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Condition and Performance Rating Procedures for Nonrubble Breakwaters and Jetties

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REMR Management Systems—Coastal/Shore Protection Structures

Condition and Performance Rating Procedures for Nonrubble Breakwaters and Jetties

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Preface

The research documented in this technical report was initiated as part of the Operations Management problem area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. The work was performed under Civil Works Research Work Unit 32672, “Development of Uniform Evaluation for Procedures/Condition Index for Civil Work Structures.” The effort was completed in the Civil Works O&M Management Tools Research Program. The work was performed as part of Civil Works Research Work Unit 67890, “Simplified Condition Index.”

The original sponsor was Mr. Harold Tholen, U.S. Army Corps of Engineers, Directorate of Civil Works, Operations Division (CECW-O). Mr. James D. Hilton (CECW-OD) took over after Mr. Tholen’s retirement in late Fiscal Year 2000 (FY00). Mr. Charles M. Hess (CECW-O) was Chief of the Operations Division, Directorate of Civil Works.

The research effort was coordinated by Mr. Donald Plotkin, Construction Engineering Research Laboratory (CERL). After his departure, the research was completed by Mr. Stuart Foltz and Mr. Dave McKay, Facilities Maintenance Branch (CF-F). Mr. Doug Pirie is now an independent consultant. Mr. Mark W. Slaughter was Chief, CF-F and Dr. Alan W. Moore was Director, CERL.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL James R. Rowan, EN, and the Director of ERDC is Dr. James R. Houston.

1 Introduction

Background

In an effort to improve maintenance techniques and practices for inland waterway and coastal structures, the U.S. Army Corps of Engineers (USACE) established the Repair, Evaluation, Maintenance, and Rehabilitation Research (REMR) program, which was funded from 1984 to 1998. Within the REMR program is a group of projects dedicated to the development of computerized maintenance management systems for coastal and inland waterway navigational structures. The general intent of these REMR Management Systems is to provide maintenance managers at all levels with tools to promote easier and more effective maintenance and budget planning. Additional objectives are to create uniform procedures for assessing the condition of structures and to create assessment methods that will allow the condition of structures, and their parts, to be expressed numerically to take best advantage of the benefits available from the use of microcomputers in maintenance management.

The condition and performance rating procedures described here evolved over several years through the joint effort of a number of people throughout the Corps coastal operations and maintenance (O&M), engineering, and research community. Representatives of each Coastal Engineer Division have been part of the advisory group guiding the project, and suggestions from people in every Coastal Engineer District have been used to produce the rating system documented here. It is expected that field application of these condition rating procedures will lead to further refinement and improvement over time.

Objectives

The objectives of this phase of the project were to:

a. Establish a rational, standard procedure for evaluating the physical condition and performance of nonrubble breakwaters and jetties.

b. Create a method for determining numerical condition and performance ratings, which in turn would be used to produce Condition Index (CI) values for the structures.

This report describes the system created to accomplish these objectives. It also describes a process for collecting the information needed to make the condition and performance evaluations. Some of the required information is not used directly in producing CI values, but is considered necessary for a good inspection, analysis, and evaluation.

Scope

The condition rating system described here represents the second stage in developing a maintenance management system for coastal navigation and protection structures. The first stage consisted of the development and fielding of a rubble mound breakwater management system. The computer software (called BREAKWATER) that was developed for rubble breakwaters and jetties has not been modified to include nonrubble structures.

The complete O&M budget planning process (and thus a complete maintenance management system) must incorporate the following major factors, generally evaluated in this sequence:

a. structure condition,

b. structure performance,

c. risk/reliability,

d. economics, and

e. policies and priorities.

The evaluation system described here covers the first two factors for nearly all types of breakwaters and jetties except rubble mound construction, including cribs, pile and plank, sheet pile, caissons, monoliths, and various hybrids. Results from this evaluation system are intended to feed methods for handling factors c, d, and e. Unfunded efforts include the creation of similar systems for seawalls, bulkheads, groins, and revetments.

Approach

The research for this project was conducted as a joint effort between the Construction Engineering Research Laboratory (CERL) and the Corps coastal divisions and districts. Assisting in development was the Coastal Structure Advisory Group (CSAG), which included representatives from each of the nine Coastal Engineer Divisions, the Coastal Engineering Research Center, and Corps headquarters.

Concepts for the condition rating procedures were generated by the authors, the CSAG, and other members of the Corps' coastal community. These concepts were refined through experience and field testing by the Engineer Districts. The procedures documented here were the result of many iterations of development and refinement. The intent was to produce a system specific enough so all structures would be assessed in the same manner, and yet broad enough to allow for the many variations inherent in coastal structures.

Mode of Technology Transfer

It is recommended that these evaluation procedures be distributed to the field through an Engineer Circular and incorporated into an Engineer Regulation.

2 REMR Management Systems

REMR Management Systems are intended to provide maintenance managers at all levels with tools to promote easier and more effective maintenance and budget planning. They are decision support tools to help managers determine when, where, and how to effectively allocate maintenance and rehabilitation dollars for Civil Works facilities. These systems are being developed to provide:

a. More objective condition assessment procedures,

b. Corps-wide consistency in structure assessment,

c. A means for comparing the condition of facilities and tracking change in condition over time,

d. A means for O&M project development based on consistent structure condition and performance criteria, and

e. Computer software for storing and organizing data, performing calculations, and producing a variety of reports (on structure condition, budgets, maintenance and repair records, etc).

The primary objective of the REMR Management Systems is to help managers obtain the best facility condition for a given budget level. The basic system features are shown schematically in Figure 1.

Application of the Maintenance Management Systems

The REMR Management Systems are intended to help determine when structures will warrant repair action, and the appropriate type and extent of repairs. Structure or project deficiencies that cannot be corrected through standard maintenance or repair actions are beyond the scope of these systems and must be handled through other processes.

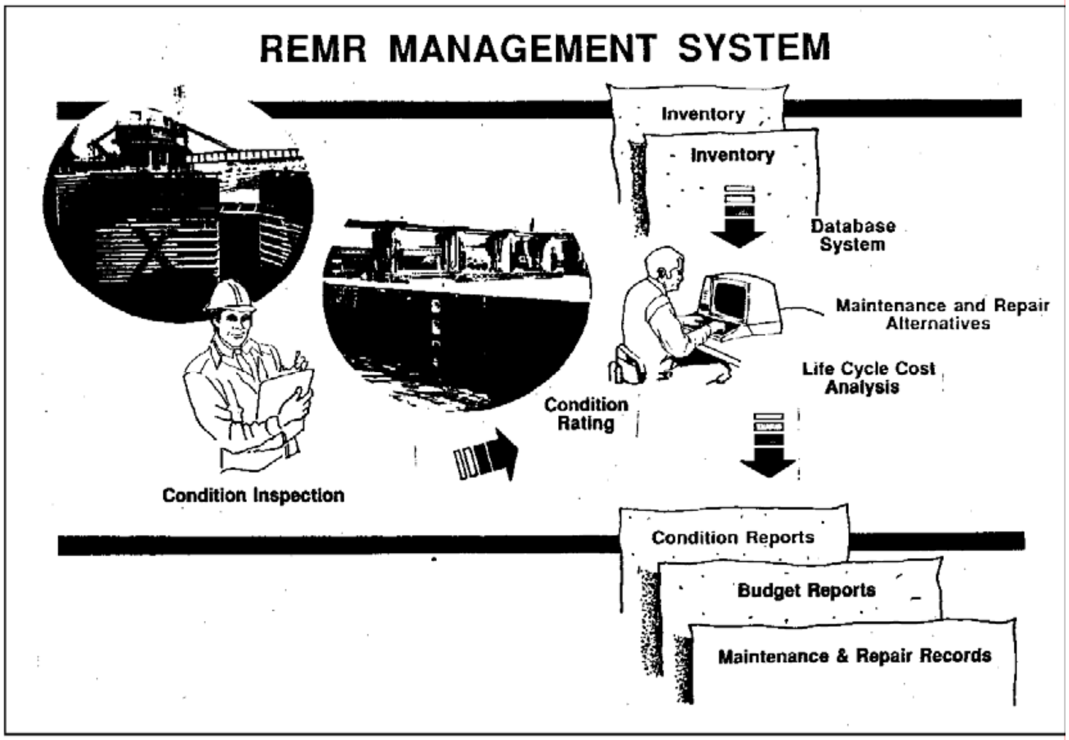


Figure 1. REMR Management System.

Performance-Based Evaluation

The evaluation process described in this manual is performance-based. Its main purpose is to answer the question: Is the structure in good enough condition to provide the intended performance? To answer this question it is essential to establish the performance requirements for each structure:

a. What function(s) is the structure intended to perform?

b. What level of performance is expected for each function?

Once these performance requirements are established, the physical condition of the structure is assessed. Any structural defects found are then evaluated according to their effect on loss of structure function, which in turn leads to a decision on the need for repair.

In a performance-based system, the difference between current structure condition and as-built (or like new) condition is not, in itself, a deciding factor on the need for repair. Rather, it is a structure's documented loss of function as a result of structural deterioration that is most important.

The Condition Index

One objective of REMR Management Systems is to create assessment methods that will allow the condition of structures, and their parts, to be expressed numerically to take best advantage of the benefits available from the use of microcomputers in maintenance management. This "numerical language" for expressing the condition of facilities is the CI.

Index numbers (or condition ratings) for all structures covered by REMR management systems are based on the general CI scale shown in Table 1. While each structure, structure part, or rating category has its own scale and corresponding condition descriptions, all CI scales contain the same three zones and seven condition levels, and their general interpretation remains the same. Index values in all scales (from the most general to the most specific) are properly interpreted as representing the conditions found at the time the structure was inspected and rated.

The main objectives of the CI system are to:

a. Create a more uniform method for evaluating and describing the condition of coastal structures.

b. Create a concise reporting system that indicates the deficiencies a structure may have, which parts of the structure are deficient, and the relative severity of the deficiencies.

c. Create a convenient means for comparing the condition of structures over long time periods.

Referring to the general CI scale (Table 1), structures rated within Zone 1 (70 to 100) are fully functional. Those rated in Zone 2 (40 to 69) have significant functional deficiencies, but their functions are still considered adequate to perform their primary missions. Structures rated in Zone 3 (0 to 39) are functionally inadequate.

Table 1. CI scale.

Observed Damage Level	Zone	Index Range	Condition Level	Description
Minor	1	85 to 100	EXCELLENT	No noticeable defects. Some aging or wear may be visible.
		70 to 84	GOOD	Only minor deterioration or defects are evident.
Moderate	2	55 to 69	FAIR	Some deterioration or defects are evident, but function is not significantly affected.
		40 to 54	MARGINAL	Moderate deterioration. Function is still adequate.
Major	3	25 to 39	POOR	Serious deterioration in at least some portions of the structure. Function is inadequate.
		10 to 24	VERY POOR	Extensive deterioration. Barely Functional.
		0 to 9	FAILED	No longer functions. General Failure or complete failure of a major structural component.

It is intended that this system conform with the assessment that knowledgeable inspectors would make based on the results of their own visual inspections (and additional data, when available).

Condition Index for Nonrubble Breakwaters and Jetties

For coastal structures, the CI is determined from a Functional Index (FI) and a Structural Index (SI). The FI indicates how well a structure (or reach*) is performing its intended functions, while the SI for a structure or structural component indicates its level of physical condition and structural integrity.

Before the first inspection and ratings are made, each structure must be divided along its length into permanent reaches as discussed in Chapter 4. These reach boundaries will apply to all future CI inspections and ratings. In addition, structure performance requirements must be defined, as well as the minimum structural integrity level that will permit proper performance. (See **Steps in the Functional Rating Process** in Chapter 6.)

The structural and functional rating and index process is diagramed in Figures 2 and 3. Starting at the bottom of Figure 2 and working upward, an inspector (or inspection/engineering group) produces ratings in structural categories for each reach of a breakwater or jetty. These ratings are determined primarily from visual inspections of the structure, along with the rating guidance provided in this report. (Additional information such as hydrographic surveys or underwater inspections may also be useful.) The ratings for each reach are entered into the management computer program, which will calculate SI values for superstructure, substructure, and foundation, and then an SI for the reach.

A functional analysis is then made, using field inspections, local reports, and other observations of how the structure performed during the last budget cycle. Functional ratings are based on the loss of function due to structural deterioration, which was documented during the structural rating process.

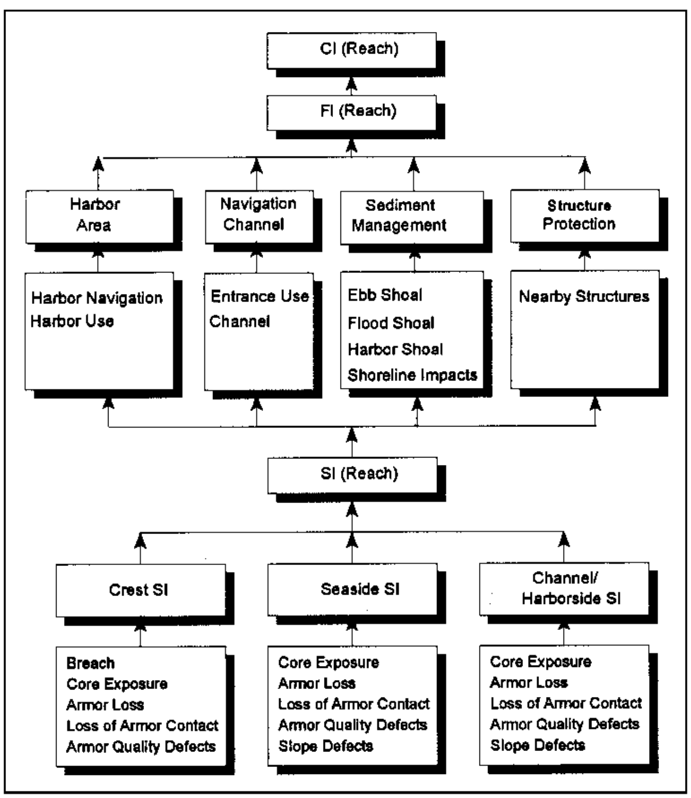


Figure 2. CI process for a reach.

