristics of systems into similar categories or relationships. Classification systems have been used since the 1800s to describe rivers and streams. Some examples of these classification systems include Montgomery and Buffington’s geomorphological classification of drainage channels in the Pacific coastal ecoregion (Montgomery and Buffington, 1993) and Rosgen’s classification of stream channels for restoration design (Rosgen, 1996).

Crafting an approach to the guidelines that helps orient the Mapping Partner to the physical characteristics and processes present at a given flood insurance study site location is an important consideration in planning the content of the new Guidelines. Based on this information the Mapping Partner can work through the guidelines to determine the types and relative importance of coastal hazards to consider (erosion, setup, overtopping, drift logs, etc) and select the appropriate methods to properly define hazard zones. A coastal classification system (perhaps in a flow chart or table format) would be provided in the guidelines for this purpose.

An example of a potential procedural flowchart that could assist Study Contractors to determine site history, conditions and relevant issues related to Sheltered Water areas is shown in Figure 2. The approach shown in the figure would encourage a Mapping Partner to systematically identify and understand the processes and the physiographic setting within, and beyond, a specific study

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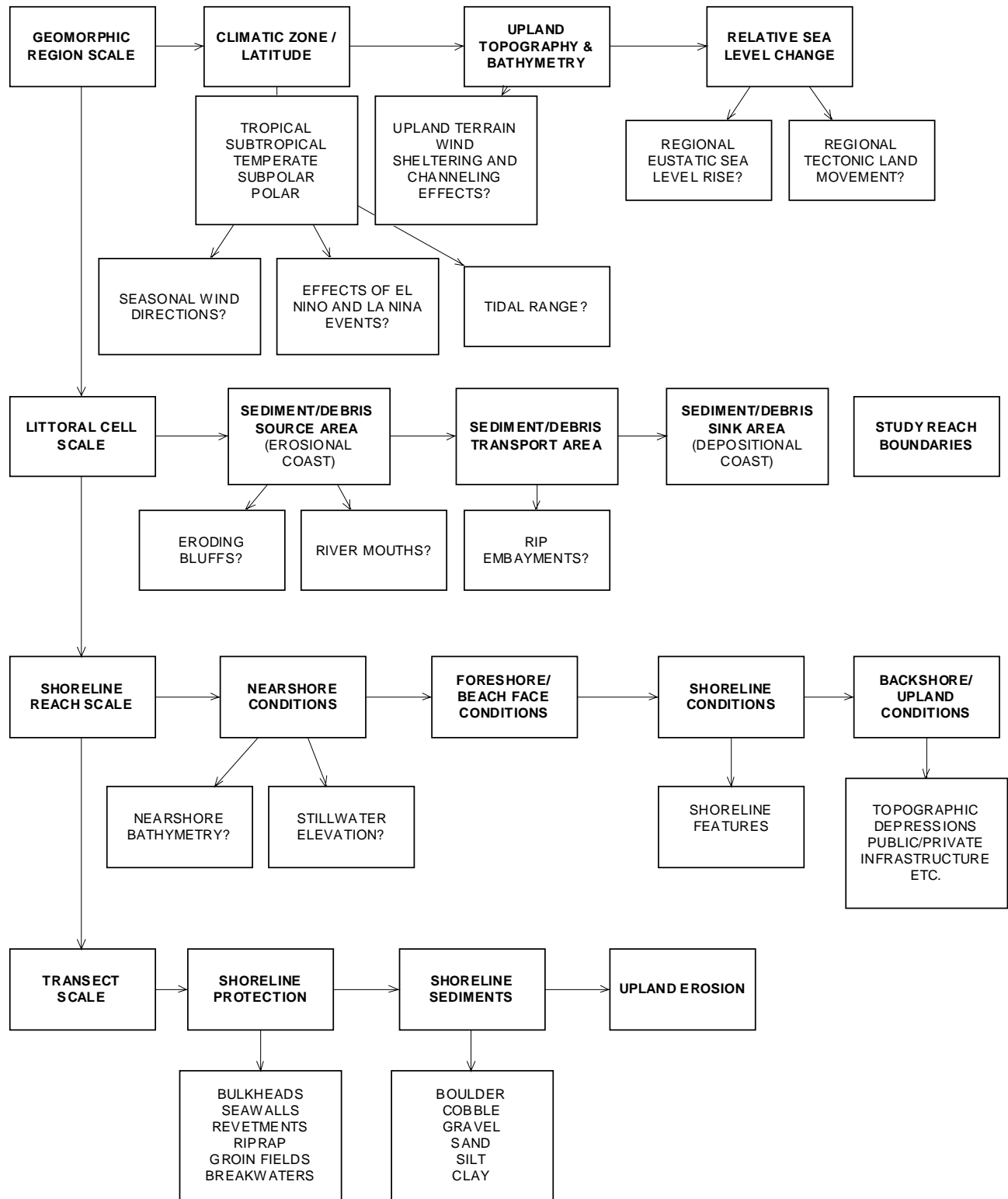


Figure 2. Conceptual procedural flow chart for a sheltered water classification system.

site at multiple spatial scales. For example, seasonal wind patterns and the sheltering effect of surrounding terrain would be identified at a regional scale. Sediment and erosion characteristics would then be identified at the littoral cell scale and shoreline and backshore features at the project reach and transect scale. Site classification (determination of site conditions and relevant issues) is typically the first step in conducting a flood hazard assessment and it is an essential part of scoping a study to reduce the chance of missing important study needs specific to a project's location, setting and history.

