D.2.10 Coastal Structures

This subsection provides guidance for certifying coastal protection structures for use in the NFIP and outlines methods for analyzing the stability and effects of coastal structures during 1-percent-annual-chance flood conditions

D.2.10.1 Purpose and Overview

Because coastal structures can significantly affect local topography and flood hazards, the evaluation of coastal structures is a necessary part of any flood hazard study. The evaluation should, where possible, determine whether a coastal structure will survive the 1-percent-annual-chance flood and provide protection to upland areas.

- If a particular structure is expected to remain intact through the 1-percent-annual-chance flood, the structure geometry shall be used in all ensuing FIS analyses that accompany the flood event (e.g., event-based erosion, wave runup and overtopping, and determination of wave crest elevations).

- If a particular structure is expected to fail during the 1-percent-annual-chance flood, the coastal structure shall either be removed entirely before ensuing analyses, or be replaced by an appropriate failed configuration before ensuing analyses (D.2.10.3.2).

- If the performance of a particular structure is uncertain, both intact and failed configurations should be analyzed, and the most hazardous flood conditions should be mapped.

For the purposes of these Guidelines and Specifications, coastal structures are classified as follows:

- **Coastal Armoring Structures:** Generally shore-parallel structures constructed to prevent erosion of uplands and mitigate coastal flood effects (e.g., seawalls, revetments, bulkheads, and levees). Please note that coastal levees are classified as armoring structures here, but are often referred to as flood control structures.

- **Beach Stabilization Structures:** Structures intended to stabilize or reduce erosion of the beach, which, by doing so, afford some protection to upland areas (e.g., groins, breakwaters, sills, and reefs).

- **Miscellaneous Structures:** Structures not included above that can affect flood hazards, especially in sheltered waters (e.g., piers, port and navigation structures, bridges, culverts, and tide gates).

Criteria for evaluating the stability and performance of coastal armoring structures for FIS purposes are well-developed and are discussed in detail. Criteria for evaluating beach stabilization structures have not been developed yet, and only basic guidance is provided (beach

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nourishment is addressed in Subsections D.2.1.2.5 and D.2.9.3.5.1). Criteria for evaluating miscellaneous structures are not standardized, and only basic guidance is provided.

D.2.10.2 Evaluation Criteria

Mapping Partners are not required to perform detailed engineering evaluations of all coastal structures within the study area, and, in fact, rarely do so. However, when such an evaluation is performed, there are specific evaluation criteria that must be applied.

D.2.10.2.1 Detailed Engineering Evaluation of Coastal Armoring Structures

Specific criteria for evaluating coastal armoring structures are contained in an April 23, 1990, FEMA memorandum (FEMA, 1990), "Criteria for Evaluating Coastal Flood Protection Structures for National Flood Insurance Program Purposes."[12] The evaluation criteria from the 1990 memorandum are provided below[13]:

> General
>
> For purposes of the NFIP, FEMA will only recognize in its flood hazard and risk mapping effort those coastal flood protection structures that meet, and continue to meet, minimum design and maintenance standards that are consistent with the level of protection sought through the comprehensive floodplain management criteria established by 44 CFR Part 60.3. Accordingly, the procedure describes the types of information FEMA needs to recognize, on NFIP maps, that a coastal flood protection structure provides protection from the base flood. This information must be supplied to FEMA by the community or other party seeking recognition of such a coastal flood protection structure at the time a flood risk study or restudy is conducted, when a map revision under the provision of 44 CFR Part 65 is sought based on a coastal flood protection structure, and upon request by the Administrator during the review of previously recognized structures. The FEMA review will be for the sole purpose of establishing appropriate risk zone determinations for NFIP maps and shall not constitute a determination by FEMA as to how a structure will perform in a flood event.
>
> Design Criteria
>
> For coastal flood protection structures to be recognized by FEMA, sufficient evidence must be provided that adequate design, construction, and maintenance have been undertaken to provide reasonable assurance of durable protection from the base flood. The following requirements must be met:
>
> 1. Design Parameters. A coastal flood protection structure must be designed using physical parameters that fully represent the base flooding event, including the following:

[12] The criteria discussed in this memorandum are based in large part on Technical Report 89-15 prepared by the U.S. Army Corps of Engineers, Coastal Engineering Research Center (USACE CERC) for FEMA, Criteria for Evaluating Coastal Flood-Protection Structures (Walton et al., 1989). The criteria in the memorandum have been adopted as the basis for National Flood Insurance Program (NFIP) accreditation of new or proposed coastal structures to reduce the flood hazard areas and elevations designated on NFIP maps, but can be applied to existing coastal structures.

[13] The use of the term *stillwater* in this memorandum shall be understood to refer to total stillwater, or MWL.

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i. Design water levels evaluated should range from the mean low water at the site, to the 1-percent-annual-chance stillwater elevation. The full range of elevations must be examined to determine the critical water level because the most severe conditions may not occur at either extreme.

ii. Wave heights and periods must be calculated for each water level analyzed. At a minimum, significant wave heights and periods should be used for "flexible" structures such as revetments, and larger wave heights, up to the 1-percent-annual-chance wave height (1.67 times the significant wave height), used for more rigid structures such as seawalls and bulkheads. The U.S. Army Corps of Engineers (USACE) Shore Protection Manual (1984 or later edition), provides guidance and procedures for determining appropriate wave heights and periods.

iii. Breaking wave forces under structure-perpendicular loading must be considered in the design unless it can be demonstrated that the structure will not be subject to breaking waves. The very high, short duration "shock" pressures must be used for low mass structures such as bulkheads, while only the secondary "non-shock" pressures need to be used for massive structures such as gravity seawalls. Analyses of the breaking wave forces using methods such as those identified in the USACE report "Criteria for Evaluating Coastal Flood Protection Structures," (WES TR CERC-89-15) must be submitted.

2. Minimum Freeboard. The minimum freeboard for coastal flood protection structures to be recognized on FEMA flood maps for protection against the storm surge component of the base flood shall be 2 feet above the 1-percent-annual-chance stillwater elevation [and 1 foot above the height of the 1-percent-annual-chance wave or the maximum wave runup (whichever is greater)].

3. Toe Protection. The loss of material and profile lowering seaward of the structures must be included in the design either through the incorporation of adequate toe protection or an evaluation of structural stability with potential scour equal to the maximum wave height on the structure. Engineering analyses such as those recommended in the USACE's "Geotechnical Engineering in the Coastal Zone" (WES IR CERC-87-1) or "Design of Coastal Revetments, Seawalls, and Bulkheads" (COE EM 1110-2-1614) must be submitted for toe protection, or an analysis of scour potential such as found in "Criteria for Evaluating Coastal Flood Protection Structures," (WES TR CERC-89-15) must be submitted.

4. Backfill Protection. Engineering analyses of wave runup, overtopping, and transmission must be performed using methods provided in the USACE report "Criteria for Evaluating Coastal Flood Protection Structures," (WES TR CERC-89-15). Where the structure height is not sufficient to prevent overtopping and/or wave transmission, protection of the backfill must be included in the design. This should address prevention of loss of backfill by rundown over the structures, by drainage landward, under, and laterally around the ends of the structure as well as through joints, seams, or drainage openings in the structures.