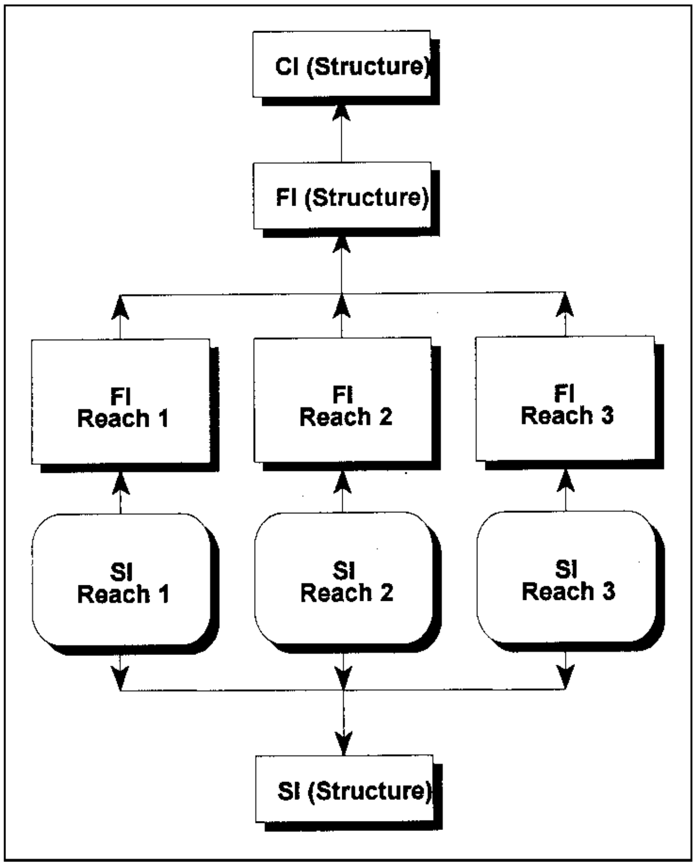


Figure 3. CI process for a whole structure.

As with structural ratings, the functional ratings are also entered into the management computer program. From the SI and FI for each reach, the program will determine the SI, FI, and CI for the whole structure, as diagramed in Figure 3.

Interpreting and Using The Condition Index

The CI is primarily a planning tool, with the index values serving as an indicator of the structure's general condition level. The CI values are also intended for monitoring the structure's change in condition over time and to serve as a means for comparing the condition of different structures.

For some purposes, there may be more interest in values at the lower end of the CI process (the structural ratings within each reach, as shown in Figure 2). For other purposes, there may be more need for the values nearer the top (the index values for whole reaches or structures, as shown in Figure 3). In either case, the CI values for any structure should be thought of as including all levels of detail.

One of the main uses of CI values is to track changes in condition over time, as illustrated in Figure 4. With historical trends, and knowledge of structure environment, future rates of deterioration may be estimated and used to plan the timing of repairs and corresponding maintenance expenditures. To achieve this purpose, it is essential that the ratings (and calculated index values) represent conditions as recorded at the time the structure was inspected (or, for functional ratings, proven by recent events). Any attempt to include expectations of future condition would distort the values and make them useless as a record of actual structure condition, and thus useless for estimating deterioration rates.

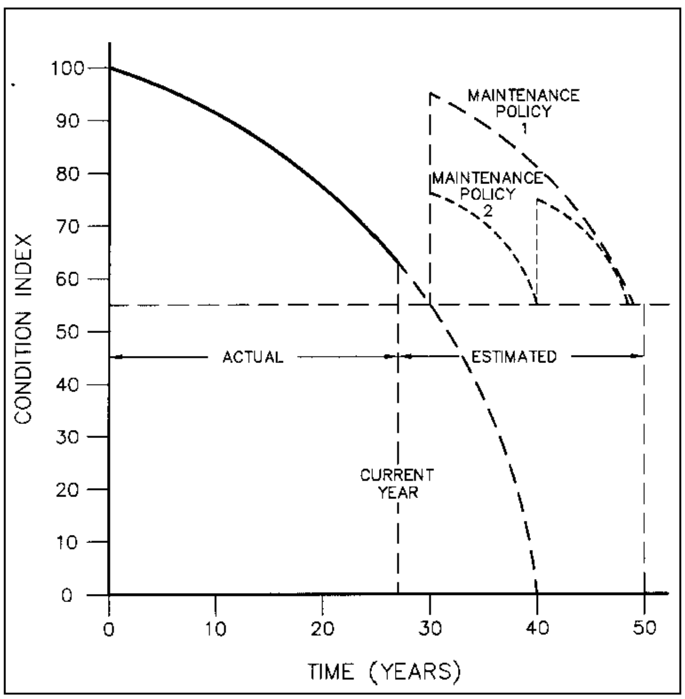


Figure 4. Using CI values to track condition changes over time.

It is important to understand that the process of determining condition is different than the process of deciding what action, if any, to take because of structure condition. If two breakwaters (Structures 1 and 2, for example) are both in moderately good physical condition, they both may have SI values of about 65. If Structure 1 has shown progressive deterioration over the past 5 years and is in a heavy wave environment, it may warrant repairs in the near future. If Structure 2 is in a more moderate wave environment and its condition has been stable over the past 5 years, it may not warrant any action. The greater need for action does not make Structure 1's condition worse than that of Structure 2. Thus, it should be clear that condition influences maintenance and repair (M&R) actions only in combination with additional information, such as knowledge of structure history, operating environment, budget levels, policies, etc.

The condition ratings and index values are simply a numerical shorthand for describing structure physical condition and functional performance, and they represent only one part of the information required to make decisions about when, where, and how to spend maintenance dollars. It must be emphasized that the CI system is not intended to replace the detailed investigations needed to fully document structure deficiencies, to identify their causes, and to formulate plans for correcting them.

Suggested Actions

Once the condition of structures is understood and documented, the next steps in the maintenance management process are to initiate action to correct unsatisfactory conditions and to begin planning for future M&R needs. For this purpose, the CI system for coastal structures includes a set of five suggested actions as part of the structural and functional rating process.

While the CI ratings and index values are used to describe and report conditions, the suggested actions allow inspectors and raters to indicate what they think should be done about those conditions. These action categories are explained in Chapters 5 and 6 in the sections covering the use of the rating forms.

3 System Instructions and Definitions

Steps in Using the Rating System

Steps 1-5 are Initial (mostly one time only):

1. DETERMINE WHAT FUNCTIONS STRUCTURE SERVES

Use the 11 Functional Rating Categories (Chapter 6).

2. DIVIDE STRUCTURE INTO REACHES BY FUNCTION

Decide which parts of the structure perform which of the 11 functions. Divide where major functional changes occur (see Chapter 4).

3. FURTHER DIVIDE REACHES INTO SUBREACHES BY STRUCTURAL AND LENGTH CRITERIA

Subdivide where differences in construction occur (e.g., cross section, armor size or type, underlayer, or core) (see Chapter 4).

Further subdivide to maximum 500-ft size (minimum 200 ft).

4. ESTABLISH FUNCTIONAL PERFORMANCE CRITERIA

Decide what level of performance is expected for each function that applies to the structure. (See Chapter 4, **Establishing Functional Performance Criteria**, Chapter 6, and Rating Tables.)

Table 15: (SPRDSHT2.FNC) Left Side. (See Chapter 6, **Storm Events.**)

Based on required performance levels, set minimum acceptable cutoffs for functional ratings as shown conceptually by dashed horizontal line in Figure 4.

5. ESTABLISH STRUCTURAL REQUIREMENTS

Decide how much deterioration can be tolerated without either dropping below minimum required function levels or creating serious risk of structural instability: an initial estimate. (See Chapter 4, **Establishing Structural Requirements**, Chapter 5, and Tables 4 – 9.)

Table 15: Center.

Set minimum acceptable cutoffs for structural ratings, as shown conceptually by dashed horizontal line in Figure 4. These cutoffs trigger timing for repair evaluation.

Steps 6 – 8 are repeated as required:

6. INSPECT STRUCTURE - PRODUCE STRUCTURAL RATING

Determine *current* physical condition.

Use the six Structural Rating Categories and their Rating Tables (see Chapter 5 and Tables 4 – 9). Use Structural Rating Form (one for each subreach).

SIs are calculated (see Chapter 7).

7. ASSESS FUNCTIONAL PERFORMANCE - PRODUCE FUNCTIONAL RATING

Determine to what extent structural deterioration has affected function (see Chapter 6).

Use Table 15: Right Side.

Use the Functional Rating Form – (One for each full reach) and the Functional Rating Tables (Tables 16 – 19 shown in Chapter 6).

FIs are calculated (see Chapter 7).

If significant loss of function has occurred due to structural deterioration, consider repair options.

8. REVIEW STRUCTURAL REQUIREMENTS

Table 15: Center. Relate Performance to Structural Deterioration – will be perfected through long-term, repeated analysis.

Based on structural and functional evaluations (Steps 6 and 7), review structural requirements set in Step 4 and adjust as needed.

Basic Components

Breakwaters and jetties are constructed to: maintain navigation channels across ocean inlets, control shoaling by preventing sediment from being driven into harbors and channels by waves and currents, create quiet waters for marinas and harbors, and provide shore protection along eroding coastlines. The following basic definitions are derived from those given in the *Shore Protection Manual* (U.S. Army Coastal Engineering Research Center 1984).

> *Breakwater*. This structure is placed directly in the path of waves to create a quiet area of shelter, usually for a harbor, port, or marina. In some cases the sole purpose of a breakwater is to alleviate shoreline erosion by absorbing the energy of waves. A breakwater may be connected to shore at one end or entirely detached and more or less parallel to the shore.

> *Jetty*. This structure is used to train and control strong currents that flow through tidal inlets, harbor entrances, or the mouths of major rivers. Usually constructed in pairs, jetties serve both to confine the channel to a narrow location and to prevent sand and other sediments from collecting in the channel and forming shoals.

> *Weir Jetty*. This structure is a variation on the jetty concept in which a section of the jetty near the shoreline is deliberately built low to allow sediments to pass over the weir and into a designated sand trap that was previously dredged to provide room for this inflow. This greatly facilitates subsequent maintenance dredging and bypassing of sand past the inlet.

Figures 5 and 6 illustrate the use of these structures. Each of these is a schematic representation of various types of structures. Simple jetty systems of one or two structures are shown in Figure 5a and b. Figure 5c shows a weir jetty system and sand trap. Figure 6 shows dual jetties with attached and detached breakwaters.

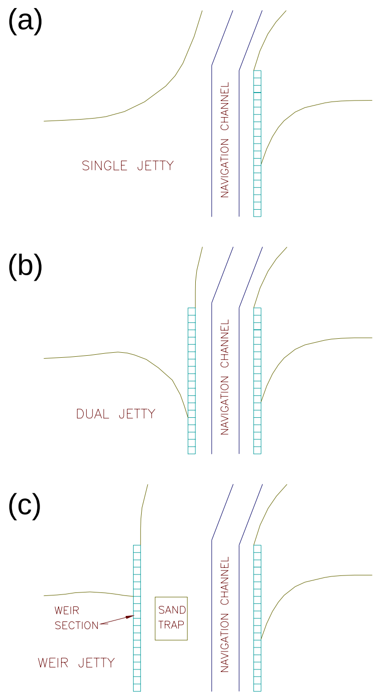


Figure 5. Jetty configurations.

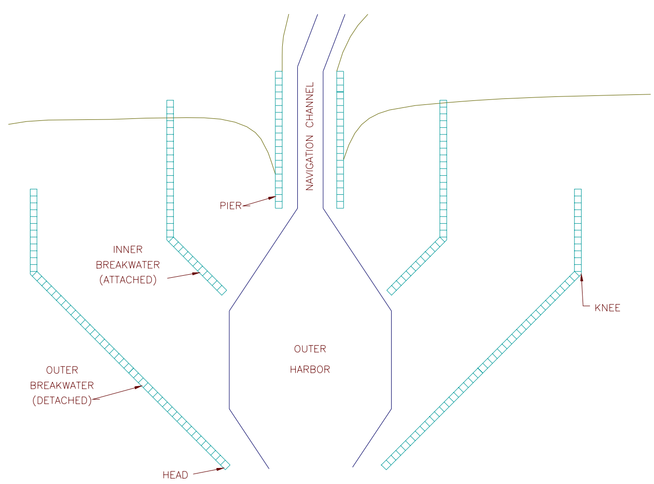


Figure 6. Breakwater configurations.

Figures 7a–g illustrate some of the many variations of non-rubble breakwaters and jetties. Table 2 provides additional description of the superstructure, substructure and foundation of each type of structure shown in the figures. Figure 8 shows a less conventional alternative, a Floating Ladder Type Breakwater. Figures 9a–d show a failing timber crib and alternatives that may have been used to make the repairs, including Figure 9d where only the foundation of the timber crib remains in the rehabilitated structure that has been repaired using concrete monoliths, steel sheet pile, and a tie rod anchored on the landside.

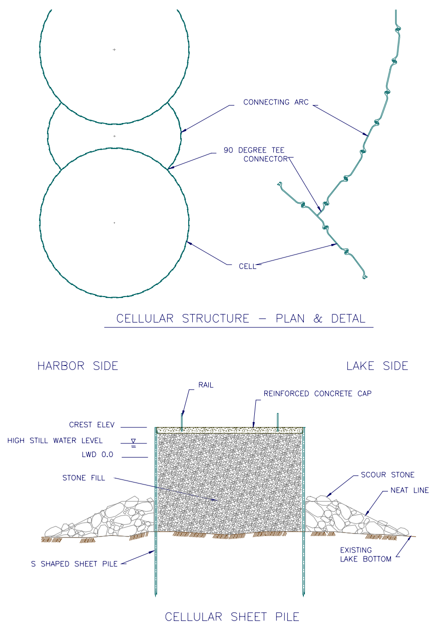


Figure 7a. Cellular sheet pile.

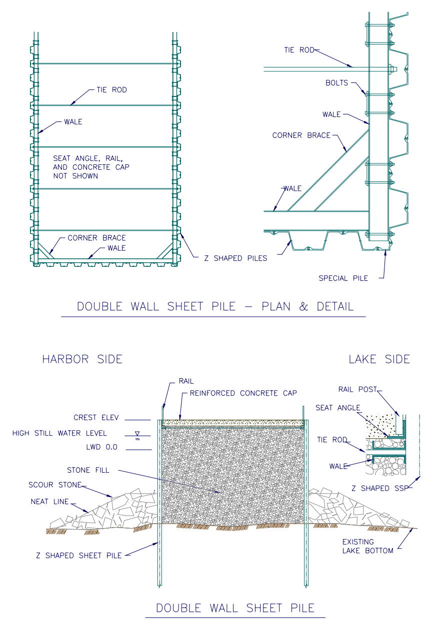


Figure 7b. Double wall sheet pile.

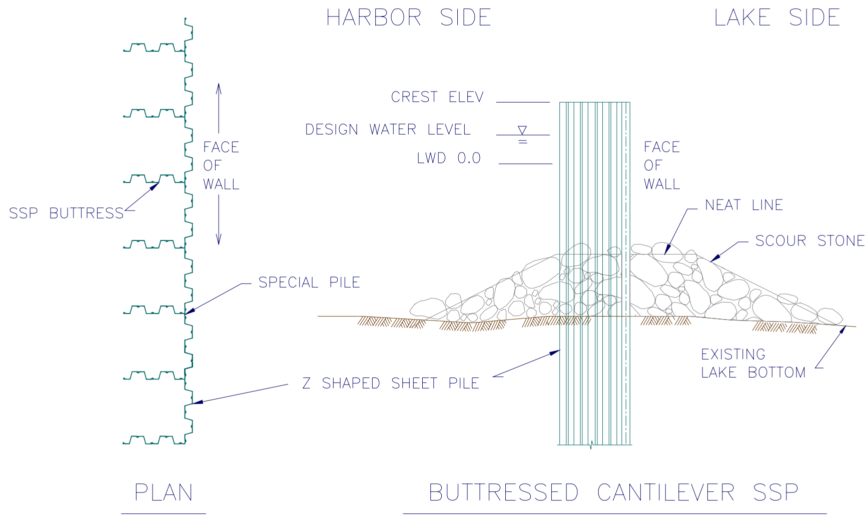


Figure 7c. Buttressed cantilever steel sheet pile.