Additional improvements to existing guidance in the *G&S* are as follows:

- ④ Section D.1 – “General guidance”: New references to FEMA-accepted flood insurance studies in sheltered water areas (Port Angeles 1995, Whatcom County 2001) should be included in the references for all coasts. Phase 2 efforts should involve a review of these studies to determine their appropriateness to serve as references for guidance.
- ④ Section D.1.2.4 – “Methods by which barriers, inlets and rivers have been treated”: Where these methods involve sheltered water, specialized guidance should be referenced in a separate section to explain how the storm surge model took into account sheltering affects of high terrain, large forested vegetation stands, urban development, deep-cut navigation channels, etc.
- ④ Section D.2.1. and Section D.3.1 – “Typical shoreline types”: New guidance should be provided to support the proposed classification system described in the next section.
- ④ Section D.2.2. and Section D.2.2.2 – “Upland regions” and “Topographic data”: For sheltered water studies, the wind sheltering and channeling effects of nearby upland terrain on regional storm systems are important, as is the proximity of river mouths and the associated terrain and land use characteristics within river watersheds. New guidelines should provide guidance for evaluating these broader topographic data issues.
- ④ Section D.2.2.4 – “Land cover data”: New guidelines should broaden the review of these data to support the proposed geographic setting classification system and allow an evaluation of sources of wave-cast floating debris. In addition, if storm-induced erosion is to be addressed in the new guidelines, then geology and soils data may be best discussed in this section of the guidelines.

2.1.4 Recommendations

The recommendations for Topic 6a include:

1. Review previous sheltered water flood studies – Document how studies have been done in the past and compare methods approved by the various FEMA Regions.

2. Define Sheltered Water (non-Open Coasts) for the purposes of FEMA flood insurance studies - Compile a list of sheltered water flood study definitions and clarify terminology used in guidelines.
3. Identify sheltered water physical processes and site characteristics - Identify physical processes that may need to be considered to map the coastal flood hazard; consider processes common to all coastal areas and those unique to the identified landform class. Identify specific site characteristics (in this case sheltered water) that may need to be considered, evaluated and quantified to map the coastal flood hazard within a certain coastal class.
4. Review classification systems established by others and refine/adapt a system for sheltered water areas – Provide a framework for standardizing an approach to coastal flood studies and identifying the relative importance of certain physical characteristics and processes to coastal flood hazards, based on the physical location of a flood study project site.
5. Write Guidelines for Sheltered Water in the Pacific Coast Region with information useful to the Atlantic, Gulf and Great Lakes Regions as appropriate.

Table 1 at the end of this report contains a summary of the key findings and recommendations for Topic 46. Table 2 at the end of this report presents estimates of times required to accomplish the various tasks in this topic.

2.2 CRITICAL TOPIC 6B – PREPARE GUIDANCE FOR RECONSTRUCTING HISTORIC FLOOD CONDITIONS TO VALIDATE FLOOD STUDY RESULTS

2.2.1 Description of the Topic

The current FEMA Guidelines provide limited guidance on methods that can be used to obtain past flood data, reconstruct historic flood conditions, and use the data to validate new flood study results. This is an extremely important consideration because the complexity of coastal flood events can impart great uncertainty into the estimation of final Base Flood Elevations. The ability to compare theoretical results of the 1-percent-annual-chance flood to observed flood data can greatly reduce the uncertainty involved. This effort can increase the credibility of FEMA studies and reduce the potential for appeals.

Therefore, an objective of this work will be to prepare guidance for using historic flood observations to validate new flood study results.

2.2.2 Current FEMA Guidance on the Topic

The following section from the current FEMA Guidelines addresses this topic:

- ④ Section D.2.2.9 – “Historical floods” and “buildings flooded” are discussed and general guidance is provided encouraging acquisition of all available data related to high water marks and tidal flooding from extreme coastal flood events.

2.2.3 Alternatives for Improvement

In sheltered water areas, many buildings and other features of the built environment are closer to the shoreline and often more exposed to flooding than along open coast areas. An opportunity exists to expand guidance on historical flood data acquisition to include methods for reconstructing past flood water elevations observed on these landmarks found in sheltered water areas (buildings, mailboxes, street signs, etc.) together with new survey data. Reconstruction implies converting qualitative flood observations (e.g., homeowner account of “flood water up to my deck”) to a quantitative elevation using local survey methods employed on recent studies in Puget Sound (Whatcom County, WA - Sandy Point 2001 and Birch Bay 2002) can be reviewed and summarized for use as case study examples in the new guidelines.