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5. Structural Stability, Minimum Water Level. Analyses of the ability of the structures to resist the maximum loads associated with the minimum seaward water level, no wave action, saturated soil conditions behind the structures, and maximum toe scour must be submitted. For coastal dikes and revetments, geotechnical analyses of potential failure in a landward direction by rotational gravity slip must be submitted.
    i. For coastal dikes and revetments, geotechnical analyses of potential failure in a landward direction by rotational gravity slip must be submitted.
    ii. For gravity and pile-support seawalls, engineering analyses of seaward sliding, seaward overturning, and foundation adequacy using the maximum pressures developed in the sliding and overturning calculations must be submitted.
    iii. For anchored bulkheads, engineering analyses of shear failure, moment failure, and the adequacy of the tiebacks and deadmen to resist the loadings must be submitted.
6. Structural Stability, Critical Water Level. Analyses of the ability of the structure to resist the maximum loads associated with the critical water level, which may be any water level from the mean low water level to the 1-percent-annual-chance stillwater elevation, including hydrostatic and hydrodynamic (wave) loads, saturated soil conditions behind the structure, and maximum toe scour must be submitted.
    i. For coastal dikes and revetments, geotechnical analyses of potential failure in a seaward direction by rotational gravity slip and of foundation failure due to inadequate bearing strength must be submitted.
    ii. For revetments, engineering analyses of the rock, riprap, or armor block stability under wave action; uplift forces on the rock, riprap, or armor blocks; toe stability; and adequacy of the graded rock and geotechnical filters must be submitted.
    iii. For gravity and pile-supported seawalls, engineering analyses of landward sliding, landward overturning, and foundation adequacy using the maximum pressures developed in the sliding and overturning calculations must be submitted.
    iv. For anchored bulkheads, engineering analyses of shear failure and moment failure using “shock” pressures must be submitted.
7. Material Adequacy. Documentation and/or analyses must be submitted that demonstrate that the materials used for the construction of the structure are adequate and suitable, including life expectancy considerations, for the conditions that exist at the site.
8. Ice and Impact Alignment. Where appropriate, analyses of ice and impact forces must be submitted.
9. Structure Plan Alignment. A shore protection project should present a continuous structure with redundant return walls at frequent intervals to isolate locations of

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failure. Isolated structures, or structures with a staggered alignment, must submit analyses of the additional forces from concentrated, diffracted, and/or reflected wave energy on the different sections and ends.

10. Other Design Criteria. FEMA will require that flood protection structures described above, regardless of type, be evaluated on the basis of how they may react structurally to applied forces. Therefore, analyses normally required of one structure type may also be required by another type that would react in a similar manner to applied forces. In unique situations, FEMA may require that other design criteria and analyses be submitted to show that the structure provides adequate protection. In such situations, sound engineering practice will be the standard on which FEMA will base its determinations. FEMA will provide the rationale for requiring any additional information.

Adverse Impact Evaluation

All requests for flood map revisions based upon new or enlarged coastal flood control structures shall include an analysis of potential adverse impacts of the structure on flooding and erosion within, and adjacent to, the protected area.

Community and/or State Review

For coastal flood protection structures to be recognized, evidence must be submitted to show that the design, maintenance, and impacts of the structures have been reviewed and approved by the affected communities and by any Federal, State, or local agencies that have jurisdiction over flood control and coastal construction activities.

Maintenance Plans and Criteria

For a coastal flood protection structure to be recognized as providing protection from the base flood, the structure must be maintained in accordance with an official adopted maintenance plan. A copy of this plan must be provided to FEMA by the owner of the structure when recognition is being sought or when the plan for a previously recognized structure is revised in any manner. All maintenance activities must be under the jurisdiction of a Federal or State agency, an agency created by Federal or State law, or any agency of a community participating in the NFIP that must assume ultimate responsibility for maintenance. This plan must document the formal procedure that ensures that the stability and overall integrity of the structure and its associated structures and systems are maintained. At a minimum, maintenance plans shall specify the maintenance activities to be performed, the frequency of their performance, and the person by name or title responsible for their performance.

Certification Requirements

Data and analyses submitted to support that a given coastal flood protection structure complies with the structural design requirements set forth in paragraphs 1 through 10 above must be certified by a registered professional engineer. Also, certified as-built plans of the structure must be submitted. Certifications are subject to the definition given at § 65.2 of 44 CFR Part 65. In lieu of these certification requirements, a Federal agency with responsibility for design of coastal flood protection structures may certify that the structure has been adequately designed and constructed to provide protection against the base flood.

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Where a Mapping Partner chooses to perform a detailed engineering evaluation of an existing coastal armoring structure during an FIS, FEMA requires the evaluation to be based upon the criteria outlined above from the April 23, 1990, FEMA memorandum, and upon as-built documentation. When as-built documents are not available, the evaluation should be based upon best available data, standard design and engineering assumptions, and conservative estimates of material properties. The evaluation should be confirmed and documented by past performance during severe storm events. The underlying requirement is that the evaluation must yield an accurate assessment of coastal structure performance during the 1-percent-annual-chance flood, based upon available evidence.

It should be noted, however, that the art of coastal structure evaluation is constantly evolving. Thus, the Mapping Partner may choose to propose evaluation criteria that differ from those contained in the April 23, 1990, FEMA memorandum (e.g., from the CEM [USACE, 2003], or from other authoritative and accepted references). However, permission should be obtained from the FEMA Study Representative prior to utilizing alternative evaluation procedures and criteria.

D.2.10.2.2 Coastal Armoring Structure Evaluation Based on Limited Data and Engineering Judgment

For the purposes of an FIS, the Mapping Partner may not have sufficient resources and time to conduct a detailed evaluation of each coastal armoring structure within the study area. In such cases, the Mapping Partner can apply engineering judgment (albeit, guided by the FEMA memorandum and USACE CERC *Technical Report 89-15 "Criteria for Evaluating Coastal Flood Protections Structures*") to determine the likely stability of each structure during the 1-percent-annual-chance flood. These conclusions may be based largely on available archive information and local observations, including historic evidence of storm damage and maintenance. Note that any data and procedures used in the evaluations shall be documented (see Subsections D.2.10.6 and D.2.10.7), and communities and property owners shall be made aware that these evaluations are for mapping purposes only.

If the available information does not clearly point to survival or failure of a coastal structure, the Mapping Partner may either:

1. Conduct a detailed evaluation based on the FEMA criteria (April 23, 1990) (see the previous subsection).
2. Perform the erosion and wave analyses for both the intact and failed structure cases and map the flood hazards associated with the more hazardous case.

If option 1 is selected, the Mapping Partner shall clearly document the results of all cases investigated and specify which case is used for mapping purposes. It should be noted that a failed coastal structure may or may not yield the greatest flood hazards. Therefore, coastal flood analyses for the intact and failed conditions should be performed, with the greatest resulting flood hazard being mapped. Maintaining results of all analyses may be useful in the event map revisions are requested by property owners based upon certified structures[14.]

[14] Often, property owners request revisions to the FIRM based upon existing, new, or proposed coastal structures. Map revisions based upon coastal structures require a detailed evaluation and certification by a professional engineer

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D.2.10.2.3 Evaluation of Beach Stabilization Structures

Guidance on how to predict the survival or failure of groins, which usually fail by loss of profile (through settlement, displacement, or deterioration) and/or by becoming detached at their landward ends, is not readily available. Likewise, guidance on how to predict the failure of breakwaters, sills, and reefs (usually through loss of profile) is not readily available. Some information on failure modes may be available in technical or historical literature, and should be consulted by the Mapping Partner.

If a Mapping Partner chooses to evaluate beach stabilization structures during an FIS, the proposed evaluation methods and procedures should be discussed with the FEMA Study Representative, in advance, and approval by FEMA must be obtained before the evaluations can be carried out.

D.2.10.3 FIS Treatment of Coastal Armoring Structures

Technical Report 89-15 identifies four primary functional types of coastal flood protection structures: gravity seawalls, pile-supported seawalls, anchored bulkheads, and dikes or levees. A fifth type, revetment, is added here (see Figure D.2.10-1b).

Technical Report 89-15 recommends as a general policy that "FEMA not consider anchored bulkheads as providing flood protection during large storms." Thus, the default assessment for open coast anchored bulkheads should be that they are assumed to fail during the 1-percent-annual-chance flood. Mapping Partners may choose to treat some anchored bulkheads as surviving the flood and/or providing some degree of flood protection, but those instances should be limited (e.g., to sheltered waters, where the bulkhead may be stable during 1-percent-annual-chance flood conditions).