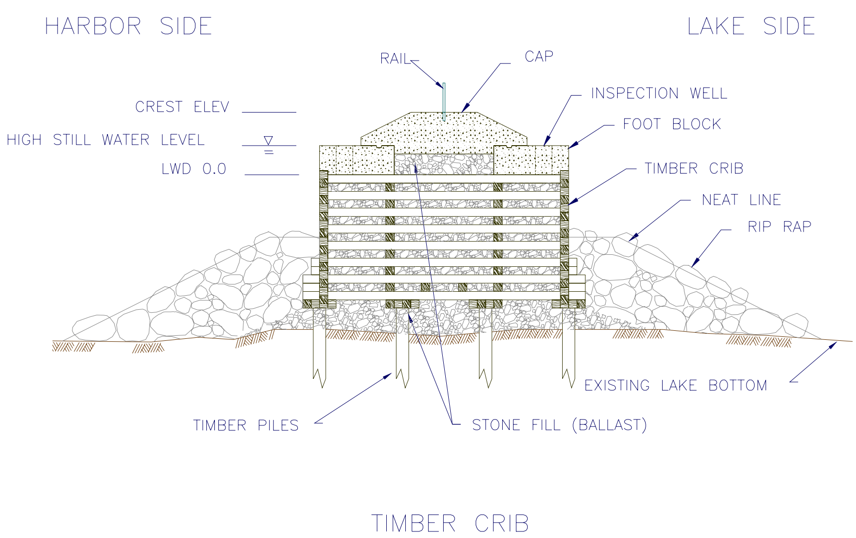


Figure 7d. Timber crib.

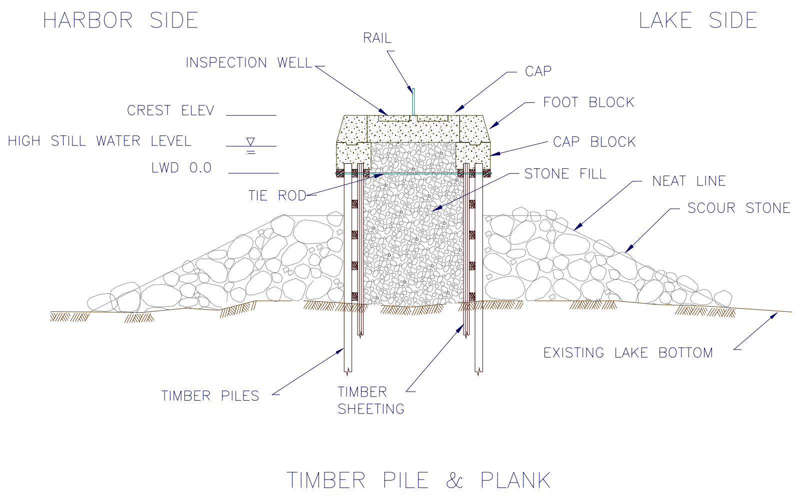


Figure 7e. Timber pile and plank.

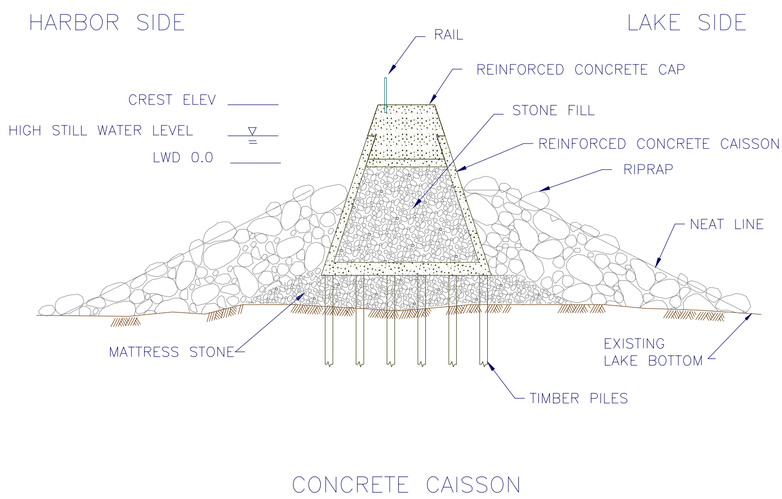


Figure 7f. Concrete caisson.

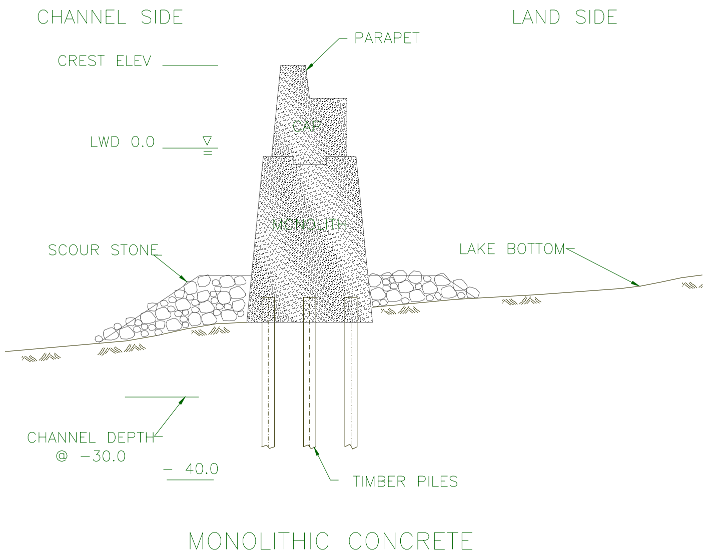


Figure 7g. Monolithic concrete.

Table 2. Types of structures and major components.

Type of Structure	Superstructure	Substructure
<u>Cellular</u> (Three dimensional structure where outer protective structure encloses inner fill.) Includes: cribs, doublewall sheet-pile, timber pile & plank, etc. See Figures 7a, 7d, & 7e	Parapet Cap (Material Type) Cap to Sub-connections Foot Blocks Cap Blocks Inspection Ports Hand Rails Mooring Points Aids to Navigation Fender Piles and Wales	Sheeting Material Tees & Special Piles Seat Angles Crib or Cellular Fill Wales Tie Rods Seat Angles Connections Horizontal Cribbing Toe and Wave Protection Foundations Piles Foundation Mattress
<u>Sheet-pile</u> (Basically 2-dimensional thin or single vertical thickness of protective sheeting) includes: steel sheet-pile concrete sheet-pile timber pile and plank buttressed cantilever ssp See Figures 7b, 7c, 7d, & 7e	Wale Parapet Pile Cap – Narrow Pile Cap – Wide Parapet Connections Cap Blocks Hand Rails Mooring Points Aids to Navigation Fender Piles and Wales	Piles Planks (Sheeting) Wale Tie Rods Connections Buttress Piles or Sheeting Toe and Wave Protection Foundation Mattress
<u>Concrete Caisson or Monolith</u> See Figures 7f & 7g	Cap (Material Type) Parapet Connections Inspection Ports Hand Rails Mooring Points Aids to Navigation Fender Piles and Wales	Concrete Walls Granular Fill Mass Concrete Fill Toe and Wave Protection Foundation Mattress Bearing Piles

Bar Point Harbor Large Breakwater (#1)

View of Misalignment Between Southern Most Modules

Figure 8. Floating ladder-type breakwater.

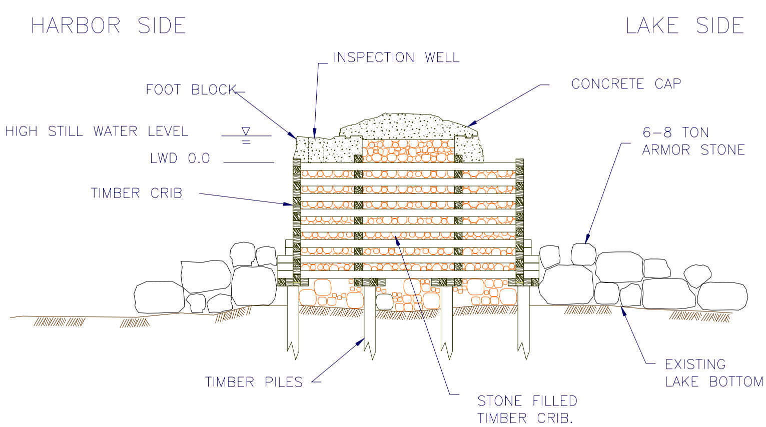


Figure 9a. Timber crib in need of repair.

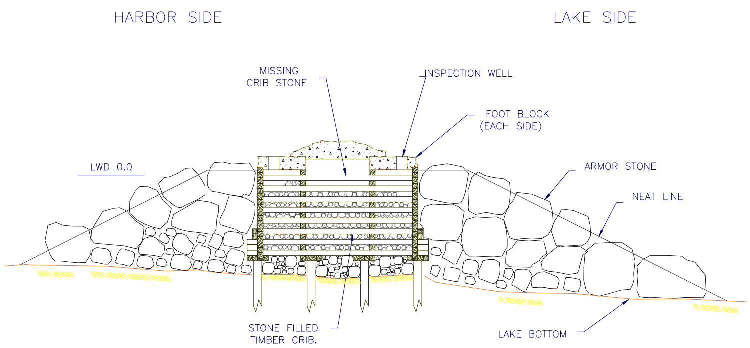


Figure 9b. Stone encapsulation.

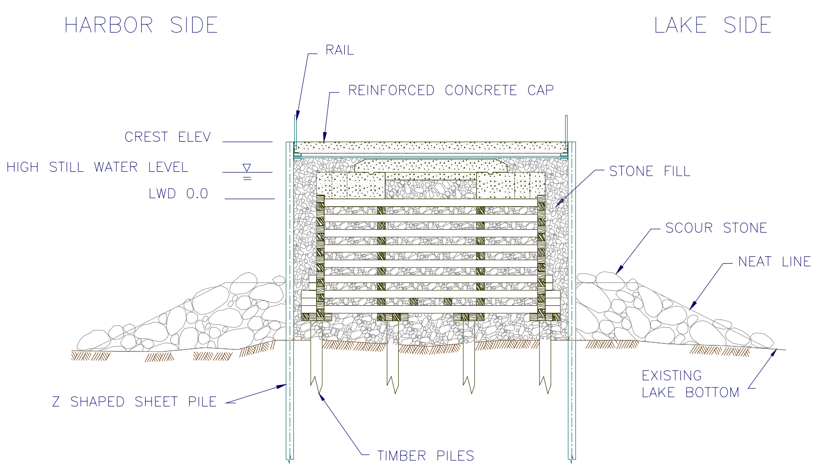


Figure 9c. Steel sheet pile encapsulation.

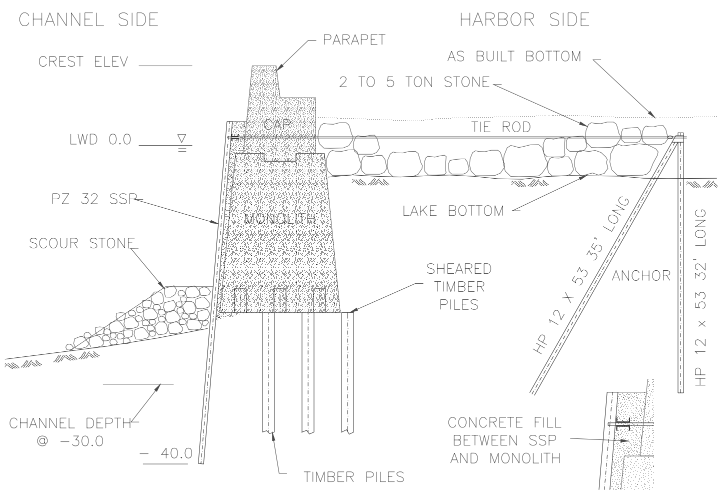


Figure 9d. Monolithic structure reinforced after failure.

It is important to note that construction and cross-sectional composition of such structures may differ considerably from that shown on Figures 7, 8, and 9. Where significant differences do occur, the inspector may need to adjust the interpretation of some rating categories and decide ratings accordingly. (Likewise, as-built drawings do not always reflect actual construction.) Definitions of key components shown on the figures are as follows:

Anchors or Tie-Backs. Large diameter, threaded steel rods that tie the face of a sheet pile wall to a point of anchorage behind the wall. In land-based bulkhead construction the anchor is within the fill material retained by the wall. For sheet pile breakwater sections, it is more common for the anchor rods to pass entirely through the structure to an opposing sheet pile wall on the other side of the breakwater. The anchor rod then ties these opposite walls and the intervening fill together into a single gravity structure. The point of attachment between the anchor rod and the sheet pile is generally reinforced using a waler.

Armor Layer. The armor layer is the outer layer of the structure, typically constructed with the largest stones, or with prefabricated concrete units. A rock armor layer commonly has a thickness of at least two armor stones. For structures constructed with uniform sized stone, the outer two layers will be considered as armor, with all underlying layers considered as core.

Batter Piles. Piles used as brace members in sheet pile and timber and plank construction.

Cap. A horizontal structural member at the top of a sheet pile wall that provides additional strength in the horizontal direction and a uniform, finished surface at the top as opposed to the irregular edge of adjoining sheet pile sections after they have been driven in.

Channel/Harbor Side. The side of a nonrubble structure that is opposite the primary direction of wave advance.

Composite Breakwater. In a typical composite breakwater, most of the underwater portion is a conventional rubble mound or stone-filled timber crib. The upper portion, however, would be of different construction (hence the term "composite") such as a large concrete gravity section or sheet pile wall. There is an enormous variety of these kinds of structures. Sometimes the bulk of the structure may be a massive concrete monolith with rubble toe protection that is invisible from the surface. In other cases, the structure may be composed almost entirely of rubble with a relatively small concrete parapet.

Core. The core is the interior portion of a rubble-mound structure. It generally consists of a widely graded mix of small stones. This widely graded mix makes the structure relatively impermeable to wave energy (which would otherwise pass directly through the voids in larger stones), prevents movement of sand through the structure, and creates a filter layer (or mat) to support the underlayer and armor stones on the foundation soils. For structures constructed with uniform sized stone, the outer two layers will be considered as armor, with all underlying layers considered as core.

Crest. The top portion of the cross section of a structure that is usually constructed above the design water level.

Foundation Layer. The foundation consists of a layer of small graded stone, sometimes with geotextile underneath, placed on the in-situ soil to form a base on which the structure is built. The foundation layer helps reduce structure settlement and lateral movement at the base.

Gravity Structure. A structure, or component of a larger structure, which resists movement by waves or currents primarily or solely because of its great mass. Gravity structures are often built as single homogeneous units, such as concrete monoliths. Alternately, a gravity structure can be an assemblage of smaller units that are tied together in a structural array, but which act in unison as a single, consolidated gravity unit. A stone-filled, timber crib is an example of a porous, heterogeneous gravity structure. A gravel-filled, cellular steel sheet pile breakwater is an example of a nonporous, heterogeneous gravity structure.