Accordingly, expanded field reconnaissance guidance for sheltered water flood studies will be developed. This guidance may include the following:

- ④ Develop sample “flood hazard questionnaire” for Mapping Partners to edit and send out to local government officials and property owners during the reconnaissance phase of a flood study.
- ④ Develop field reconnaissance guidance on how to find and document coastal flood high water marks and wave heights.
- ④ Develop guidance for “historic flood reconstruction” methods that convert qualitative flood observations to more quantitative data for results validation.

2.2.4 Recommendations

The following recommendations for Topic 6b include:

1. Review previous sheltered water flood studies and document methods used for validating flood study results – A summary of the review may include a checklist for results validation.
2. Review of previous sheltered water flood studies and compare results of past flood studies to actual damage and flood observations made by community officials and residents.
3. Prepare field reconnaissance guidance for reconstructing historic flood observations.

2.3 CRITICAL TOPIC 6C – SEEK PEER INPUT ON NEW SHELTERED WATER GUIDELINES NEEDS

NOTE: This Topic was deleted during Work Shop 2.

2.4 CRITICAL TOPIC 6D – PREPARE GUIDANCE FOR DEFINING THE 1-PERCENT-ANNUAL-CHANCE FLOOD EVENT IN SHELTERED WATER AREAS

2.4.1 Description of the Topic

The current guidance in Appendix D focuses on open coast areas and does not provide any recommended procedures for developing the 1-percent-annual-chance flood event in sheltered water areas. Guidance needs to be provided for the unique conditions found in sheltered waters where high terrain obstructs and channels the winds associated with regional storm systems as they traverse sheltered water bodies. Some sheltered water areas also receive strong influences from seasonal fresh water inflows, often leading to the need for assessing the joint probability of such combined influences of coastal and terrestrial flood conditions.

This topic will be coordinated with Topic 51 addressed by the Storm Meteorology Focused Study Group.

2.4.2 Current FEMA Guidance on the Topic

The following sections from the current FEMA Guidelines generally address this Topic:

- ④ Section D.2.2.1 and Section D.2.2.7 – The current guidelines state “only the 1-percent-annual-chance SWEL is required for coastal analyses” and “the basic presumption...is that wave hazards occur coincidentally with the 1-percent-annual-chance flood (“flood” is assumed to mean stillwater).”
- ④ Section D.2.2.6 - The current 1-percent-annual-chance flood event guidance was developed primarily for open-coast settings on the Atlantic and Gulf Coasts; e.g., guidance refers to storm meteorology associated with Northeasters and hurricanes and “rules of thumb” are provided for typical wind speed and surge conditions. As mentioned above, the current Guidelines appear to define the 1-percent-annual-chance “stillwater” as the “flood” event.
- ④ Section D.2.2.7 – The “analysis of restricted fetches” in “sheltered coastal sites” is mentioned in the existing guidelines and the Mapping Partner is referred to ACES user manual for guidance.
- ④ Section D.2.5.2 – Wave height and period estimates “suitable for runup computations at fully exposed coastal sites” are provided in Table D-4.

2.4.3 Alternatives for Improvement

Alternatives for improvement may be provided in sheltered water flood studies conducted for FEMA in Region X (CH2M Hill, 1989; PWA, 2002). These studies resulted in different methods that were approved by FEMA to estimate the 1-percent-annual-chance flood event for sheltered water areas of Puget Sound (Figure 3). A comparison of these methods to each other and to observed flood data would be informative to assess the sensitivity and accuracy of the methods. Based on the findings, more definitive guidance could be provided to Mapping Partners for estimating the 1-percent-annual-chance flood event for sheltered water areas.

Where streams are tributary to sheltered water, definition of the 1-percent-chance flood event requires consideration of the joint probability effects of riverine and tidal flooding. The dependence or independence of these two events in a flood frequency analysis is a complex issue, based on the size and speed of the regional storm system and the resulting coincidence or lag between peak occurrences of storm surge and river runoff. Guidance could be provided to Mapping Partners to define and enable mapping of these complex flood hazards.