Many seawalls, revetments, and (some) bulkheads may be recognized on flood hazard maps if analysis based on the evaluation criteria in Subsection D.2.10.2 shows they will remain intact during the 1-percent-annual-chance storm (in some cases, even if overtopped). These structures may provide total or limited protection against flooding, erosion, and waves, depending upon their location, strength, and dimensions.

D.2.10.3.1 Failure and Removal of Coastal Armoring Structures

In the event that a coastal structure is determined to fail, the Mapping Partner shall remove the structure entirely from the analysis transect, or estimate the partial collapse of the structures where appropriate (see Subsection D.2.10.3.2). If the failed structure is removed entirely, the remaining soil profile should be altered to achieve its likely slope immediately after structure failure. Information on slopes behind failed structures is limited. These slopes may vary from 1 on 100 (v:h) for unconsolidated sands, to 1:1 or steeper for consolidated material landward of the failed structure.

The post-failure slope for this analysis should be in the range of 1:1 to 1:1.5 (v:h). Note that the post-failure slope may not necessarily match the long-term stable slope, but will serve as the

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registered in the subject State. FEMA has distributed the *Coastal Structure Form* (MT-2, Form 5, available at <http://www.fema.gov/pdf/fhm/mt2_f5.pdf>) to evaluate coastal structures as the basis for map revisions.

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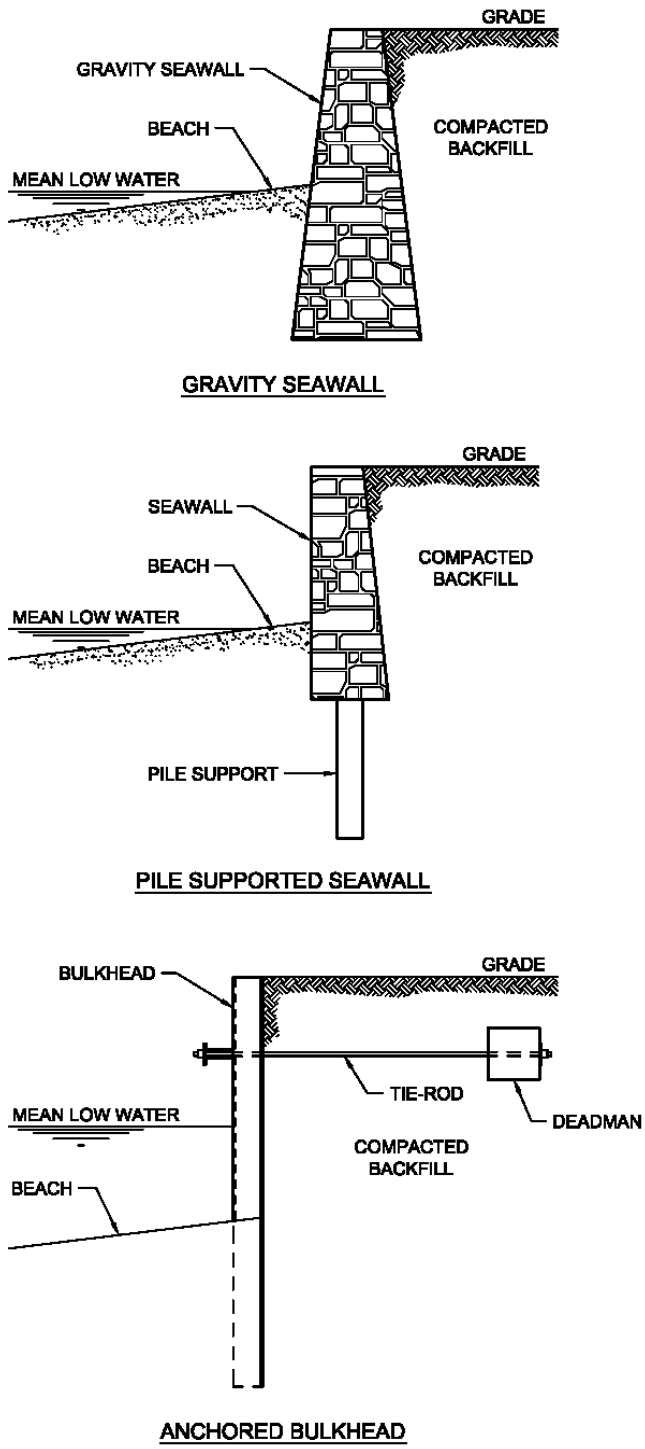
basis for subsequent site-specific, event-based erosion (D.2.9), wave height (D.2.7), wave runup (D.2.8), and wave overtopping (D.2.8) analyses.



PRIMARY FUNCTIONAL TYPE OF COASTAL ARMORING STRUCTURES

Figure D.2.10-1a. General Classification of Coastal Armoring Structures

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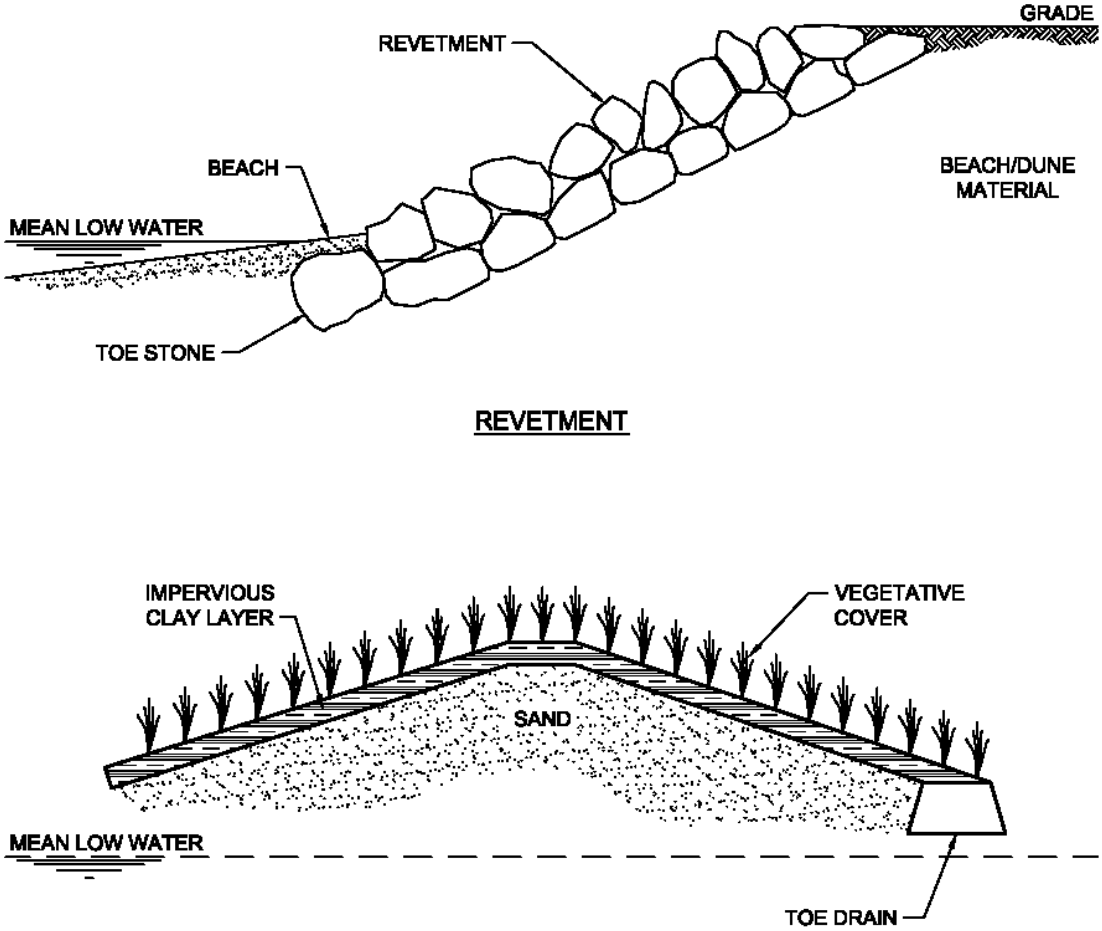

Figure D.2.10-1b. General Classification of Coastal Armoring Structures

D.2.10.3.2 Partial Failure of Coastal Armoring Structures

Coastal structures are frequently constructed of either concrete or large individual armor units. Consequently, it is improbable that the structural components will be completely destroyed or removed from the vicinity during the 1-percent-annual-chance flood. It may be appropriate to assume partial failure of such structures and to model accordingly.