Head. The outer end or terminus of a breakwater or jetty.

Parapet. A gravity or pile structure that is built at the top of a breakwater to extend its height and limit or prevent wave overtopping. A typical application would be a large concrete gravity wall placed atop a low rubble breakwater. Other applications are a pile and plank or sheet pile structure with brace and batter piles for support.

Reach. Part of a structure that is uniform in its functional purposes, type of construction and cross sectional dimensions over its length. Once defined, the number of reaches (and their limits) should remain constant over time, as they serve as primary references for condition rating.

Root. The landward reach or origin of a structure which forms a permanent anchor or land connection. The root may be in contact with water on its channel/harborside, as in Figures 10 and 11 (shown in next chapter).

Seaward Side. The side of a nonrubble structure that faces the main force of the waves.

Sheet Pile. A slender, flat pile (sheet) that is driven into the ground or seabed, which, when meshed, interlocked, or combined with other sheet piles, will form a wall or face of a breakwater.

Steel sheet piles are usually used for breakwater construction. Timber, aluminum, and concrete are common for bulkhead construction within harbors. The sheet piles can form the solid interface between the fill material and the water. In steel sheet pile construction, the sheets, in combination with the **cap** and the **anchors** can provide all of the structural strength needed to retain the fill. Sheet piles can also be used as an internal diaphragm in a rubble structure with the upper portion of the sheet piles forming a parapet to prevent overtopping. More commonly, the sheet piles can be driven in closed geometric shapes (when viewed in plan) to form circular or rectangular cells.

Subreach. For management purposes, reaches may be divided into subreaches due to changes in type of construction, cross sectional dimensions, or to maintain rated segments of relative uniform length throughout the structure. Once defined, the number of subreaches (and their limits) should remain constant over time, as they serve as primary references for structural rating.

Timber Crib. A structure which is built using multiple layers of horizontal timber lattice and stone fill. This forms a bin, or crib, which retains the stones that fill the crib. The timbers hold the structure together and the stones provide the weight that is needed for stability.

Toe. The bottom portion where the structure meets the existing bottom.

Trunk. The main body of the structure, which extends between the root section at the landward end and the head at the seaward end.

Underlayer. The underlayer is a layer of smaller stones directly beneath the armor layer, commonly about one-tenth the weight of the units in the armor layer. The underlayer helps absorb the wave forces and prevents the smaller underlying core stones from being lost through voids in the armor layer. (Not all rubble structures have a separate underlayer.)

Waler. A large timber member or structural metal section such as a channel, which is placed horizontally across the face of a sheet pile or timber wall. The waler distributes the applied loads along the wall. For steel sheet pile walls, the waler also serves as the attachment point for anchor (or tie-back) rods.

Operations and Maintenance Items

The following items are considered in several functional rating categories (see Chapter 6) and thus are not rated separately. Because they have a great influence in the evaluation of structure performance, they warrant separate definition and explanation.

Dredging Costs. The decision to dredge (or do more frequent or additional dredging) is commonly an alternative to: (1) accepting actual or potential navigation delays or hazards, or (2) incurring the cost of structural repair or modification. Dredging costs serve as one means for evaluating structure performance.

Sand Bypassing. Without dredging, many improved navigation entrances would eventually reach an equilibrium state in which sand would naturally bypass the structures, deposit sediment in the channel (or at the channel entrance), and eventually nourish the downdrift beaches. Some projects have a structural configuration designed to facilitate sand bypassing or they incorporate a sand bypassing system to reduce channel sedimentation and protect the adjoining shoreline. The effectiveness of natural bypassing is included in the functional ratings for Harbor Area, Navigation Channel, Sediment Management, and Structure Protection.

Shoaling (Sediment). Shoaling is the buildup of excessive sediment in and around the channel or harbor. Shoaling may reduce the maximum available draft or reduce the channel to a width too narrow for safe passage, or may otherwise lead to navigation difficulties and delays. In addition, where depths are reduced due to shoaling, hazardous breaking wave conditions may develop in the channel.

Thalweg Location. The thalweg is the deepest portion of the navigation channel. The purpose of the navigation structures, particularly jetties, is to maintain the thalweg in a uniform and consistent position for predictable and safe passage by vessels. If the structures are only partially effective, the thalweg may tend to migrate and create a navigation hazard.

Design Storm

Performance in each functional rating category is measured in reference to three levels of storm events. The design storm is the largest storm (or most adverse combination of storm conditions) the structure (or project) is intended to withstand, without allowing disruption of navigation or harbor activities, or damage to the structure or shore facilities. The design storm is usually designated by frequency of occurrence or probability of occurrence. Authorizing documents, design notes, project history, and current requirements should be used to confirm the appropriate design storms for a project. Chapter 6 contains more detail on this subject.

Rating and Index

This evaluation system uses ratings and indexes. As used here, a rating is a value selected by an inspector or engineer, usually from a table of condition or performance levels. A rating category is an evaluation category requiring the selection of a rating.

An index, or index value, is a number calculated from several ratings. The calculation is made using a standard rule or formula. The index represents a summary or weighted average of the individual ratings.

4 Defining Reaches, Subreaches, and Structure Criteria

Defining Reaches and Subreaches

To implement the condition rating process, each structure must first be divided along its length into reaches and, further, into subreaches with permanent boundaries. This step need be done only once. After reaches and subreaches are defined, their limits are not changed unless major structural or functional changes are made to the structure. Reach and subreach limits are based on three criteria and are chosen as described below. Figures 10, 11, and 12 show examples of applying these criteria.

a. *By function*: Determine the functions provided by different portions of the structure. This is done through an office study using authorizing documents and project history in combination with the functional descriptions in Chapter 6. Set the reach limits where functional changes occur. Structure functions are chosen from the list of 11 rating categories within the 4 main functional areas, as described in Chapter 6. Of the 11 rating categories, select only those on which the structure has a significant effect. As structure and reach purposes vary, it should be expected that different reaches will have a different number and different types of functions assigned to them. Further, the assigned functions need not include all of the four major functional areas or all of the categories listed within each functional area.

b. *By construction*: Further division into subreaches is made based on changes in structural characteristics. Using past inspection reports, photographs, and drawings (which have been field verified), note where there are significant changes in type of construction, type or size of armor, cross sectional dimensions, or geometry; these points should define further divisions.

c. *By length*: Final divisions are made based on length. Where function and construction are uniform over a long length, divisions should be made so that subreaches will not be overly long; 500 feet is a suggested maximum, and 200 feet a suggested minimum.

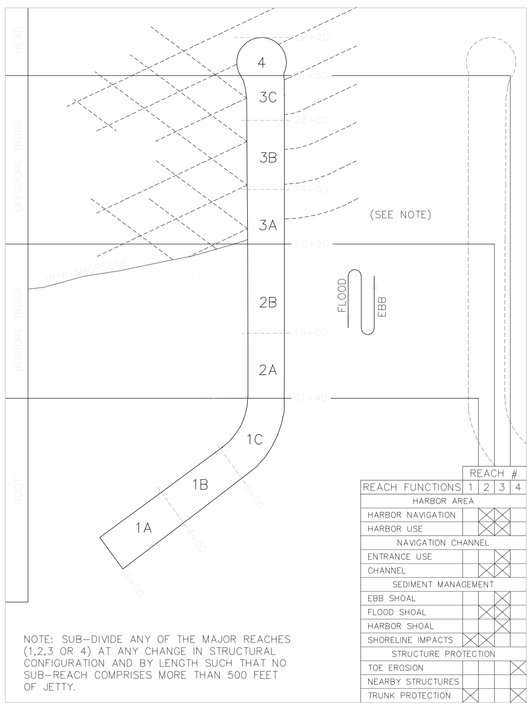


Figure 10. Typical reaches of a jetty.

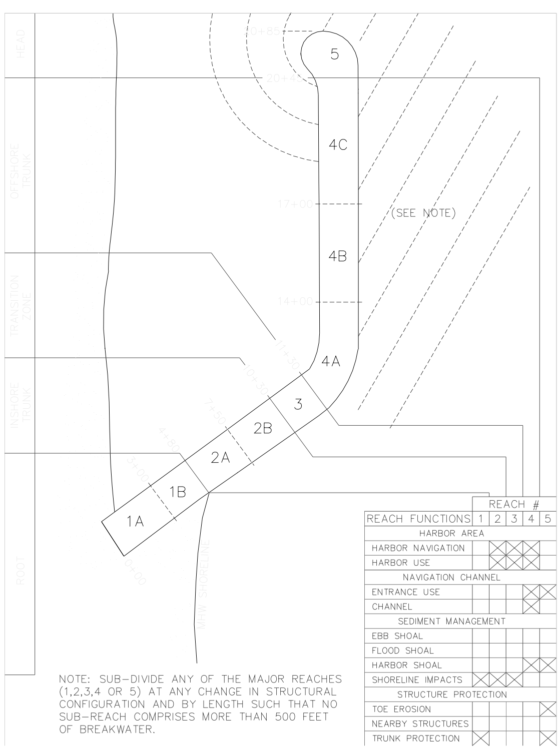
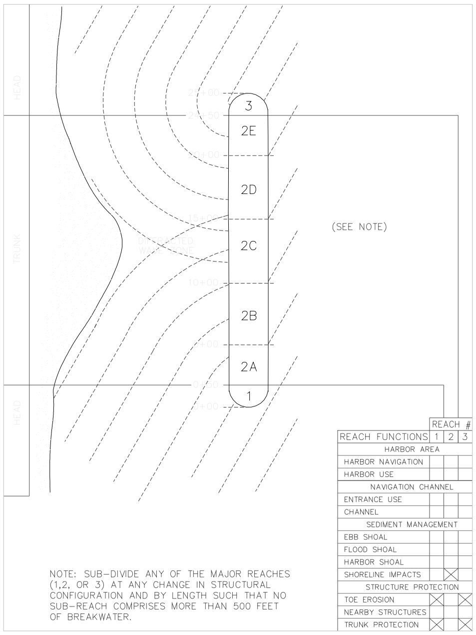


Figure 11. Typical reaches of a shore-connected breakwater.



REACH FUNCTIONS	REACH # 1	2	3
HARBOR AREA			
HARBOR NAVIGATION			
HARBOR USE			
NAVIGATION CHANNEL			
ENTRANCE USE			
CHANNEL			
SEDIMENT MANAGEMENT			
EBB SHOAL			
FLOOD SHOAL			
HARBOR SHOAL			
SHORELINE IMPACTS		X	
STRUCTURE PROTECTION			
TOE EROSION	X		X
NEARBY STRUCTURES			
TRUNK PROTECTION	X		X

Figure 12. Typical reaches of a detached breakwater.

NOTE: Due to its unique function (and typically different construction), the head of a structure is always considered a separate reach. Where there is no difference in construction at the outer end of a structure, a recommended length for the head reach is 50 to 100 feet. The general case assumed here is that the head does not have adequate length to materially impact waves and currents in the harbor or navigation channel — it is a sacrificial element that only protects the trunk. In exceptional situations where these assumptions may not apply, explanation should be given and other appropriate functions may be assigned to the head.

A convenient method for numbering reaches is to begin at the landward end and use both consecutive numbers and letters: 1A, 1B, 2A, 2B, 2C, etc., where the number indicates common function (a reach), and the letter indicates further division (a subreach) due to structural changes or maximum length requirements. This system is used in Figures 9, 10, and 11.

It is important to emphasize that the same reach definitions are to be used for both structural and functional ratings, so the reach limits should be selected with this in mind. In addition, permanent stationing markers should be applied to each structure to assure uniformity in reporting the location and limits of structure defects and to facilitate future inspections.

Establishing Functional Performance Criteria

Once structure functions have been determined, the next step is to determine the expected performance level for each rating category. These criteria must be based on how well the structure could perform when in perfect physical condition. Design deficiencies cannot be corrected through the M&R process and should not be considered in this analysis. Begin by reviewing the authorizing documents and structure history. Check if the original expectations have been changed, or if they need to be changed.

When defining performance requirements, refer to the section “Design Storm” and the rating tables in Chapter 6 to see how performance is measured in the different functional categories. Determine to what extent the structure should control:

a. waves, currents, seiches,

b. sediment movement, and

c. shoreline erosion and accretion.

To help decide required wave, current, and sediment control; determine the normal dredging frequencies and sand bypassing requirements; decide what size ships should be able to pass through the entrance and channel under normal conditions and during higher wave or storm conditions; and determine if any flooding of shoreline facilities should be expected during storm events and, if so, to what extent.

Establishing Structural Requirements

Structural ratings are produced by comparing the current physical condition, alignment, and cross sectional dimensions of a structure to that of a “like new” structure built as intended, according to good practice, and with good quality materials. Seldom, though, does a nonrubble coastal structure require full structural integrity to have continuity in function. In fact, most nonrubble structures are built with some allowance for damage before function is compromised, and many are overbuilt for constructability. Thus, structural damage does not automatically equate to loss of function.

After determining performance requirements, it is necessary to determine what minimum cross-sectional dimensions, crest elevation, and level of structural integrity are needed to meet those requirements. Initial efforts in determining these dimensions can be aided by estimating the impact on functions if the reach under study were to be completely destroyed. Project history, authorizing documents, public input, and analysis may be required to identify these dimensions. As this is not an exact science, some engineering judgment will be necessary to produce a reasonable estimate. Once established, these structural requirements are used to help identify sources of functional deficiencies in the existing structure. Table 15 contains columns to record this information.

5 Structural Rating Procedures

Introduction

The structural rating procedures are used to determine the appropriate rating for six categories that apply to the superstructure and substructure for each reach or subreach of a structure. From these ratings, structural index (SI) values are calculated, as described in Chapter 7, for each of the main structural components (superstructure and substructure), for each reach or subreach, and for the whole structure. The SI values are indicators of physical condition and structural integrity. These values are expressed as numbers from 0 to 100 and are interpreted according to the general SI scale shown in Table 3.

For each structural rating category, the inspector determines ratings from a field inspection, using the structural rating tables (Tables 4 – 9). Each of these tables follows the format and general interpretation of the SI scale in Table 3, but the wording is specific to the category being rated. SI values are then calculated from the field ratings.

Table 3. Structural CI rating scale.

Observed Damage Level	Zone	Structural Index	Condition Level	Description
Minor	1	85 to 100	EXCELLENT	No significant defects - only slight imperfections may exist.
		70 to 84	GOOD	Only minor deterioration or defects are evident.
Moderate	2	55 to 69	FAIR	Deterioration is clearly evident, but the structure still appears sound.
		40 to 54	MARGINAL	Moderate deterioration.
Major	3	25 to 39	POOR	Serious deterioration in some portions of the structure.
		10 to 24	VERY POOR	Extensive deterioration.
		0 to 9	FAILED	General failure.

Table 4. Rating guidance for loss of elevation or alignment.