Additional improvements to existing guidance in the *G&S* are as follows:

- ④ Section D.2.2.1 and Section D.2.2.7: Recent sheltered water studies in Puget Sound recognized the wind sheltering effect of high mountainous terrain on low-pressure storm systems approaching the Pacific Coast and alternate methods were employed to estimate the 1-percent flood event with restricted fetches limiting the wave growth regions throughout Puget Sound. The methods used in these studies involved the estimation of the 1- through 100-year return period tides for use in joint probability statistical analyses. Therefore, new guidelines may actually require Mapping Partners to consider more than just the 1-percent-annual-chance flood (stillwater) elevation for estimation of the 1-percent-annual-chance flood event caused by the combination of wind waves and tide.
- ④ Section D.2.2.6: Definition of the recurrence interval of this stillwater event is deemed important for providing a basis from which to assign recurrence intervals to observed historic extreme stillwater events and for assessing wave conditions likely associated with this stillwater event. These storm systems are addressed because of their potential differences in duration of the surge event. Therefore, new guidelines may need to address the duration of the surge event and not just the peak elevation of the stillwater event alone. The duration, or time history, of the tidal surge event may become important if more detailed guidance is provided on methods for determining the probability of the simultaneous occurrence of two events, as opposed to the related occurrence of the events within a broader time period.
- ④ Section D.2.2.7: New guidelines might expand on the “fetch-limited” wave height calculations made through the use of the currently referenced ACES Windspeed Adjustment and Wave Growth computer routine.

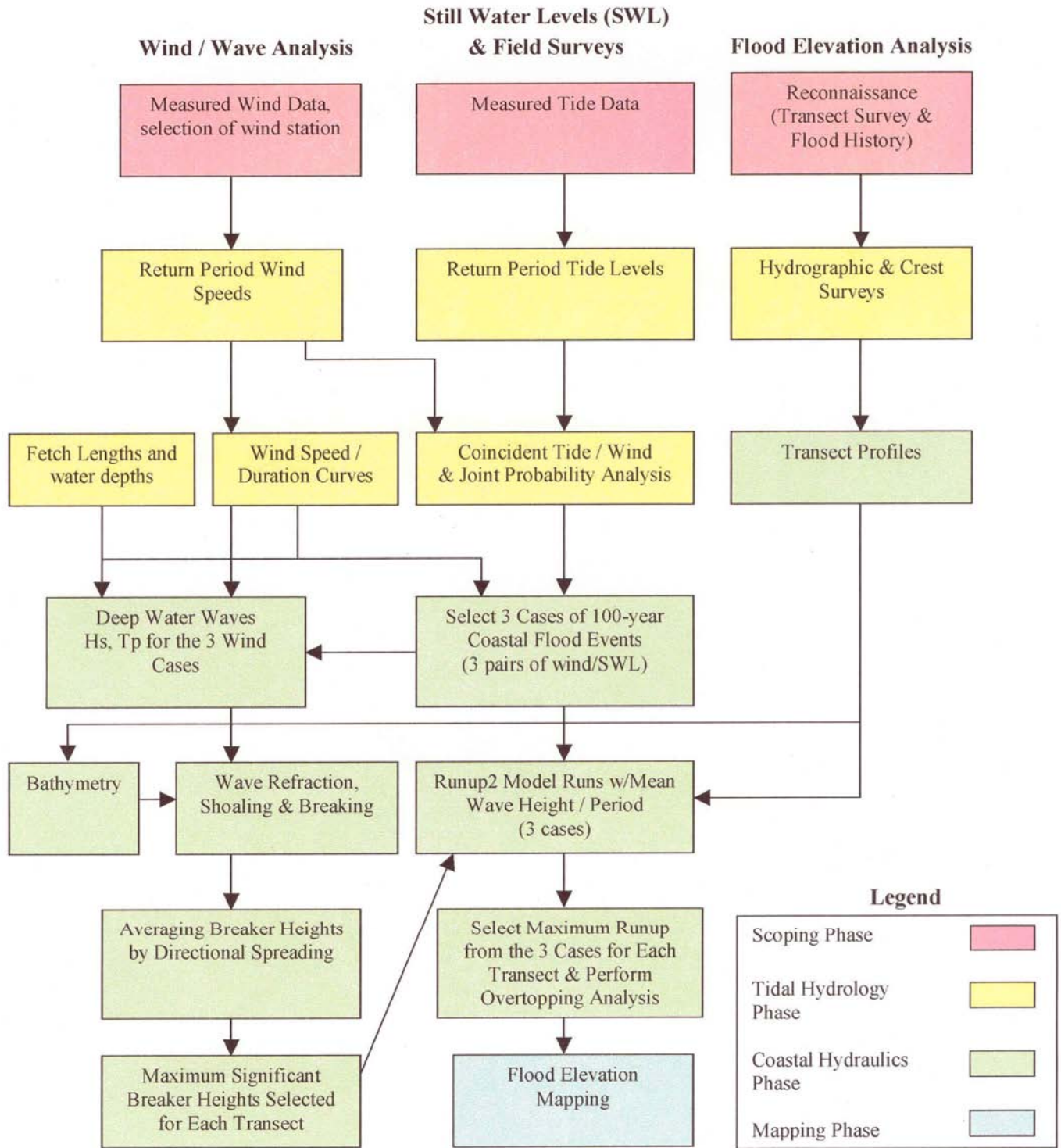


Figure 3. Representative sheltered water methodology.