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A recommended simple geometric approach for approximating partial failure of a vertical or near-vertical coastal armoring structure is as follows (see Figure D.2.10-2):

1. Estimate toe scour at the subject structure based upon the methods described in the CEM (USACE, 2003).
2. Assume the structure fails and falls into a rough, porous slope at 1:1.5 (v:h).
3. Extend the 1:1.5 failure slope from the depth of scour at the structure toe landward to the point where it intersects the existing grade.

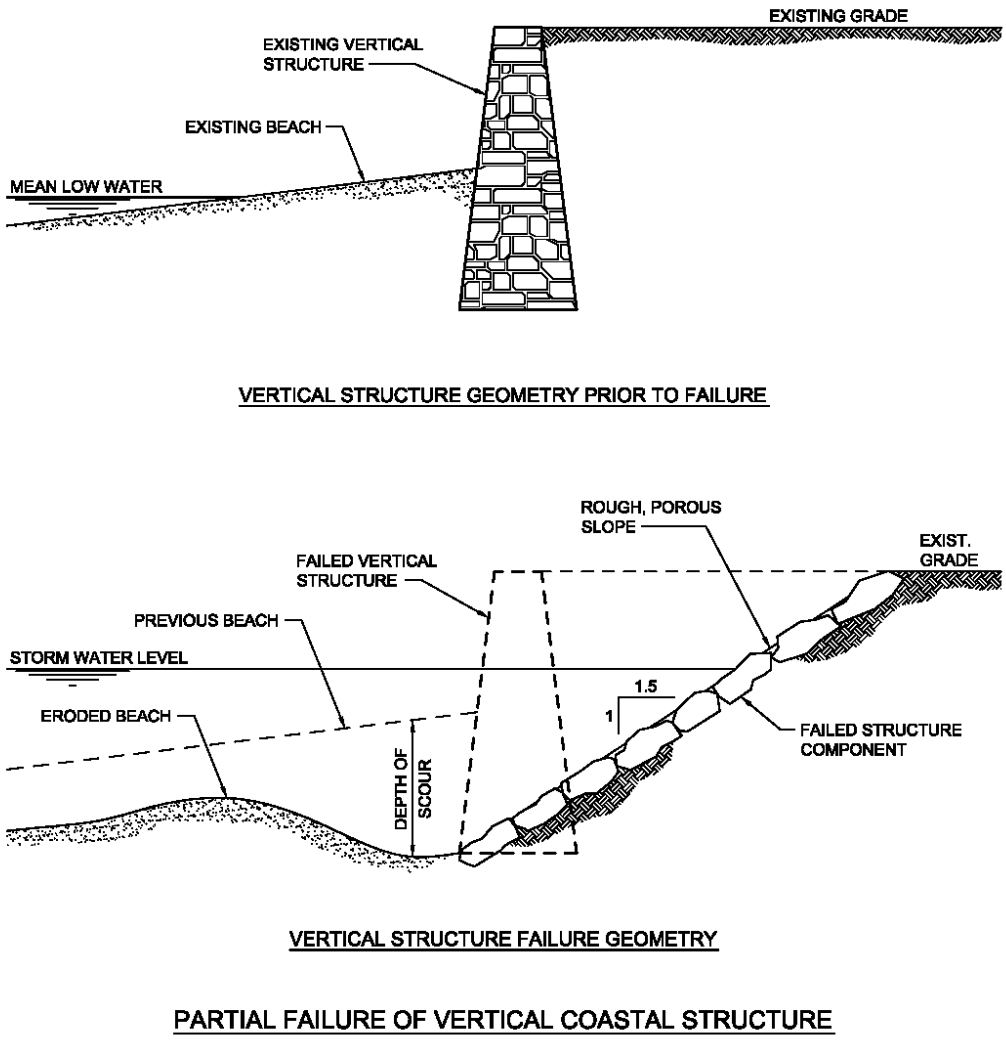

Figure D.2.10-2. Partial Failure of Vertical Coastal Structure

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A recommended approach for approximating partial failure of a sloping revetment (due to undermining at the toe, or to collapse at the top due to erosion behind the structure) is as follows (see Figure D.2.10-3):

1. Assume scour at the base of the structure is equal to the depth of the armor layer.
2. Assume the structure will collapse in place into a triangular section throughout the structure footprint, with side slopes equal to the original structure slope.
3. Assume the landward side of the failed configuration will be half exposed and half buried. Approximate the soil slope landward from the failed structure at a slope in the range of 1:1 to 1:1.5 (v:h).

After determining an appropriate failure configuration, the Mapping Partner shall conduct overland wave height propagation (D.2.7) and wave runup (D.2.8) analyses upon the failed structure, as discussed in preceding subsections. The Mapping Partner shall select an appropriate roughness factor when conducting runup and overtopping analyses on the failed structure.

In some cases, the assumed failed slope may result in the undermining of buildings located landward of the coastal structure. If this occurs, the building shall be removed from the analysis transect and not considered during subsequent wave effects modeling.

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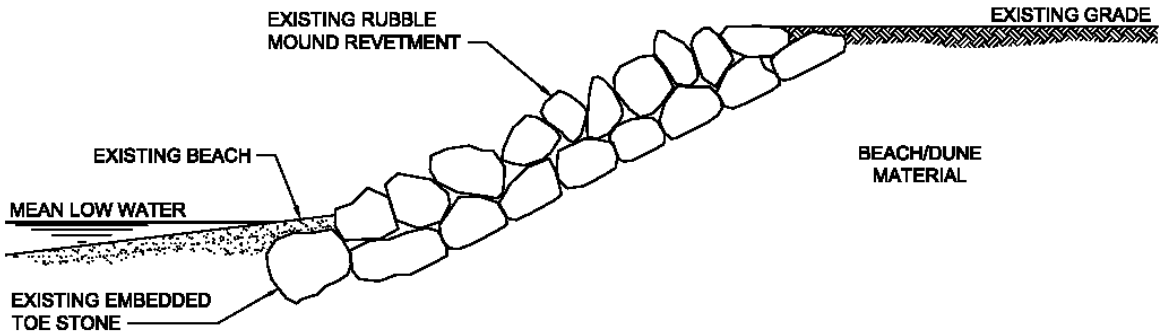
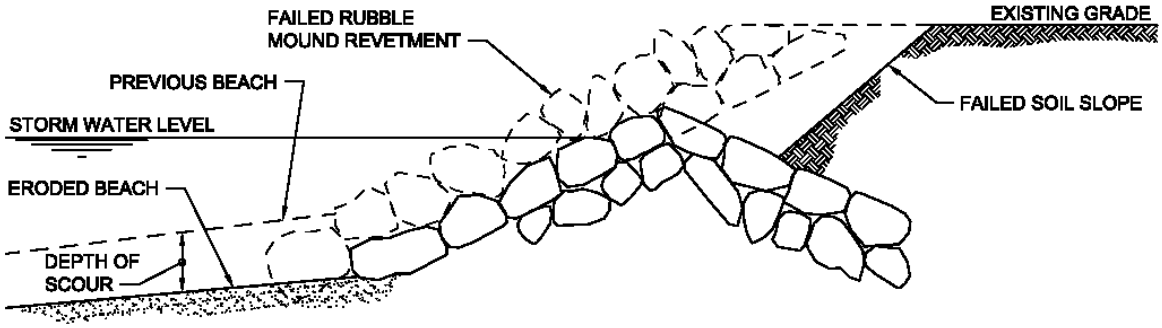


REVETMENT GEOMETRY PRIOR TO FAILURE



REVETMENT FAILURE GEOMETRY

PARTIAL FAILURE OF A SLOPING REVETMENT

Figure D.2.10-3. Partial Failure of a Sloping Revetment

D.2.10.3.3 Buried Coastal Structures

In some instances, coastal structures may be covered or buried by sediments and not readily observable during an FIS site reconnaissance. For example, Figure D.2.10-4 shows two photographs of nearly buried structures on the Atlantic coast. The top photo shows a revetment, the bottom a buried seawall. This is one example where a dune is building up in front of the structures and will one day cover the structures. Some buried structures are of a size and construction to possibly affect coastal flood hazards, and should—like exposed structures—be considered during the FIS.