Structural Rating	Description
Minor or No Damage	
85 to 100 (Excellent)	At most, there are small deviations from the as-built alignment. The crest may show a slight gradual differential settlement or horizontal alignment deviation of less than a couple inches in one or two places. There are no misalignments between adjacent sections of the structure.
70 to 84 (Good)	Along the reach there is some waviness in the crest elevation and/or horizontal alignment. Slight leaning or misalignments between adjacent sections may be visible, but are of no practical significance. No signs of recent movement are observed.
Moderate Damage	
55 to 69 (Fair)	Slight leaning or misalignment is visible between several sections of the structure with significant alignment or angular deviation in a few limited locations. Indications of a small amount of recent movement may be visible. The freeboard, or distance from the crest of the structure to the normal water level, has been reduced by up to 10% of its design value.
40 to 54 (Marginal)	Leaning and horizontal misalignment may be visible at many sections, with significant deviations in several locations or pronounced deviation in one location. Significant recent movement may have occurred. The crest has an irregular appearance when viewed down its length. For vertical movement, the freeboard has been reduced by up to 25% of its design value, and large storm waves easily overtop the structure.
Major Damage	
25 to 39 (Poor)	The crest is very irregular, with significant horizontal and vertical misalignment. At least one serious breach may be present and additional smaller breaches may have formed. The freeboard at the most serious breach has been reduced by up to 40% of its design value. Storm waves frequently overtop the structure. Leaning may be pronounced in several sections and may threaten stability in one location. Significant recent displacement of components may have occurred.
10 to 24 (Very Poor)	Leaning or misalignment of major structural components threatens structural stability. More than half the reach has breaches that reduce the freeboard up to 75% of its design value. In non-storm conditions waves commonly overtop the structure.
0 to 9 (Failed)	Leaning or misalignment of major structural components has resulted in structural failure. Parts of the reach are at or below normal water level due to major breaches. The reach no longer provides significant wave protection.

Table 5. Rating guidance for structural damage or defects.

Structural Rating	Description
Minor or No Damage	
85 to 100 (Excellent)	The structure has suffered no damage. The main structural members (i.e., piles, walers, caps, sheetpile) are in excellent condition and intact. Only slight imperfections may exist, with no visible signs of distress.
70 to 84 (Good)	Noncritical components show minor signs of distress due to loading of structure. Minor impact damage may be present or minor damage to a few structural members. Some signs of strain at connections may be visible.
Moderate Damage	
55 to 69 (Fair)	Noncritical components show significant deformation or other signs of distress due to loading of structure. Some impact damage may be present enough to noticeably deform a structural member of result in a small hole in sheetpile. Minor deformation of connections. Walers may show significant wear some damage, but members are still sound.
40 to 54 (Marginal)	Critical components show deformation or other signs of distress due to loading of structure, such as structural cracks or fractures in parapets or caps due to ice loads or vessel impacts. A few isolated connections may be broken. Significant voids behind sheetpiles. Gaps at interlocks or holes in the structure are evident. Structure has been significantly weakened.
Major Damage	
25 to 39 (Poor)	Critical components show significant major signs of distress due to loading of structure. Serious collision damage may be present. Gaps or holes in the sides of the structure are large enough to permit loss of fill material. Several isolated or a few adjacent tendons or tie-backs have broken. Walers and the points of attachment between the tendons and the wall are broken in several places and are distressed in many others. If subjected to peak design loads, failure of structure is likely. Sheetpiles are missing or moving with wave energy.
10 to 24 (Very Poor)	Critical components seriously weakened or are breaking. Connections are generally weak or several nearby have broken. Tendons or tie-backs have broken or pulled through the wall in many locations. Continued normal operating loads may fail structure. Thin sheet structures are missing major component sections and allowing energy to bypass.
0 to 9 (Failed)	General structural failure.

Table 6. Rating guidance for material deterioration or defects.

Structural Rating	Description
Minor or No Damage	
85 to 100 (Excellent)	At most, some aging or wear is evident. Only slight imperfections may exist and surface corrosion in steel, small hairline cracks or scaling in noncritical areas of concrete, weathering in timber. May have concrete honeycombing not exposing reinforcement.
70 to 84 (Good)	Minor surface cracks and spalls may be visible on concrete surfaces. Steel surfaces have minor pitting of exposed pieces. Timber members are sound with no evidence of rot, although minor splitting or checking may be visible. No members have broken or significantly weakened.
Moderate Damage	
55 to 69 (Fair)	In isolated cases cracks in concrete allow corrosion of reinforcing steel; rust staining may be visible, but is limited in extent. Steel surfaces have minor scaling; pitting may be widespread on exposed pieces. Timber members are sound, but splits and large checks are visible in several places. No members have broken due to degradation or deterioration, although several appear to be approaching what appears to be an overstressed situation. Steel sheets are corroding at the interlocks and starting to thin.
40 to 54 (Marginal)	Concrete has deep cracks in several locations; spalling is widespread. Rust staining from rebar corrosion is visible. In a few locations, concrete near the surface may have ruptured, exposing corroded rebar beneath. Occasional cracks may be deep enough to expose rebar at depth. On steel, rust scale is heavy on exposed pieces. Timber members appear to be suffering from rot or marine borer activity; splitting may be common. A few members have broken due to deterioration and overstress. Interlocks and junctions between sheets are thinning or impact spalling.
Major Damage	
25 to 39 (Poor)	Concrete is heavily cracked or spalled. Rebar corrosion is evident in most locations. Bars near the surface have corroded so heavily that the surface of the concrete has completely ruptured and spalled in many places. In steel, corrosion results in significant section loss, threatening failure of a few components. Timber is rotting or severely split. If marine borer activity is present, significant loss of section has occurred in submerged timber. Rebar connecting major concrete components is seriously corroded and loss of junction is likely with the next storm energy.
10 to 24 (Very Poor)	Large pieces of concrete have broken due to deterioration; rebar corrosion is extensive. Corrosion has heavily damaged steel pieces; few remain functionally intact. Marine borers or rot have left some timber members with little remaining strength. Cracked and broken members may be common.
0 to 9 (Failed)	General material failure.

Table 7. Rating guidance for loss of fill level.

Structural Rating	Description
	Minor or No Damage
85 to 100 (Excellent)	At most, slight settlement of fill material may have occurred (for timber crib or sheetpile structures). There are no gaps in the structures through which retained fill might be lost.
70 to 84 (Good)	Slight settlement, displacement, or degradation of fill is evident. A small amount of fill may have been lost from sheetpile structures or timber cribs, but cap and sidewall support is still solid.
	Moderate Damage
55 to 69 (Fair)	Settlement, displacement, or degradation of fill is readily apparent. One or more voids may have formed. Cap or sidewall may be losing support in small, isolated locations.
40 to 54 (Marginal)	Significant voids can be seen within the fill of cellular sheetpile or timber crib structures. Large sections of cap, sheetpiling, or sidewalls are beginning to lose support due to fill settlement, displacement, or loss.
	Major Damage
25 to 39 (Poor)	Large voids within the structure are evidence of major fill loss. Large sections of cap have settled, and some sections of sidewall have lost support.
10 to 24 (Very Poor)	Large loss and displacement of fill from timber crib or sheetpile structures. Large areas of cap have settled or displaced, and sections of sidewall have failed due to fill loss.
0 to 9 (Failed)	General failure from loss of fill.

Table 8. Rating guidance for loss of scour and wave protection.

Structural Rating	Description
Minor or No Damage	
85 to 100 (Excellent)	At most, slight displacement or scattering of toe blanket has been detected in isolated portions of the toe. Slight displacement of wave protection armor stone with <1/4 armor size movement or depressions.
70 to 84 (Good)	Some minor toe stone displacement degradation, or settlement of toe. Any toe scour that has been observed is not serious and represents no threat to the structure. Any waviness or movement of the wave protection armor is on the order of 3/4th of the dimensions the armor and bridging is on the order of <1/2 of the armor size.
Moderate Damage	
55 to 69 (Fair)	Toe stone displacement has left bottom toe of structure exposed in small isolated areas or loss of individual or small groups of wave armor units have allowed more wave exposure of the structure to storm wave energy, but structure stability is not yet threatened.
40 to 54 (Marginal)	Toe scour is clearly evident along at least one large section of the reach. Wave protection stones are missing to a degree that underlayers are exposed or the structure is exposed to attack by moderate waves (to beyond design expectations). Reach stability is threatened.
Major Damage	
25 to 39 (Poor)	Toe scour has resulted in general subsidence and leaning. Structure is losing stability and may be further undermined by moderate storm conditions. Wave protection is minimal and moderate storm waves are impacting and damaging the primary structure.
10 to 24 (Very Poor)	Toe scour or increased wave energy exposure has led to localized failure of the structure in at least one location. Failure of adjacent areas would likely result from low level storm conditions or nonstorm conditions.
0 to 9 (Failed)	Toe scour and/or increased exposure to wave energy has led to failure of a significant portion of the reach.

Table 9. Rating guidance for loss of foundation support.

Structural Rating	Description
Minor or No Damage	
85 to 100 (Excellent)	No foundation settlement.
70 to 84 (Good)	No significant evidence of foundation settlement.
Moderate Damage	
55 to 69 (Fair)	Slight foundation settlement may have occurred.
40 to 54 (Marginal)	Foundation settlement may have resulted in noticeable loss of structure alignment or elevation. Reach stability is threatened.
Major Damage	
25 to 39 (Poor)	Foundation settlement has resulted in general subsidence and leaning. Structure is losing stability and may be further undermined by moderate storm conditions.
10 to 24 (Very Poor)	Foundation settlement has led to localized failure of the structure in at least one location. Failure of adjacent areas would likely result from low level storm conditions or nonstorm conditions.
0 to 9 (Failed)	Foundation settlement has led to failure of a significant portion of the reach.

Structural Rating Categories

Structural rating categories are described below. Lettered sections that accompany the rating categories correspond to the lettered items on the inspection form. Where multiple categories apply to the same distress, rate the distress for each of the categories. Do not limit the impact of the distress to one rating category. For example, leaning of a parapet wall may simply be the result of parapet damage or the cause may extend further into the superstructure or into the substructure. Deficiencies within a category should be selected and described as best as information allows. For example, it may not be possible to distinguish between voids, loss of material, displacement, and settlement.

A nonrubble breakwater generally becomes much less effective when damaged. Unlike rubble structures, which can often suffer damage without significant risk of progressive deterioration and loss of function, nonrubble structures can be quickly destroyed once they are significantly damaged. The actual damage mechanisms vary widely because of the many kinds of construction of nonrubble breakwaters. For instance, a homogeneous, nonporous structure such as a mass concrete breakwater can suffer few damages other than breakage of the concrete itself. On the other hand, sheet pile cells can incur various kinds of mechanical damage that can then lead to loss of the fill material retained behind the cells and destabilization of the structure.

Loss of Elevation or Alignment

This category covers geometric deviation from the as-built condition: a vertical, horizontal, or angular change in the position of the structure. It is most commonly observed by comparing the position of major components or structure sections relative to each other as well as relative to a fixed reference. A change in structure geometry often indicates that other deficiencies are present as well. For rating purposes, elevation or alignment deficiencies are described as follows:

a. Settlement. This is the vertical movement of components or a drop in elevation of the structure due to a consolidation of the subgrade materials or foundation. A large, localized drop in elevation may produce a breach: a depression (or gap) in the crest to a depth that permits significant wave energy past the structure. (A breach is not present unless the gap extends across the full width of the crest.) See Figures 13 and 14.

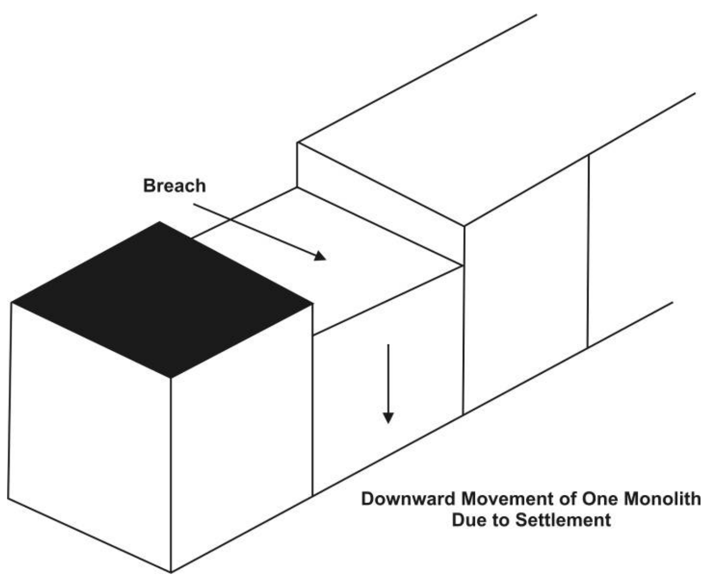


Figure 13. Breach caused by settlement.

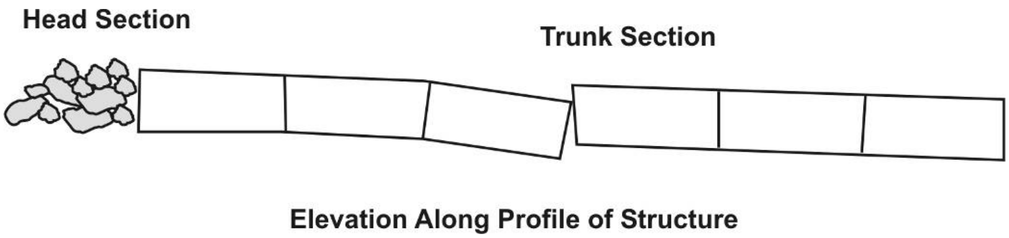


Figure 14. Drop in elevation causes a breach.

b. Displacement. This is the horizontal movement of components caused by external loads on the structure (Figure 15).

c. Leaning. This is the angular or rotational movement of components caused by differential settlement or external loads, or a combination of both. See Figures 16 and 17.

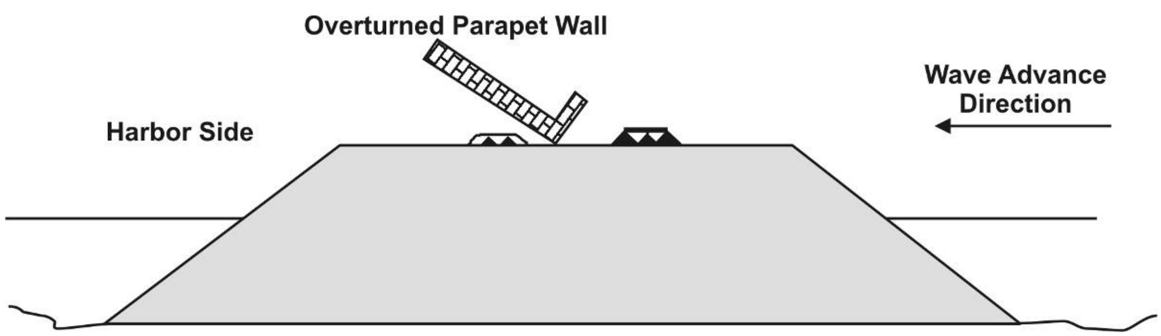


Figure 15. Wall has been displaced by wave action.