Section D.2.5.2: A similar table to Table D-4 or nomograph relating wind speed to fetch length, such as the classic Sverdrup-Munk-Bretschneider diagram (Figure 4), or improved guidance, would be useful in the guidelines to describe wave growth for sheltered water conditions based on fetch length, wind speed and duration.

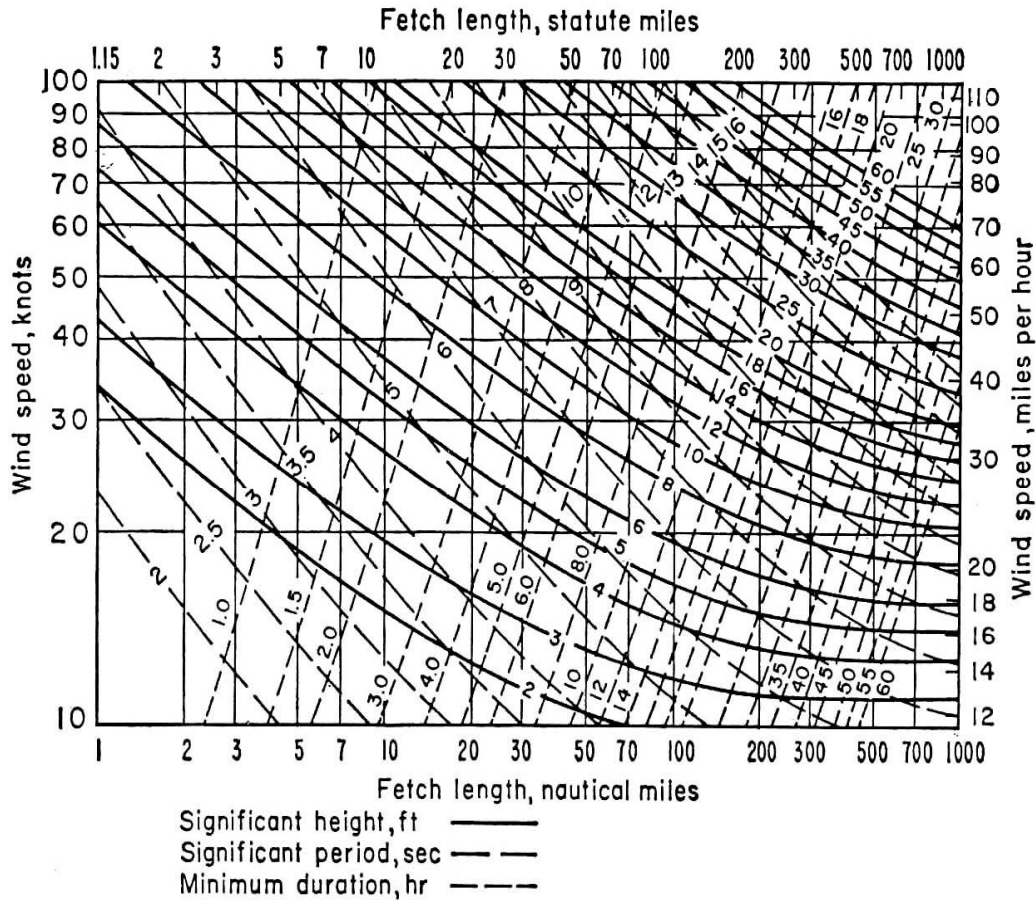


FIG. 10-15. Deep-water wave-forecasting curves as a function of wind speed, fetch length, and wind duration.

Figure 4. Sverdrup-Munk Bretschneider diagram for wave forecasting in sheltered waters

2.4.4 Recommendations

The following recommendations for Topic 6d include:

1. Review the methods used in previous FEMA-accepted sheltered water flood insurance studies for possible adoption as methods to reference in the new guidelines.
2. Prepare guidance on independent/dependent joint probability effects on the 1%-chance event considering coastal watersheds and riverine-tidal flooding.

3. Expand discussion of existing guidance on wind data acquisition and analysis and fetch-limited wave forecasting.

2.5 CRITICAL TOPIC 6E – PREPARE GUIDANCE FOR ESTIMATING STILLWATER ELEVATIONS AND CURRENTS IN SHELTERED WATER AREAS

2.5.1 Description of the Topic

Sheltered water areas encompass a variety of complex shorelines. This complexity in geography and topography can result in unique circumstances where methods derived for open coast assessments may not be directly applicable to sheltered water coastal flood studies. The objective of this work is to prepare guidance interactively with the Stillwater and Wave Transformation Focused Study Groups, refining appropriate open coast guidance (Item 8 and 55) into a reliable methodology for sheltered water areas.

2.5.2 Current FEMA Guidance on the Topic

The following sections from the current FEMA Guidelines and NFIP regulations generally address this topic:

- ④ D.2.2.1 – Guidance on the “estimation of stillwater elevations” is provided with recommendations for the use of measured water levels at gauge stations or storm surge modeling. Models are recommended for “complex shorelines” where gage records may not represent true stillwater elevations.
- ④ D.2.6.1 – Various tidal datums (MLW, MTL, MHW) are referred to in Figure D-24 of the existing Guidelines. Tidal datums are also referred to in the NFIP regulations under 44CFR60.3(e)(3) “Mean High Tide” and “normal high water” is referred to in the definition of “reference feature” in 44CFR59.1. There is currently no guidance on how to obtain these data or estimate these elevations.