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The Mapping Partner is responsible for determining whether buried coastal structures exist within the study area during the preliminary investigation phase of the FIS. The Mapping Partner should include information from the community and carefully review aerial photographs of the study area to locate buried structures.

Once the Mapping Partner has determined that a coastal structure is likely buried at a site, the next steps are to collect information about the structure and follow the study process outlined in Figure D.2.10-5. The erosion analysis will result in one of the following two scenarios: 1) the buried structure will remain buried during the 1-percent-annual-chance flood (see Figure D.2.10-6), or 2) the buried structure will be exposed by the 1-percent-annual chance flood (see Figure D.2.10-7).

Note that the buried structure study process need not be followed unless the presence of buried structures is known or is highly likely. The *Guidelines and Specifications* do not require field investigations to identify buried coastal structures. There may be some instances where limited field work (such as soil probes to locate the structure) might be useful, but this should be limited to cases where large buried structures are known to exist.

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Figure D.2.10-4. Examples of a Buried Coastal Structure that Could Affect Flood insurance risk zones and BFEs

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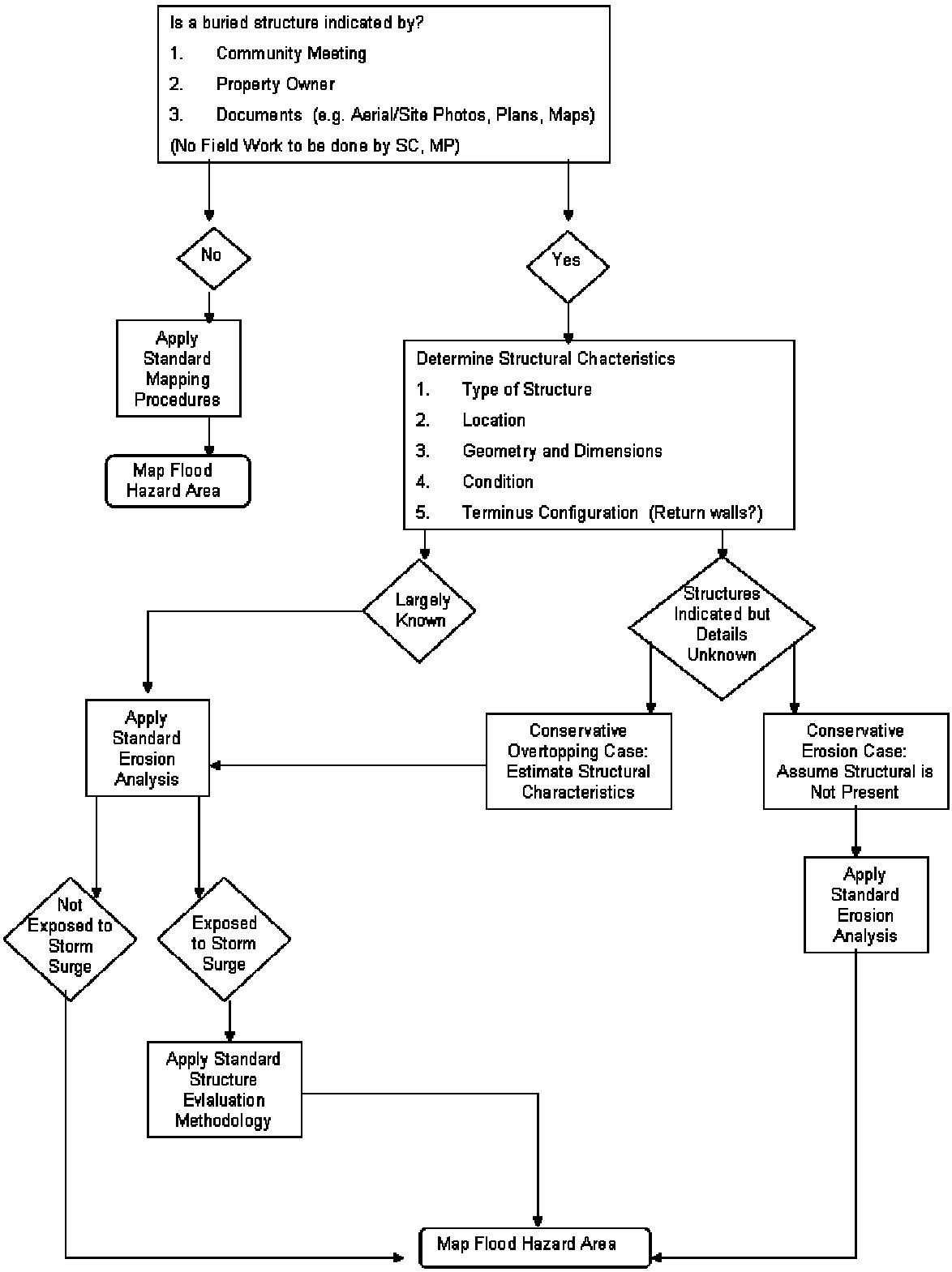

Figure D.2.10-5. Methodology for Evaluating Buried Coastal Structures

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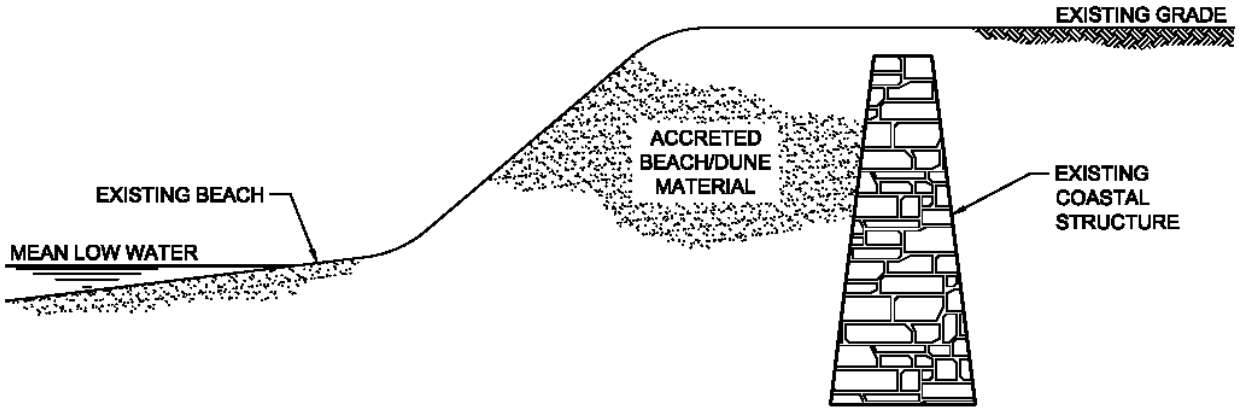
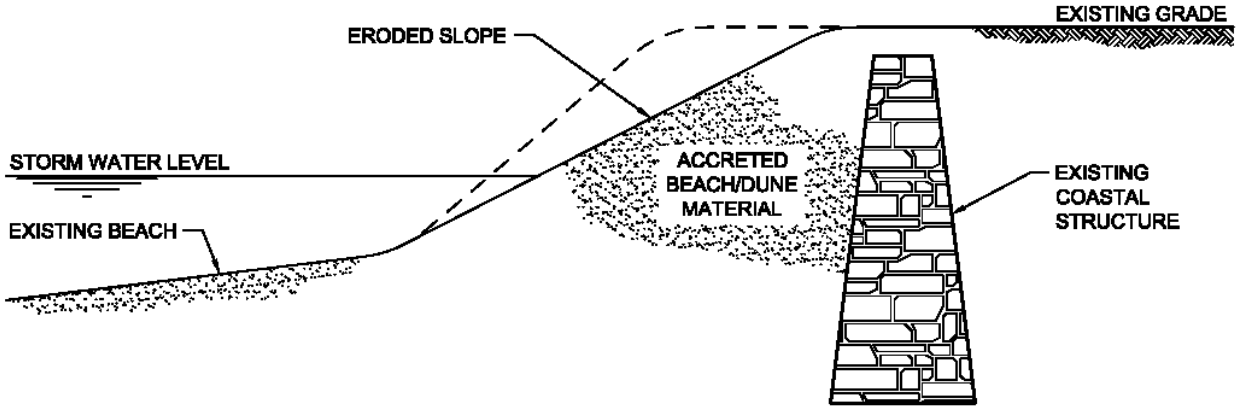