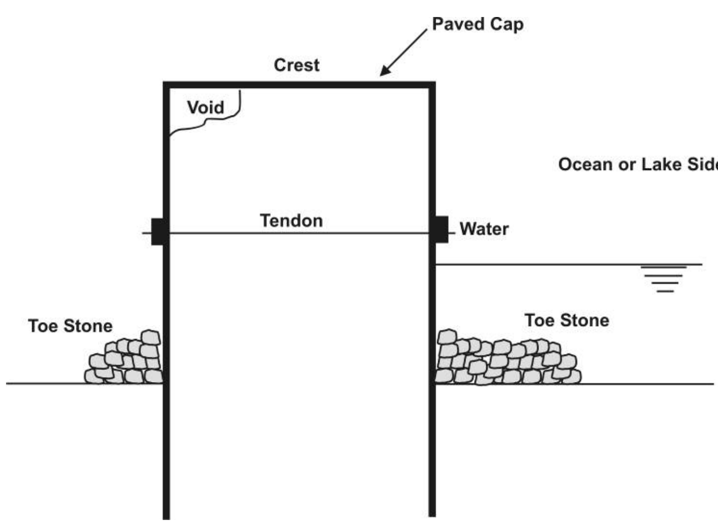


Figure 16. Settlement has caused a void.

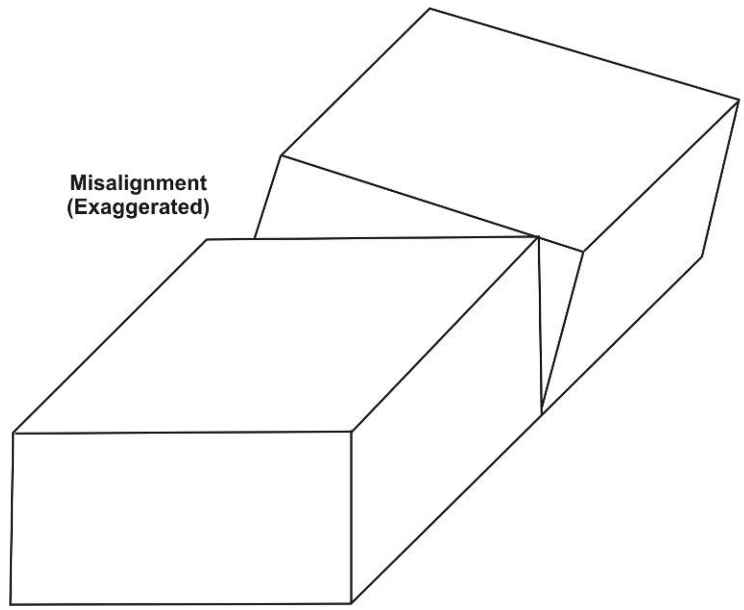


Figure 17. Misalignment caused by settlement, external loads, or a combination of both.

Structural Damage or Defects

This category covers damage or defects in the superstructure caused by the application of external loads, including damage caused by modifications to the structure and vandalism. For rating purposes these deficiencies are described as follows:

a. Deformation/load damage. Bent, buckled, crushed, twisted, or elongated members that have deformed from repeated wave attack and/or structure dead load.

b. Connection/interlock loss. Connections with missing bolts or connections show signs of being overloaded (for example elongation of bolts, sheared bolts, or torn welds). See Figure 18. This deficiency would also include an "unzipping" or opening in sheet pile interlocks.

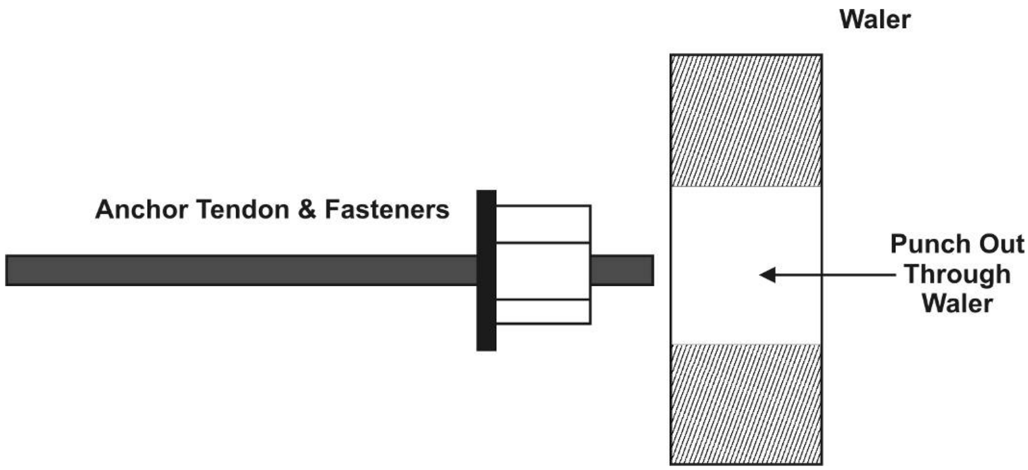


Figure 18. Connection lost between fastener and waler.

c. *Holes.* Holes, notches, or other modifications to a structure which are in locations that jeopardize the integrity of the member. See Figure 19.

d. *Fractures.* A break, crack, or split in a structural member caused by the application of external loads. Fractures may be caused by loads applied to the structure at a remote location but transmitted to the member through the structure. See Figures 20 and 21.

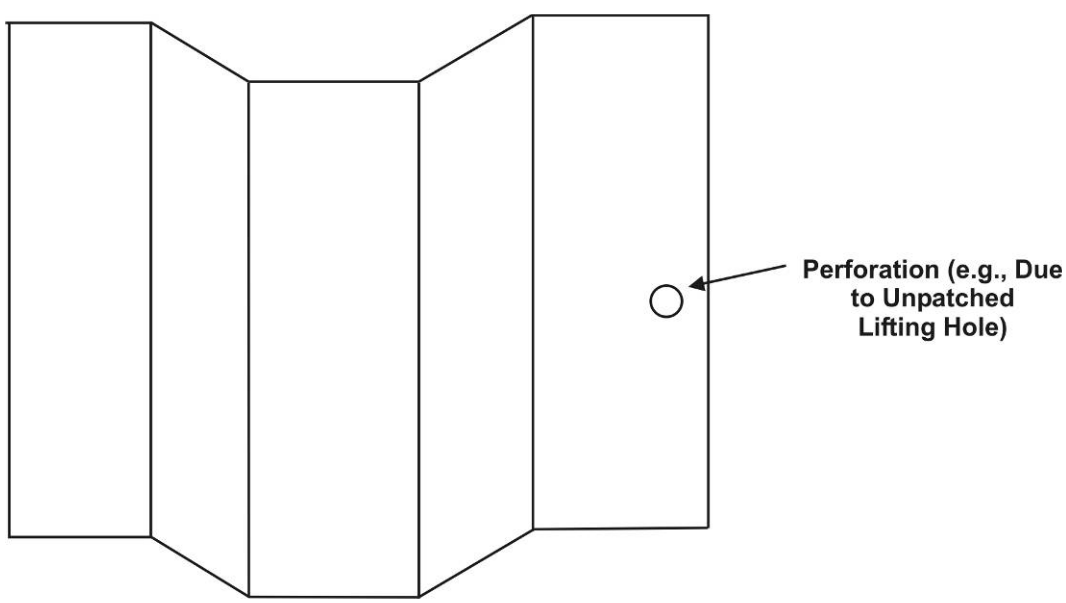


Figure 19. Perforation threatens structural integrity.

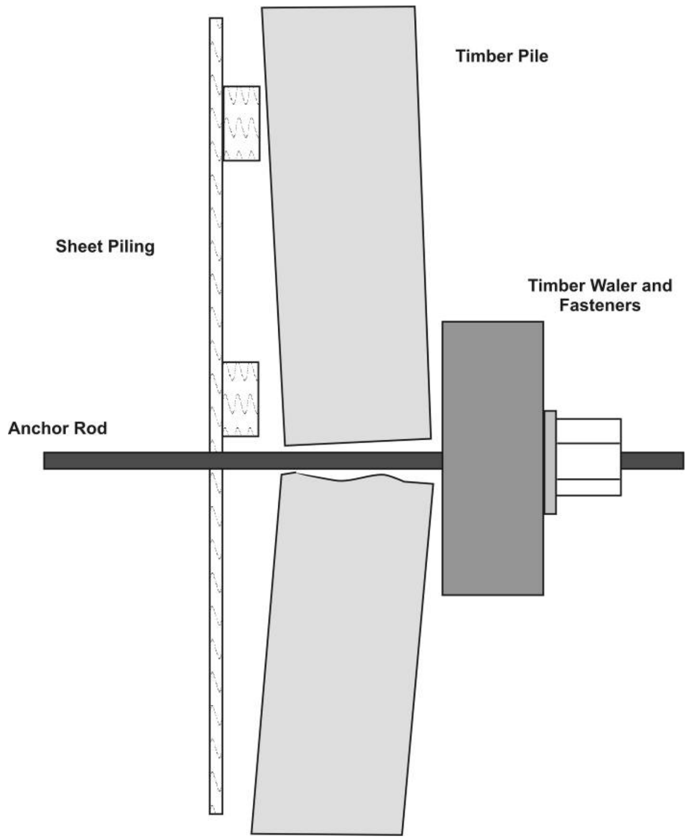


Figure 20. Fracture caused by external load.

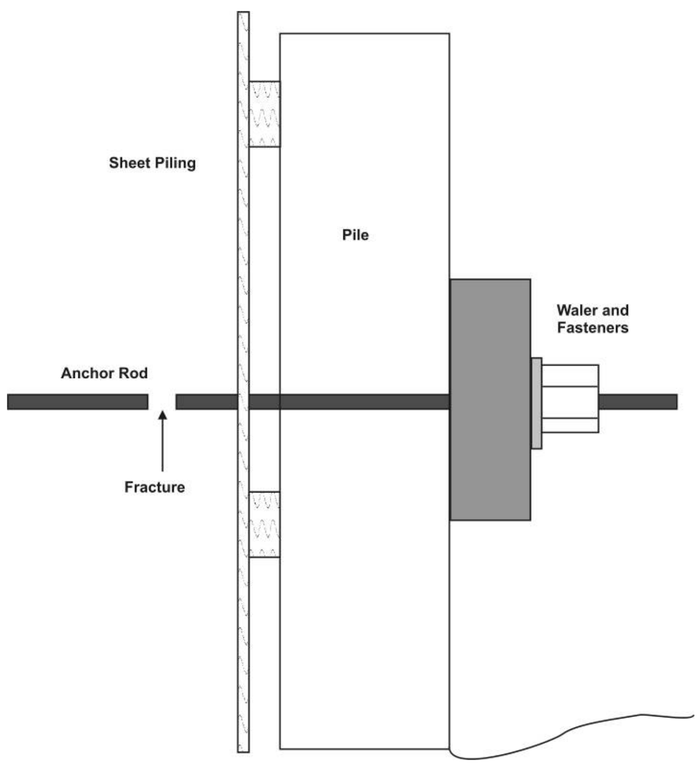


Figure 21. Fracture caused by remote external load.

e. *Member loss*. Members that have been removed from the structure. This includes timbers, walers, and sheet pile caps. See Figure 22.

f. *Impact damage*. Components which were damaged by the application of external loads such as vessel impact, wave action, ice loading, or mooring loads. Figure 23 shows typical damage.

g. *Vandalism*. Damage that is the result of deliberate action.

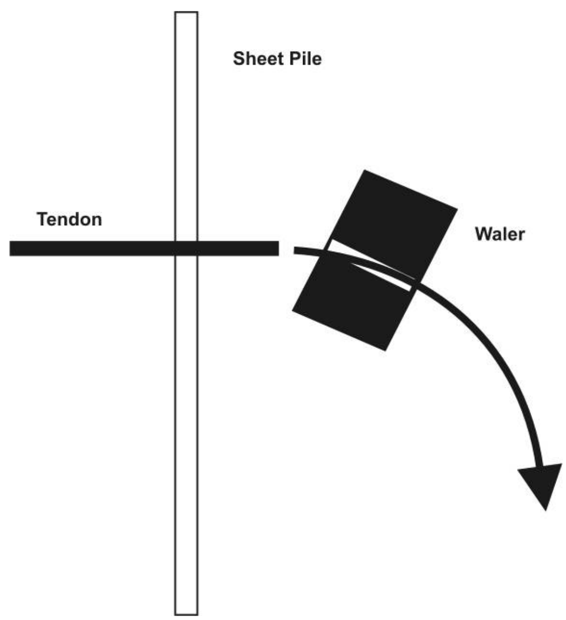


Figure 22. Waler lost from the structure.

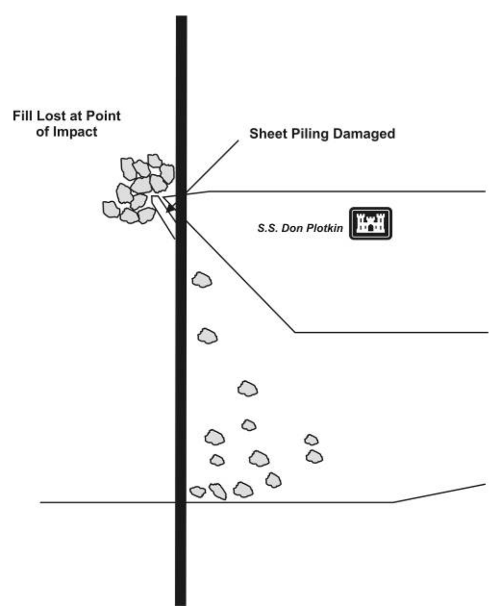


Figure 23. Impact damage.

Material Defects/Deterioration

This category is described as deficiencies in the material of a component of the superstructure or substructure. Defects are described as deficiencies intrinsic to the material (i.e., deficiencies that are not normally expected during the life of the material). Deterioration is described as deficiencies in the material which were anticipated (i.e., caused by normal corrosion or wear). The following are the most commonly observed deficiencies related to material defects/deterioration:

a. *Cracks*. Separations in the material of a structural component caused by any of a number of reasons. The type of cracking is indicative of the cause and should be carefully documented. Definitions of different types of cracking in concrete are relatively standard and can be found in a number of publications such as Technical Report REMR-OM-4 (1989). Some types of cracking are longitudinal, transverse, vertical, diagonal, pattern, and "D" type. See Figure 24.

b. *Spalls*. Flat voids in the surface of concrete caused by a fragment coming dislodged from the mass of the concrete. See Figure 25.

c. *Corrosion*. Chemical deterioration of material. See Figures 26 and 27.

d. *Checking/splitting*. Longitudinal cracking through timber members. See Figure 28.

e. *Rot/borers*. Decomposition or decay of timber structural members. See Figure 29.

f. *Scaling*. Local flaking or peeling away of the near surface portion of concrete or mortar.

g. *Honeycomb*. Voids left in the concrete due to failure of the mortar to effectively fill the spaces among coarse aggregate particles. This is a material defect.

h. *Lamellar tearing*. The separation of material resulting from through-thickness strains induced by weld metal shrinkage or applied loads.

i. *Abrasion*. Wear on a structure due to abrasion.