2.5.3 Alternatives for Improvement

Given the concentration of development and insured structures that are typical within sheltered water areas—those adjacent to low gradient shoreline beaches and estuarine wetlands—there is a need to better understand the true natural variation of tide, in addition to the hypothetical 1-percent-annual-chance stillwater elevation. These tidal variations are commonly documented at tidal gauging stations as “tidal datums.” Vertical tidal datum references are often used in the more densely populated sheltered water areas to demarcate natural and human boundaries; e.g., legal property boundaries are often establish based on the “Ordinary High Water Mark” along shorelines and rivers. Guidance should be provided 1) on where and how to obtain tidal datum information, 2) how tidal datums can be developed from tide gauge data or derived in conjunction with field investigations, and 3) how tide data and tidal datums should be validated prior to usage.

Recurrence interval stillwater data are typically derived from tidal gauging stations. These stations are normally located within a sheltered water body with open communication to the ocean. For flood study sites located in a nearby ungauged sheltered water body, the direct transfer of tide gauge elevations, or interpolation of data between two gauging stations may not be appropriate. For example, the morphology of an embayment with a narrow tidal inlet may result in “tidal choking”, resulting in stillwater elevations higher than predicted from adjacent gauge data. A sheltered bay influenced by large seasonal fresh water discharges from inland drainage areas are certain to have unique tidal characteristics (datums) during periods of high runoff. Guidance should be provided to Mapping Partners for transferring tide gauges data to ungauged locations. This guidance could be similar to the standard hydrologic methods available for transferring stream gauge data from a gauged to ungauged watershed location.

Tidal, riverine and other nearshore currents may have an effect on wave shoaling and shoreline erosion under flood conditions. The Guidelines should discuss these conditions and provide methods for assessing the significance of these physical processes on flood hazards. This topic should be coordinated with the Wave Transformations Study Group, owing to the effects of currents on wave refraction and shoaling. The key issue is that currents are often stronger in sheltered waters, and hence current effects on waves should not necessarily be neglected.

2.5.4 Recommendations

The following recommendations for Topic 6e include:

1. Review scientific literature and resource management practices related to stillwater, tidal currents and tidal datums in sheltered water areas.
2. Prepare guidance for the transfer of tide gauge data to ungauged sheltered water bodies.
3. Prepare guidance for the assessment of tidal and riverine nearshore currents and their significance to flood hazards.
4. Coordinate guideline development with appropriate Focused Study Groups.

2.6 CRITICAL TOPIC 6F – PREPARE GUIDANCE FOR EVALUATING COASTAL FLOOD PROTECTION STRUCTURES IN SHELTERED WATERS

NOTE: This Topic was assigned for coverage under Topic 21a during Work Shop 2.

2.7 CRITICAL TOPIC 6G – PREPARE GUIDANCE FOR IDENTIFYING FLOOD INSURANCE RISK ZONES IN SHELTERED WATERS

NOTE: This Topic was assigned for coverage under Topic 17 during Work Shop 2.

2.8 CRITICAL TOPIC 6H – COORDINATE THE PREPARATION OF SHELTERED WATER GUIDELINES WITH OTHER MAP MODERNIZATION OBJECTIVES AND MULTI-HAZARD PLANNING INITIATIVES

2.8.1 Description of the Topic

The development of new coastal guidelines is one of many Map Modernization objectives identified by FEMA. The sheltered water guidelines should reference other appropriate Map Modernization objectives and multi-hazard planning initiatives. This coordination can broaden the use of the new guidelines to assist Mapping Partners with other hazard mitigation activities. For example, the utility of new guidelines may be enhanced if the methods for riverine-tidal flood assessments in sheltered water areas also provide guidance for incorporating future conditions riverine hydrology into coastal flood hazard maps.

2.8.2 Current FEMA Guidance on the Topic

The current FEMA Guidelines reference past coastal guidelines, that have been incorporated into the document, and other documented methodologies that are available as supporting guidance (Section D.1.1). However, the current Guidelines do not reference other FEMA guidelines and initiatives Mapping Partners may consider when they start a flood insurance study. For example, Mapping Partners may want to plan a flood study so that data can be subsequently used for the Coastal Flood Information Tool (FIT) for eventual HAZUS modeling.