EXISTING GEOMETRY - COASTAL STRUCTURE BURIED BY ACCRETED SEDIMENTS



POST-EROSION GEOMETRY - BURIED STRUCTURE

NON-EXPOSURE OF BURIED STRUCTURE DURING 1% ANNUAL CHANCE FLOOD

Figure D.2.10-6. Buried Structure Remains Buried During 1-Percent-Annual-Chance Flood

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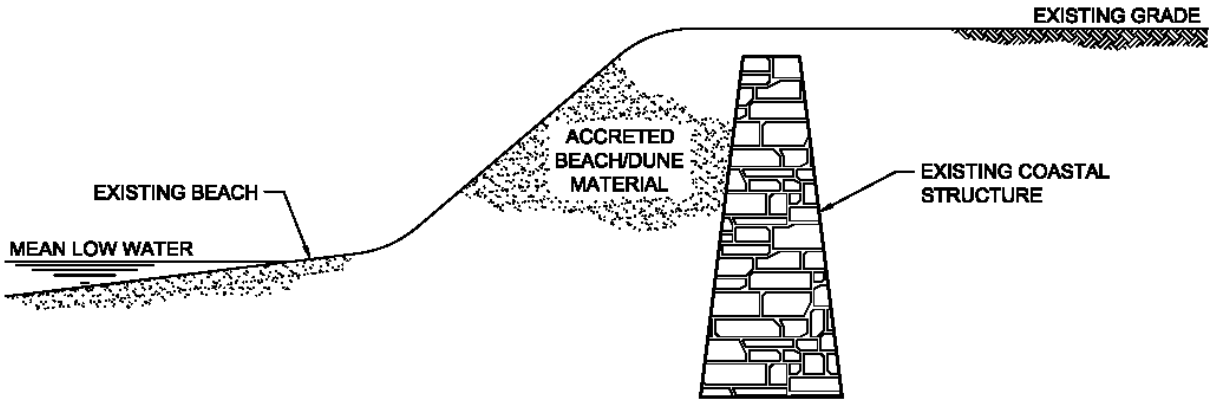
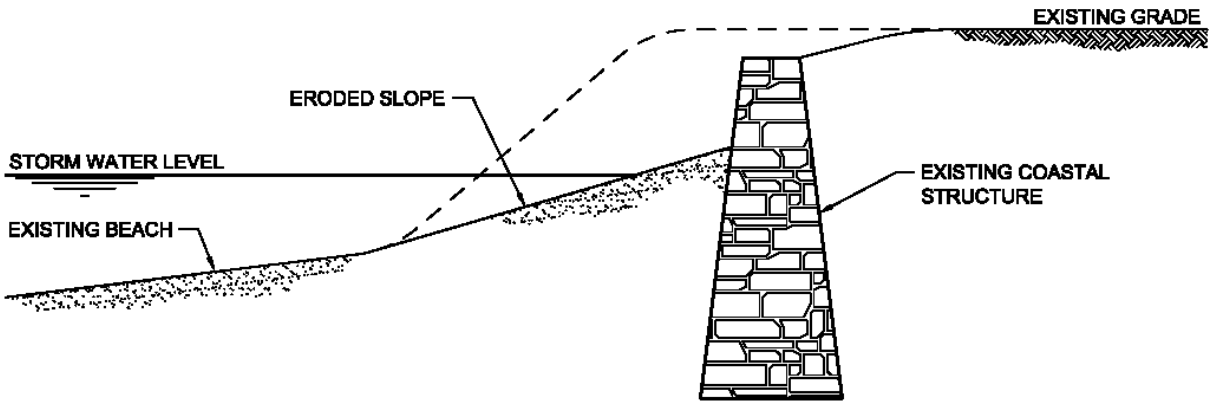


EXISTING GEOMETRY - COASTAL STRUCTURE BURIED BY ACCRETED SEDIMENTS



POST-EROSION GEOMETRY - BURIED STRUCTURE

EXPOSURE OF BURIED STRUCTURE DURING 1% ANNUAL CHANCE FLOOD

Figure D.2.10-7. Buried Structure Exposed During 1-Percent-Annual-Chance Flood

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D.2.10.3.4 Coastal Levees

Levees are man-made structures (usually earthen embankments that may or may not have their slopes and crest armored) that prevent flooding of low-lying areas. A *levee system* consists of a levee, or levees, or a floodwall and associated structures, such as closure and drainage devices, that are constructed and operated to prevent flooding of interior areas. FEMA has issued guidance on levees in Procedure Memorandum Number 34 "Interim Guidance for Studies including Levees" dated August 22, 2005. The Mapping Partner should consult Procedure Memorandum Number 34 for guidance in any new study or revision in which a levee structure influences the BFEs or hazard mapping.

For coastal levees or levee systems to be recognized as providing protection against the base flood by the NFIP and incorporated into flood hazard maps, they must be designed, constructed, operated, and maintained to resist erosion and prevent any flooding or wave overtopping landward of the levee crest during 1-percent-annual-chance flood conditions. The levee or levee system also must be certified as providing that level of protection. NFIP regulations (44 CFR Part 65.10) detail the requirements for a levee to be recognized as providing protection from flooding, including a freeboard requirement specific to coastal levees — the crest elevation of the levee must be elevated at least 3 feet above the 1-percent-annual-chance total stillwater elevation (MWL), and 1 foot above the 1-percent-annual-chance wave height or the maximum wave runup elevation (whichever is greater)[15]. Data to support that a given levee system complies with the structural requirements described in 44 CFR Part 65.10 must be certified by a registered professional engineer. In lieu of these structural requirements, a Federal agency with responsibility for levee design may certify that a levee has been adequately designed and constructed to provide protection from the 1-percent-annual-chance flood. Occasionally, exceptions to the minimum coastal levee freeboard requirement may be approved. Appropriate engineering analyses demonstrating adequate protection with a lesser freeboard must be submitted to support a request for such an exception. The material presented must evaluate the uncertainty in the estimated base flood loading conditions. Particular emphasis must be placed on the effects of wave attack and overtopping on the stability of the levee. Under no circumstances, however, will a freeboard of less than 2-feet above the 1-percent-annual-chance total stillwater surge elevation (MWL) be accepted. Additional guidance for evaluating levees can be found in Appendix H of the *Guidelines and Specifications*.