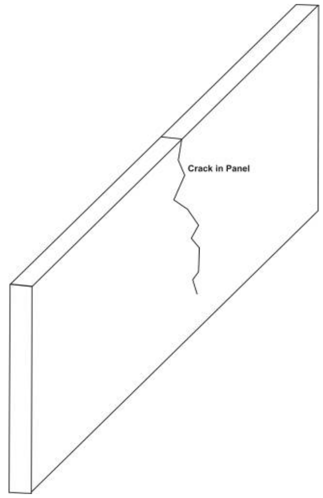


Figure 24. Vertical crack in panel.

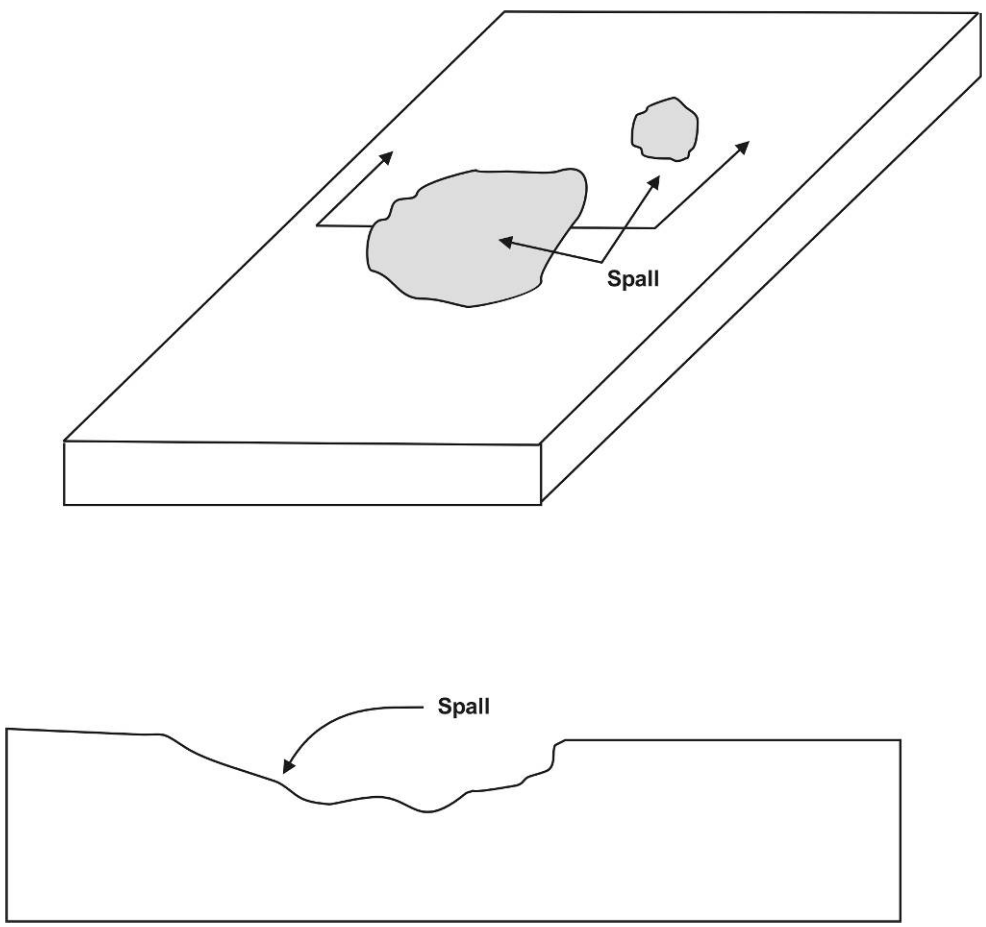


Figure 25. Spall caused when fragment becomes dislodged from concrete.

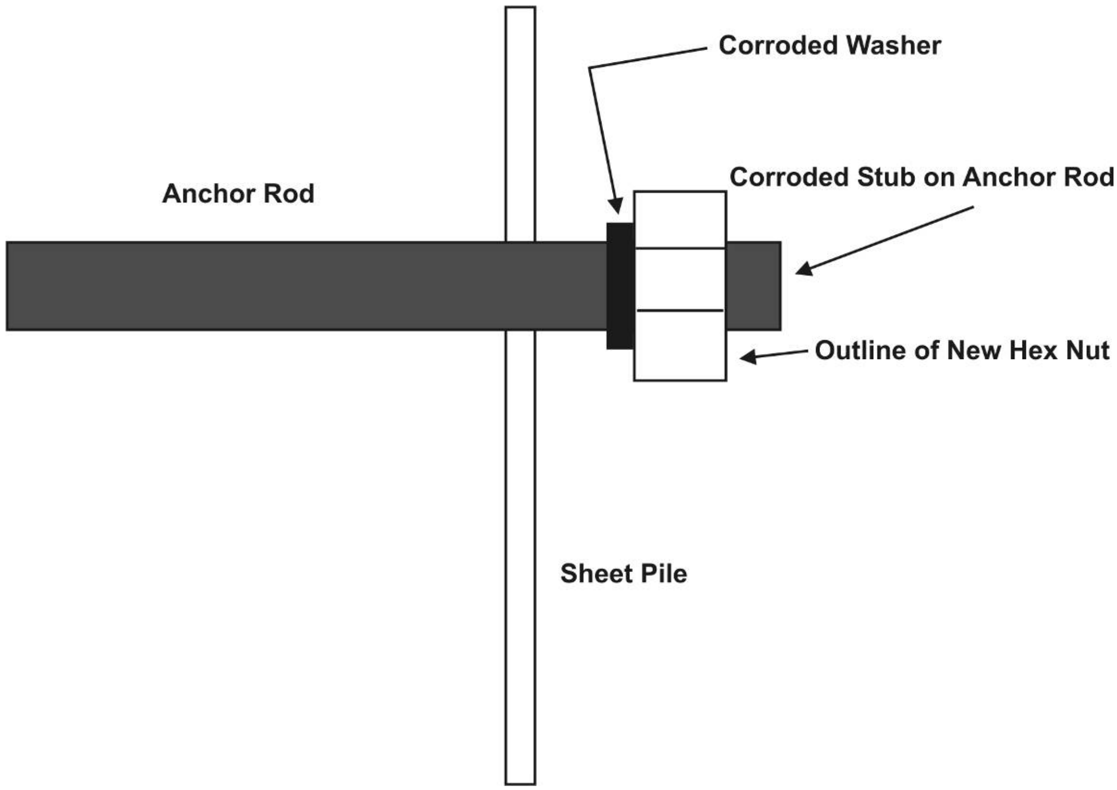


Figure 26. Corrosion is the chemical deterioration of materials.

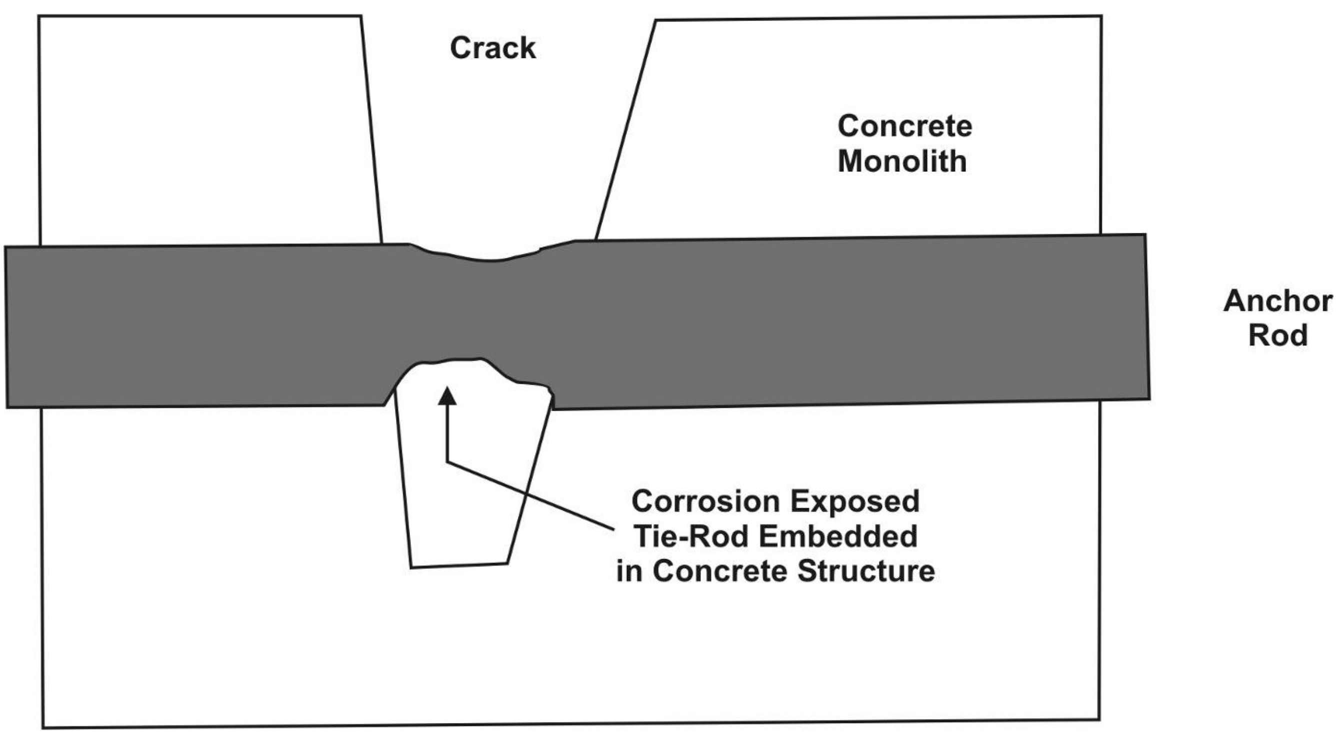


Figure 27. Deteriorated embedded tie-rod exposed by crack in concrete structure.

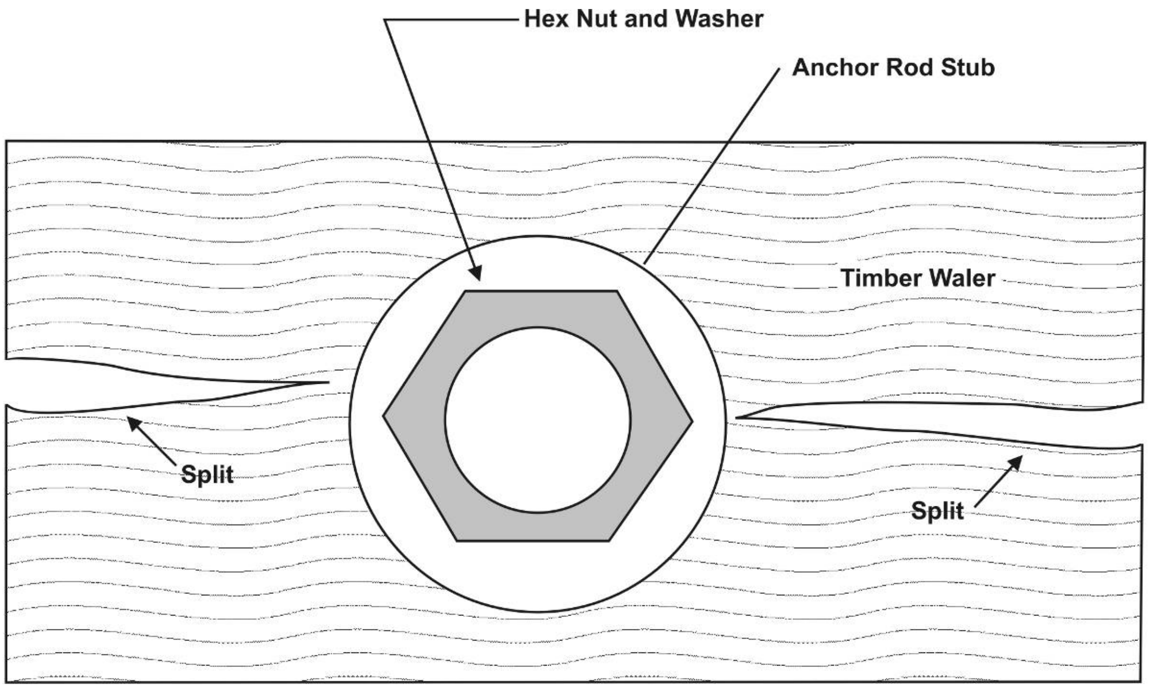


Figure 28. Longitudinal splitting of timber waler.

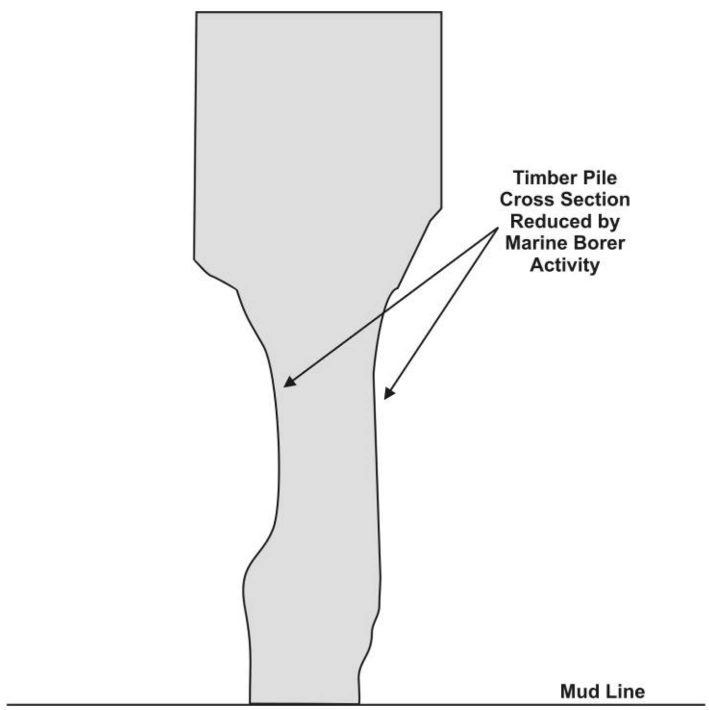


Figure 29. Timber pile cross section reduced by marine borer activity.

Loss of Fill Level

If left uncorrected, missing fill can lead to a serious loss of structural mass to resist wave loadings and can also leave other parts of the breakwater unsupported and susceptible to damage. It can also cause cracking or breakup of surface material and limit access or present a major hazard for some secondary uses of the structure.

a. *Settlement.* This is the vertical movement of components or a drop in elevation of the structure due to a consolidation of the fill materials or foundation.

b. *Voids.* Voids should be noted regardless of whether they result from material loss, settlement, degradation, structural failure, or other causes.

c. *Degradation.* The retained stones on the outer surface of a timber crib may fracture, which would allow the remaining pieces to move through the gaps in the timbers. Degradation of the stones may also lead to settlement. See Figure 30.

d. *Material loss.* Sand fill could gradually escape through small holes or gaps in a steel sheet pile structure. See Figures 16, 31, and 32.