2.8.3 Alternatives for Improvement

As the draft guidelines for sheltered water flood hazards are being defined, a nominal effort should be made to understand how these guidelines may interrelate to other FEMA initiatives to identify potential benefits that could be relayed to Mapping Partners. The new guidelines may simply include a listing of other FEMA initiatives for the Mapping Partner's reference. Example of related FEMA initiatives may include:

- ④ Mapping future conditions – FEMA has provided guidance for mapping riverine floodplains due to future conditions hydrology. Similar guidance may be appropriate for future hazards in sheltered water areas due to relative sea level change—sea level rise together with local tectonic uplift or subsidence—either separately or in combination with future riverine guidance for flood studies in areas of combined riverine – tidal flooding. The focused study team believes consideration and mapping of long-term changes are technically feasible, but problematic, given unresolved NFIP policy and implementation issues. These topics have received considerable attention by others (at federal, state and local levels), but time and budget constraints prevented this team from contributing to the topic beyond reiterating its importance.

- ④ HAZUS-MH and the Coastal Flood Information Tool (FIT) – Analysis at Levels 2 and 3 using the FIT will likely rely on flood hazards determined from detailed coastal studies performed using the new guidelines.
- ④ Letters of Map Change, Amendment and Revision MT Forms
- ④ Mapping Activity Statement (MAS) Template for Cooperating Technical Partners (CTP) Program
- ④ DFIRM standards

Lastly, Volumes 1 to 3 and the remaining appendices of the FEMA Guidelines should be reviewed to determine if changes to the *G&S* will affect content elsewhere in the document.

2.8.4 Recommendations

The following recommendations for Topic 6h include:

1. Identify and assess interrelationships of new guidelines to other Map Modernization objectives and related FEMA initiatives.
2. Review state floodplain management policies related to sheltered water.
3. Review Volumes 1-3 and other appendices of current Guidelines
4. Document and disseminate the findings to the other Focused Study Groups and integrate into the new Guidelines as appropriate.

3 AVAILABLE TOPICS

(Not Applicable)

4 IMPORTANT TOPICS

(Not Applicable)

5 ADDITIONAL OBSERVATIONS

Seiching may contribute to flood hazards in sheltered water. Seiching involves the movement of long waves that move rhythmically back and forth within an enclosed water body such as a lake or bay. The waves can be caused by a sudden air pressure change from the passage of an intense storm system or a long period wave train entering an embayment from the ocean. The resulting

wave period is a function of the size and depth of the water body. Flood hazards from seiching are limited, but could be significant if the wave period of a tsunami entering a sheltered embayment is an even multiple of the natural period of the embayment; in this case the seiching would be amplified and could potentially result in coastal flood hazards. The significance of this physical process should be considered in future Tsunami Studies.

6 SUMMARY

The Sheltered Waters Focused Study involves a unique effort because sheltered water aspects are included in many of the other Focused Studies. Accordingly, the preparation of guidance for many of the topics identified in this report will be coordinated with other appropriate focused study groups because of the interrelationship of the sheltered water and open coast topics.

Five sheltered water topics are addressed in this report. The first topic addresses the need to establish a framework for performing coastal studies and proposes the use of a classification system, to guide Mapping Partners through the scoping and execution of a coastal flood study project, and the need to simply define “sheltered waters” for FEMA flood study purposes. The second topic will expand current guidance for documenting and using data on observed flood conditions to provide validation of flood study results. The third topic will result in guidance specific to defining the 1-percent-annual-chance flood event involving dependent and independent joint probability occurrences of riverine and tidal flooding in sheltered water areas. Existing guidance on wind data acquisition and analysis and fetch-limited wave forecasting in sheltered waters will also be expanded. The fourth topic addresses guidance for estimating stillwater elevations in sheltered waters and evaluating the effects of tidal and riverine currents on wave propagation. The last topic addresses the benefits of referencing other appropriate Map Modernization objectives and multi-hazard planning initiatives. This coordination can broaden the use of the new guidelines to assist Mapping Partners with other hazard mitigation activities. These topics and recommendations for preparing associated guidelines are summarized in Table 1.

An additional observation was made to include guidance on defining flood hazards caused by seiching in sheltered water bodies.