The USACE utilizes a risk-based analysis to evaluate flood damage reduction projects such as levees. Freeboard requirements are not used in the risk-based approach but rather a level of assurance should be achieved that the levee provides protection from the 1-percent-annual-chance flood. Assurance is defined as the percent chance that flood waters associated with the 1-percent-annual-chance flood will not inundate any area landward of a levee system that would be inundated without benefit of the levee system. The levee must at least be of such height that there is a 90 percent assurance of containing the 1-percent-annual-chance wave height or maximum wave runup (whichever is greater) associated with the 1-percent-annual-chance stillwater elevation at the site. Risk-based analysis that demonstrates a 95 percent assurance of containing

[15] To be recognized by the NFIP, riverine levees require a minimum of 3 feet of freeboard above the 1-percent-annual-chance flood elevation and a minimum of 4 feet of freeboard within 100 feet of locations where the flow is constricted (e.g., a bridge). In addition, the upstream end of the levee must provide an additional 0.5 foot of freeboard added to the minimum.

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the 1-percent-annual-chance wave height or maximum wave runup (whichever is greater) associated with the 1-percent-annual-chance stillwater elevation at the site is acceptable justification for the reduction in minimum freeboard to 2 feet as provided for in 44 CFR Part 65.10.

For a coastal levee to be considered as the basis of a map revision, the "Riverine Structure Form" (MT-2, Form 3, available at <http://www.fema.gov/pdf/fhm/mt2_f3.pdf>) must be completed in addition to the "Coastal Structure Form."

For consideration of levees that are subject to both coastal and riverine conditions, the Mapping Partner shall determine freeboard requirements using water levels determined using the methods contained in Subsection D.2.4 and Subsection D.2.5. Because BFEs are required to be mapped to within a 0.5-foot tolerance (Guidelines and Specifications Appendix C.6.3), the combined total stillwater (MWL) and riverine flood profile shall be adjusted to an inland extent where the effects of waves and/or runup diminish to 0.5 foot or less. The resulting flood profile shall be compared to the crest elevations of flood protection along the combined tidal-river reach to determine whether interior areas are sufficiently protected.

D.2.10.3.4.1 Levee Failure and Removal

Current FEMA policy states that in instances where levees cannot meet the requirements for recognition by the NFIP, the levees shall be "removed" from the analysis. Two scenarios are considered here: 1) a single levee on an analysis transect, and 2) multiple levees along an analysis transect.

Single Levee Case: If a community cannot provide the Mapping Partner with evidence that a levee is certified as meeting FEMA's requirements in 44 CFR 65.10, then the Mapping Partner shall remove the levee from subsequent analyses. In such a case, the Mapping Partner shall:

- Modify the topography along the transect by erasing the levee cross section and joining the ground elevations on each side of the levee with a straight line.

- If the Mapping Partner determines that the failed levee provides substantial (but not complete) protection against incident wave action during 1-percent-annual-chance flood conditions, the Mapping Partner shall assume no wave action penetrates beyond the failed levee, and that only stillwater flooding (tide + wind setup) and locally generated waves (i.e., waves generated in the region behind the levee) affect the flooded area behind the levee.

- If the Mapping Partner determines that the failed levee provides minimal protection against incident wave action during 1-percent-annual-chance flood conditions, the Mapping Partner shall consult with the FEMA Study Representative to determine whether subsequent analyses should assume incident wave action penetrates beyond the failed levee.

Multiple Levee Case: If a community cannot provide the Mapping Partner with evidence that the outer levee is certified as meeting FEMA's requirements in 44 CFR 65.10, then the Mapping

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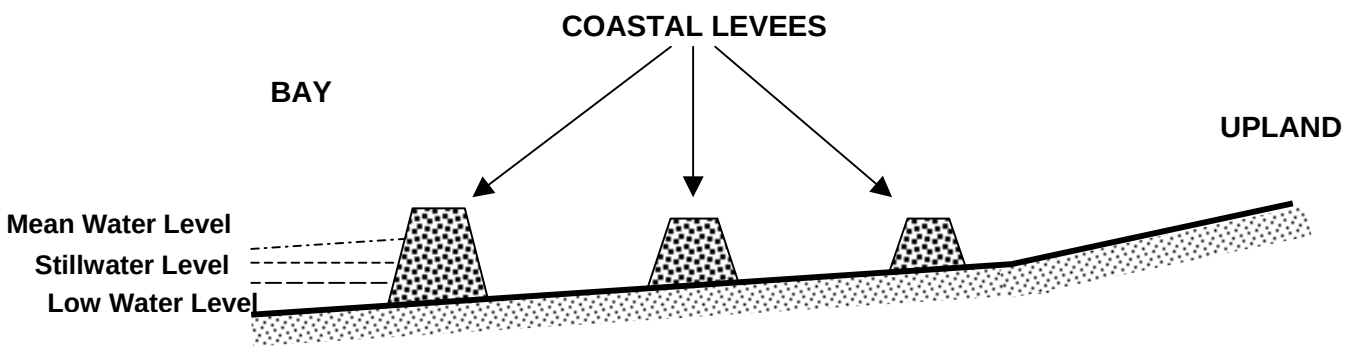
Partner shall remove the outer levee from subsequent analyses. In such a case, the Mapping Partner shall do one of the following:

- Modify the topography along the transect by erasing the outer levee cross-section and joining the ground elevations on each side of the levee with a straight line.

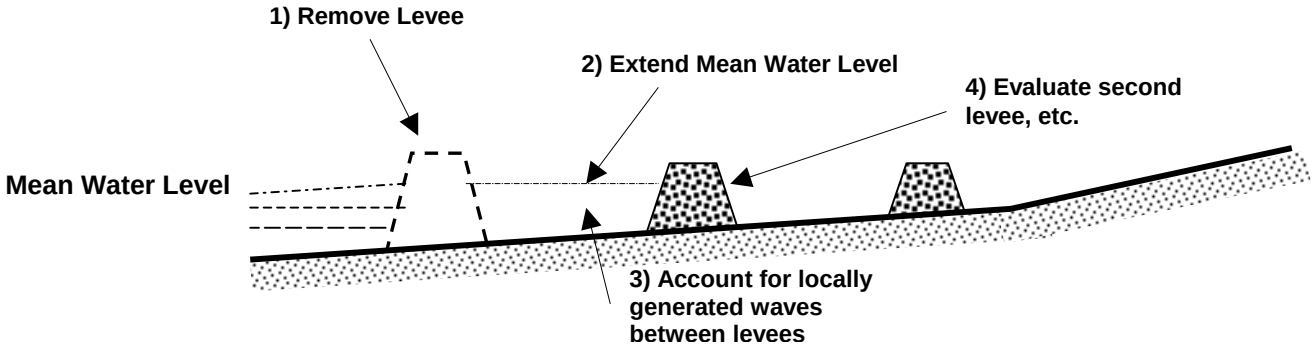
- If the Mapping Partner determines that the failed outer levee provides substantial (but not complete) protection against incident wave action during 1-percent-annual-chance flood conditions, the Mapping Partner shall assume no wave action penetrates beyond the outer levee, and that only mean water flooding (tide + wave setup) and locally generated waves (i.e., waves generated in the region behind the levee) affect the next landward levee (see Figure D.2.10-8).

- If the Mapping Partner determines that the failed outer levee provides minimal protection against incident wave action during 1-percent-annual-chance flood conditions, the Mapping Partner shall consult with the FEMA Study Representative to determine whether subsequent analyses should assume incident wave action penetrates beyond the failed outer levee.

- The Mapping Partner shall repeat steps 1 through 3 for each additional levee along the transect, for which the community cannot supply certification.