Table 1. Summary of Findings and Recommendations for Sheltered Waters

Topic Number	Topic	Coastal Area	Priority Class	Availability Adequacy	Recommended Approach	Related Topics
6a	Definitions and Classification	AC	H	MAJ	1. Review previous sheltered water flood studies, compare methods, geomorphic conditions, unique flood hazards. 2. Define Sheltered Water (non-Open Coasts) for the purposes of FEMA flood insurance studies. 3. Identify and classify Pacific sheltered water physical processes and site characteristics. 4. Review classification systems established by others and refine/adapt a system for sheltered water areas. 5. Write Guidelines for Sheltered Water in the Pacific Coast Region with information useful to the Atlantic, Gulf and Great Lakes Regions as appropriate.	1, 5, 9, 10, 11-14, 15-16, 17-19, 20, 21-27, 29, 30, 35-36, 37-43, 44-48, 50-51, 52-55,
		GC	H	MAJ		
		PC	C	MAJ		
		SW	C	MAJ		
6b	Historical Information	AC	H	MIN	1. Review previous sheltered water flood studies and document methods used for validating flood study results. 2. Compare results of past flood studies to actual damage and flood observations. 3. Prepare field reconnaissance guidance. 4. Write the guidelines.	9-10, 11-14, 17-19, 21-22, 24, 30-31, 35-36, 53
		GC	H	MIN		
		PC	C	MIN		
		SW	C	MIN		
6d	1% Annual Chance Flood Elevations	AC	H	MAJ	5. Review the methods used in previous FEMA-accepted sheltered water flood insurance studies for possible adoption as methods to reference in the new guidelines. 6. Prepare guidance on independent/dependent joint probability effects on the 1%-chance event considering coastal watersheds and riverine-tidal flooding. 7. Expand discussion of existing guidance on fetch-limited wave forecasting. 8. Write the guidelines.	4-5, 8-10, 12, 16, 19, 44-48, 50-51, 52-55
		GC	H	MAJ		
		PC	C	MAJ		
		SW	C	MAJ		

Table 1. Summary of Findings and Recommendations for Sheltered Waters						
6e	Stillwater Elevations and Tidal Currents	AC	H	MAJ	1. Review scientific literature and resource management practices related to stillwater, currents and tidal datums in sheltered water areas. 2. Prepare guidance for the transfer of tide gauge data to ungauged sheltered water bodies. 3. Prepare guidance for the estimation of tidal datums in flood insurance studies. 4. Prepare guidance for the assessment of tidal and riverine nearshore currents and their significance to flood hazards. 5. Coordinate guidelines development with appropriate Focused Study Groups.	42-48, 52-55
		GC	H	MAJ		
		PC	C	MAJ		
		SW	C	MAJ		
6h	Inter-relationships	AC	H	MIN	1. Identify and assess interrelationships of new guidelines to existing FEMA initiatives. 2. Review the status of the ongoing Pacific Coast Coastal Barrier Resources System study and review related FEMA guidance (Section 2.2). 3. Review state floodplain management policies related to sheltered water. 4. Review Volumes 1-3 and other appendices of current Guidelines. 5. Document and disseminate the findings to the other Focused Study Groups and integrate into the new Guidelines as appropriate.	All
		GC	H	MIN		
		PC	C	MIN		
		SW	C	MIN		
<p>Key:</p> <p>Coastal Area AC = Atlantic Coast; GC = Gulf Coast; PC = Pacific Coast; SW = Sheltered Waters</p> <p>Priority Class C = critical; A = available; I = important; H = helpful</p> <p>Availability/Adequacy “Critical” Items: MIN = needed revisions are relatively minor; MAJ = needed revisions are major “Available” Items: Y = availability confirmed; N = data or methods are not readily available “Important” Items: PRO = procedures or methods must be developed; DAT = new data are required; PRODAT = both new procedures and data are required</p>						

Table 2. Preliminary Time Estimate for Guideline Preparation for Sheltered Water Flood Hazards	
Item	Time (Person Months)
Time Estimates for Critical Topic 6a	
Review previous sheltered water flood studies	1
Define Sheltered Water (non-Open Coasts) for the purposes of FEMA flood insurance studies	0.5
Identify sheltered water physical processes and site characteristics	1
Develop a sheltered water classification system	1
Write the topic guidelines	0.5
Incorporate Feedback, Finalize	0.2
TOTALS	4.2
Time Estimates for Critical Topic 6b	
Document methods used for validating flood study results	1
Compare results of past flood studies to actual damage and flood observations	0.5
Prepare field reconnaissance guidance	1
TOTALS	2.5
Time Estimates for Critical Topic 6d	
Review the methods used in previous FEMA-accepted sheltered water flood insurance studies for possible adoption as methods to reference in the new guidelines	1
Prepare guidance on independent/dependent joint probability effects on the 1%-chance event considering coastal watersheds and riverine-tidal flooding.	1
Expand discussion of existing guidance on fetch-limited wave forecasting	0.5
Write the topic guidelines	0.5
Incorporate Feedback, Finalize	0.2
TOTALS	3.2
Time Estimates for Critical Topic 6e	
Review scientific literature and resource management practices	0.5
Prepare guidance for the transfer of tide gauge data to ungauged sheltered water bodies.	0.5
Prepare guidance for the estimation of tidal datums	0.5
Prepare guidance for the assessment of tidal and riverine nearshore currents	0.5
Coordinate guideline development with appropriate Focused Study Groups	0.3
Write the topic guidelines	0.5
Incorporate Feedback, Finalize	0.2
TOTALS	3
Time Estimates for Critical Topic 6h	
Identify and assess interrelationships of new guidelines to other Map Modernization objectives and related FEMA initiatives.	0.5
Review state floodplain management policies related to sheltered water	0.2
Review Volumes 1-3 and other appendices of current Guidelines	0.2
Document and disseminate the findings	0.2
TOTALS	1.1

7 REFERENCES

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