Multiple Levee Scenario, Prior to Levee Evaluation and Removal



Multiple Levee Scenario, Outer Levee Removal (prior to inner levee evaluations)

Figure D.2.10-8. Levee Removal, Multiple Levee Situation

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D.2.10.3.5 Operation and Maintenance

Both the FEMA memorandum (April 23, 1990) (D.2.10.2.1) and the NFIP regulations indicate that an operation and maintenance plan is required as part of the certification that a coastal structure will withstand the base flood. At a minimum, the plan must document the formal procedure to maintain the stability, height, and overall integrity of the structure and its associated structures and systems.

The NFIP regulations (44 CFR Part 65.10) require that all maintenance activities must be under the jurisdiction of a Federal or State agency, an agency created by Federal or State law, or an agency of the community participating in the NFIP that must assume ultimate responsibility for maintenance. Often, the aforementioned government entities are unable to take responsibility for maintenance of private structures. However, a government agency can recognize private property owners as the responsible party for maintenance of an existing structure.

For the purposes of an FIS, the Mapping Partner shall ascertain (through discussions with the community and property owners) whether operation and maintenance plans exist for coastal structures that are expected to remain intact during 1-percent-annual-chance flood conditions. Mapping Partners may not have sufficient resources and time to conduct detailed evaluations of the operation and maintenance of each coastal structure within the study area. In such cases, the Mapping Partner shall make an engineering judgment about the adequacy of structure operation and maintenance. The Mapping Partner must document data, materials, and assumptions associated with the flood hazard determinations related to structure operation and maintenance. Communities and property owners should be made aware that these evaluations are for mapping purposes only.

D.2.10.4 FIS Treatment of Beach Stabilization Structures

If a Mapping Partner chooses to evaluate beach stabilization structures (e.g., groins, jetties, sills, or similar structures) during an FIS, the following approach is recommended:

- Identify any beach stabilization structures during the FIS reconnaissance phase
- Use historical evidence and engineering judgment to determine whether the structures (or similar structures nearby) have been damaged or detached (during prior storms or gradually over time)
- Document prior damage to the stabilization structures and any resulting shoreline recession attributable to the structural damage
- Notify the FEMA Study Representative if the Mapping Partner intends to remove beach stabilization structures or reduce their effects during the FIS analyses. Obtain FEMA concurrence before proceeding with the following steps.
- Use historical evidence and engineering judgment to predict the likely shoreline configuration (in plan view and elevation) if the structures fail during 1-percent-annual-chance flood conditions.

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- Subject the modified shoreline and profile to typical FIS analyses (e.g., event-based erosion analysis, wave runup and overtopping analysis, and wave height analysis).

- Note that in the case of some stabilization structures, it is unlikely that their failure will require "removal" from analysis transects; the effects of the structure failure on the shoreline configuration, however, should be considered by the analyses.

D.2.10.5 FIS Treatment of Miscellaneous Structures

Current FEMA guidance does not address the effects of miscellaneous structures (e.g., piers, port and navigation structures, bridges, culverts, tide gates, etc.) on coastal flood hazard analysis and mapping. This subsection provides general guidance for identifying and analyzing the effects of miscellaneous structures on flooding in sheltered water areas as follows:

- The Mapping Partner shall identify structures – in addition to the coastal armoring and beach stabilization structures addressed above – that could exert a significant influence on nearshore waves and currents, coastal sediment transport, or ponding in backshore areas, during 1-percent-annual-chance flood conditions, particularly in sheltered waters. This should be done during the FIS reconnaissance phase.

- Once identified, the Mapping Partner shall use historical evidence, other readily available data, and engineering judgment to determine whether the miscellaneous structures are likely to survive the 1-percent-annual-chance flood conditions. If the structures are likely to fail, then they (and their effects on the shoreline and flooding) should be removed from subsequent analyses.

- The Mapping Partner shall notify the FEMA Study Representative as to how he/she intends to address miscellaneous structures and their effects during the FIS analyses, and obtain FEMA concurrence before proceeding.

D.2.10.5.1 Piers, Navigation Structures, and Port Facilities

The Mapping Partner shall review navigation charts, aerial photographs, and other information relative to piers, navigation structures, and port facilities (including dredged channels) that may affect the propagation and transformation or dissipation of waves within a sheltered water body, or that may affect littoral sediment transport. The Mapping Partner shall consider the range of possible effects of these structures and facilities during 1-percent-annual-chance flood conditions, using readily available data and site characteristics as a guide.

The Mapping Partner shall verify basic structure and facility information with local agencies and communities to determine the location, extent, and influence of these features. If there is any uncertainty concerning major features and their potential effects on upland flood hazards, limited field surveys or additional data collection shall be considered to augment existing data.

D.2.10.5.2 Bridges, Culverts, and Tide Gates

The shorelines of sheltered waters are often paralleled by roads and railroads in backshore areas. The effect of these structures on coastal flooding can be most pronounced where they intersect tidally influenced creeks, river channels, and floodplains. The Mapping Partner shall consider the

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presence and influence of roadways, railways, embankments and abutment fill, and bridge piers on flood hazards during 1-percent-annual-chance flood conditions.

The Mapping Partner shall identify the location and condition of culverts, tide gates, and other flow control structures in the vicinity of the study site and evaluate their potential to affect interior flood elevations. Design calculations and reports for individual culverts and tide gates, and storm drainage master plans for larger drainage systems shall be obtained and reviewed by the Mapping Partner to understand design criteria and provide data for hydraulic calculations and hazard zone delineation.

D.2.10.6 Data Requirements

The Mapping Partner shall obtain documentation for each coastal structure that could provide protection during 1-percent-annual-chance flood conditions, or significantly affect flood hazards in the study area. The documentation shall provide all information necessary to evaluate the structure according to the criteria set forth in Subsection D.2.10.2.1. Documentation should include, but is not limited to, the following:

- As-built design parameters: structure type, location, layout, dimensions, crest elevation of structure, etc.;
- Dominant site particulars (e.g., local water depth, tide, surge and wave conditions, erosion rate, sediment characteristics and geotechnical conditions, debris hazards, and ice climate);
- Construction materials and present integrity;
- Historical record for structure including: construction date, plans, and specifications; recent inspection reports and photographs; maintenance plan and responsible party; and dates and descriptions of damage, repairs, and modifications; and
- Clear indications of effectiveness or ineffectiveness.

The Mapping Partner shall develop much of this information through office activity, including a careful review of aerial and site photographs, reports and information provided by the community and property owners, and other readily available information. In the case of some major coastal structures, site inspection would be advisable to confirm preliminary judgments.

Note that the level and detail of the structure and site data collected should be consistent with the level of analysis undertaken by the Mapping Partner. An analysis based on engineering judgment, or multiple analyses assuming different structure responses during 1-percent-annual-chance flood conditions (e.g., structure survives intact, partial failure, complete failure) will require less detailed and precise information than a structural engineering and geotechnical evaluation of a coastal structure.

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D.2.10.7 Study Documentation

If coastal structures are present in the study area, the Mapping Partner shall document the data, methods, and procedures used to evaluate the likelihood that the structures will survive 1-percent-annual-chance flood conditions (D.2.10.2.1). This documentation shall include any assumptions or approximations used in the analyses. The same documentation shall be required in the event that coastal structures are indicated by information collected during the FIS, but are apparently buried and not visible during the study.

The Mapping Partner shall document the results of all analyses of coastal structures conducted for the FIS. In cases where the study contractor could not determine whether a given structure would survive the 1-percent-annual-chance flood intact, and where multiple analyses were conducted for the structure (i.e., intact condition, failed condition, and removed from the analysis transect), the Mapping Partner shall document each analysis and record the structure condition that was used to map flood insurance risk zones and BFEs. This information will be useful in the event a map revision is requested based upon a structure condition different from that used as the basis for the FIRM. Subsection D.2.12.2 describes the intermediate data submission procedures during which the documentation and analysis will be submitted to FEMA for review and the requirements for the preparation of a Technical Support Data Notebook (TSDN). The TSDN will contain the data needed by FEMA or the community to reconstruct or defend the study results on technical grounds.

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