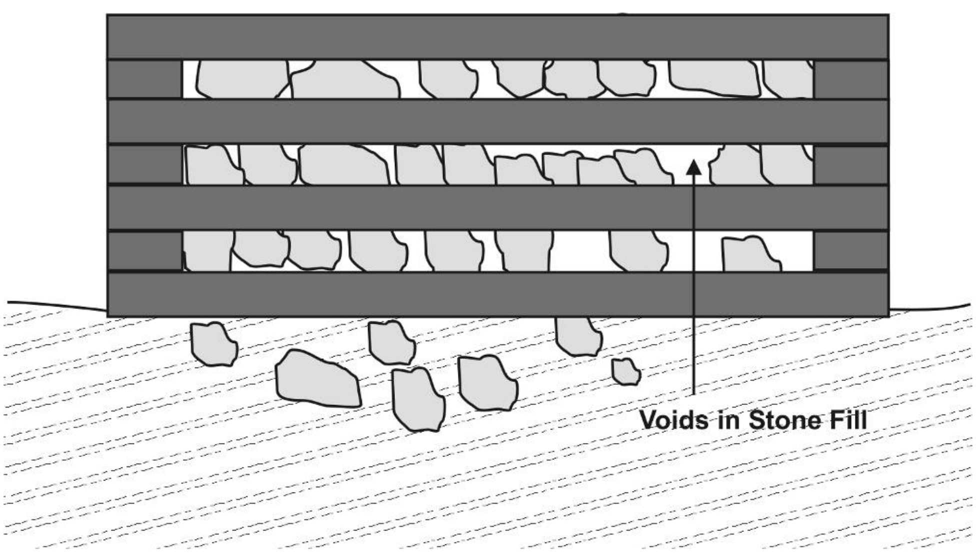


Figure 30. Loss of stone fill leaves gaps in the structure.

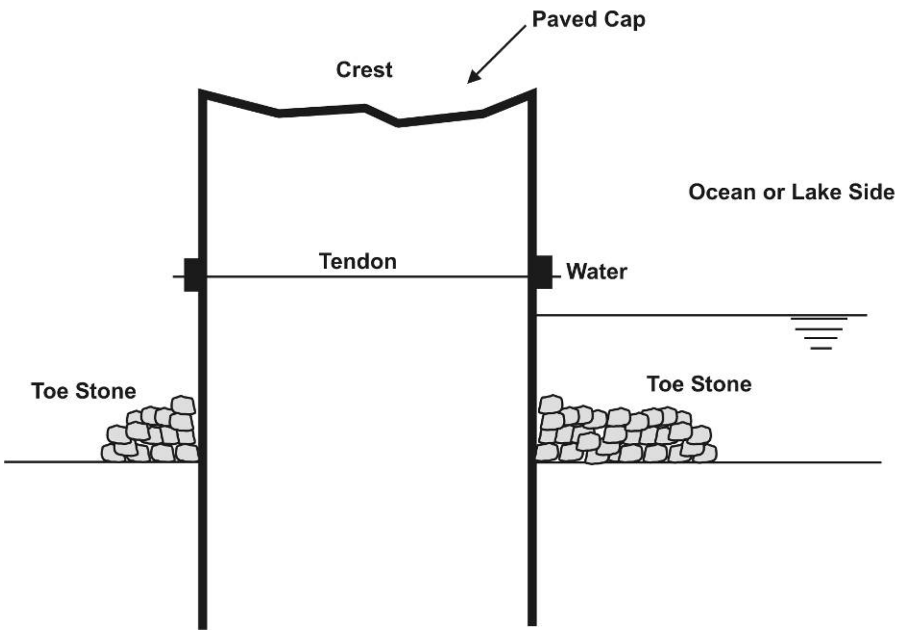


Figure 31. Loss of fill material leaves voids causing crest collapse.

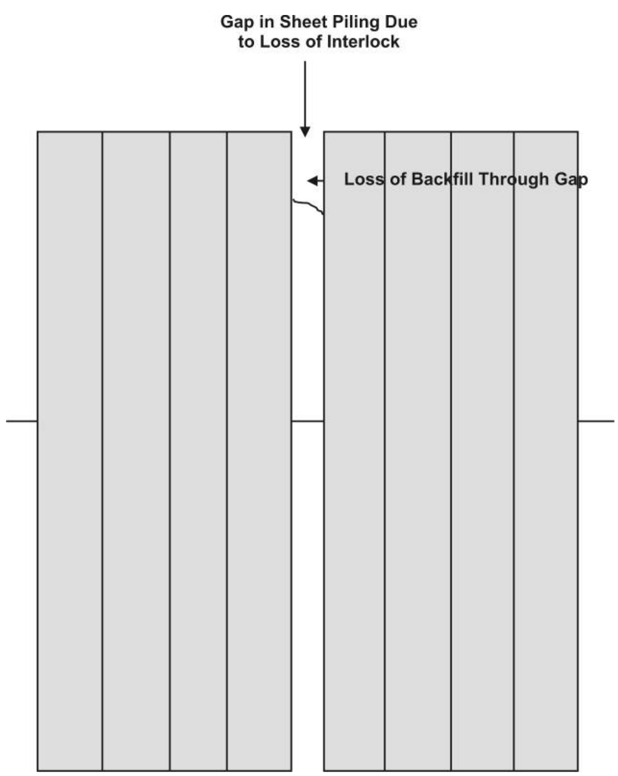


Figure 32. Gap in sheer piling causes loss of backfill.

e. *Structural failure.* As an example, if part of a timber crib cell fails, then the retained stone fill can be lost. Figure 33 shows a typical situation.

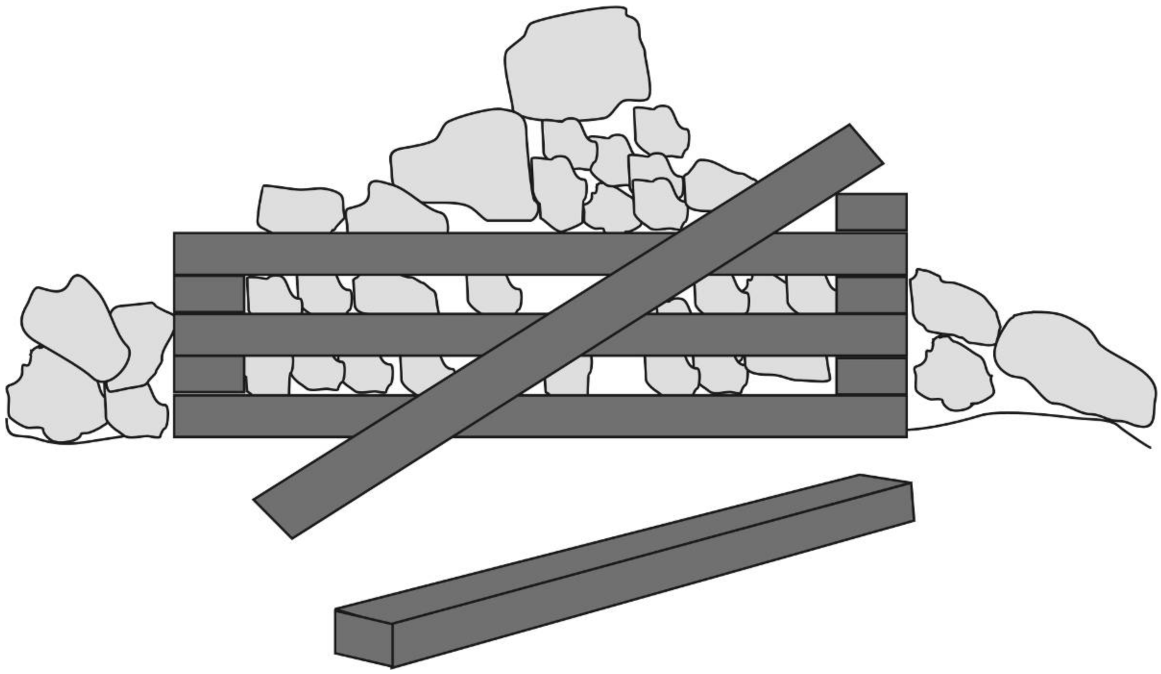


Figure 33. Retained stone fill can be lost if timber crib fails.

Loss of Scour and Wave Protection

Nonrubble structures frequently have rubble stone to protect against scour that would lead to undercutting of the structure. The rubble may also protect against excessive wave load, particularly for non-rubble structures that have been rehabilitated using rubble.

a. *Settlement*: This is the vertical movement of components or drop in elevation of the structure due to a consolidation of the fill materials or foundation.

b. *Displacement*: Movement of the stone may expose the fill or the structural members to excessive wave loadings.

c. *Degradation*: Fracturing of the stone reduces its ability to resist currents and wave loadings.

Loss of Foundation Support

a. *Settlement*. This is the vertical movement of components or drop in elevation of the structure due to inadequate foundation materials. See Figures 13 and 14.

b. *Displacement*. Undercutting of the structure can remove materials leading to instability. See Figure 34.

c. *Degradation*. This includes damage to foundation layer blankets and piles.

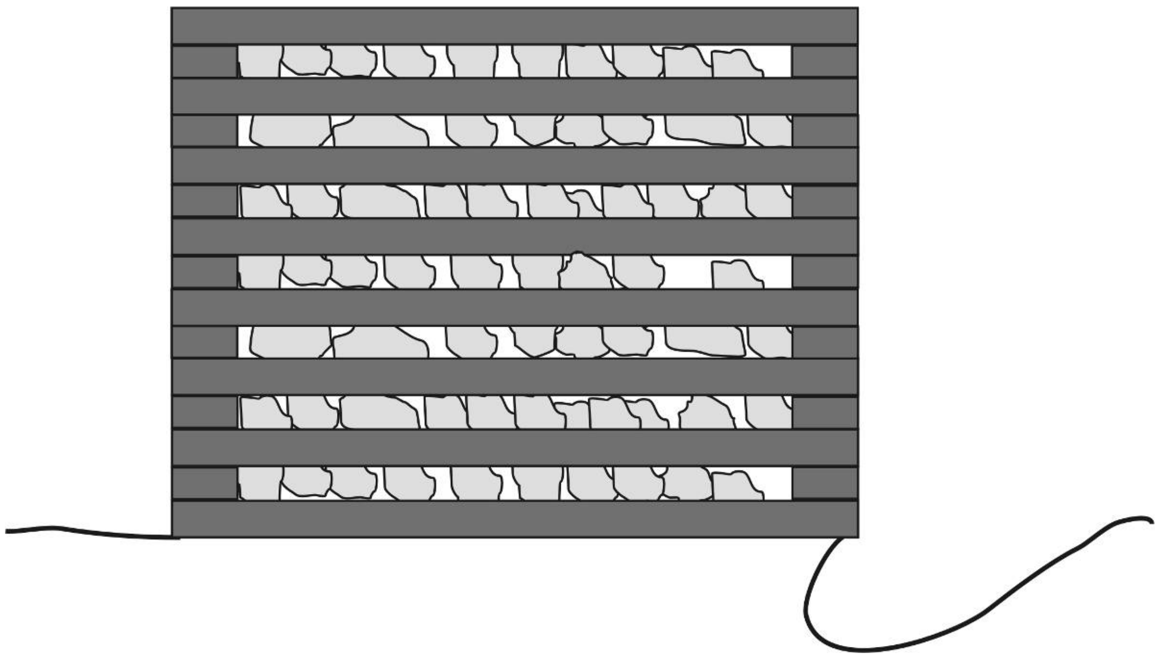


Figure 34. Undercutting of the structure can lead to instability.

Rating Tables

Tables 4 through 9 provide guidance for assigning numerical ratings to the six structural rating categories. The descriptions in the tables correspond to ratings at the center of the value range for each level.

Nonrubble structures include repaired structures such as the one shown in Figure 9b that may look like rubble structures on their exterior surfaces. The nonrubble rating categories and deficiencies do not cover rubble construction in nearly as much detail as the rubble rating procedures in TR REMR-OM-24. This is partly due to comments since the rubble CI was fielded that suggest that further detail is often not needed. If an inspector should determine that the further detail is needed, the two systems could either be applied separately or jointly. It is suggested that, if applied jointly, only the superstructure and substructure cross sections be used and that overlapping rating categories be dropped. The equations for calculating the index ratings would then have to be modified to include the added rating categories.

Using the Structural Rating Form

The structural ratings are made using the field form shown in Figures 35 and 36 (front and back, respectively). One form is needed for each reach or subreach in a structure. Figures 37 – 40 (fronts and backs) show two examples of completed forms. Because of the variability in construction of nonrubble structures, it is suggested that the Structural Feature Checklist for Nonrubble Breakwaters and Jetties in Figures 41 – 42 (front and back) be used to supplement the inspection records for each structure.

STRUCTURAL RATING FOR NONRUBBLE-MOUND BREAKWATERS AND JETTIES Page _____ of _____

PROJECT: ______________________________ REACH: _______ STA: _______ TO _______

DESCRIPTION OF STRUCTURE: ____

INSPECTED BY: ______________________________ DATE: __________ TIME: __________

WEATHER: ____

WAVE CONDITIONS: ____ SWL: __________
(water level, wave height, etc.)

INSPECTION PROCEDURE: ____

____
(walking, boating, other)

RATING TABLE

RATING CATEGORIES	DEFICIENCIES	SUPER-STRUCTURE		SUB-STRUCTURE		FOUNDATION	
		Rating (0-100)	Comment Number	Rating (0-100)	Comment Number	Rating (0-100)	Comment Number
Elevation/Alignment							
Structural							
Material							
Fill							
Scour/Wave Protection							
Foundation							

KEY TO DEFICIENCIES:
Elevation/Alignment: a) Settlement; b) Displacement; c) Out of Plumb; d) Loss of Units; e) Other
Structural: a) Fractures; b) Holes; c) Connection/Interlock Loss; d) Member Loss; e) Poor Connections; f) Load Damage/Deformation; g) Impact Damage; h) Vandalism; i) Other
Material: a) Nonstructural Cracks; b) Spalls; c) Corrosion; d) Rot/Borers; e) Checks/Splits; f) Scaling, g) Other
Fill: a) Settlement; b) Voids; c) Degradation; d) Loss of Fill; e) Other
Scour/Wave Protection: a) Settlement; b) Displacement; c) Degradation; d) Other
Foundation: a) Settlement; b) Displacement; c) Degradation; d) Other

INTEGRATED OR APPURTENANT STRUCTURES
Some deficiencies may be caused by the existence or condition of **integrated or appurtenant structures**. If that is the case, describe the impact that the integrated or appurtenant structure has on the inspected structure in the comments. Major integrated or appurtenant structures which could have an impact on the inspected structure should be inspected separately.
Items which should be inspected and commented on include: **Aids to Navigation, Warning Signs, Gates, Walkways, Stairs, Railings, Mooring Structures,** etc.

Comment Numbers

______________ WARNING SIGNS/GATES
______________ AUXILIARY STRUCTURES (**walkways**, stairs, **railings**, aids to navigation, fender piles, fendering etc.)

Figure 35. Structural rating form (front).

COMMENTS/RECOMMENDED ACTIONS
Action Key: **IA** = Immediate Action; **A** = Action; **M** = Monitor; **I** = Investigate; **N** = No Action

Comment Number	Action	Location (Stations)	Comments and Sketches

Figure 36. Structural rating form (back).

STRUCTURAL RATING FOR NONRUBBLE-MOUND BREAKWATERS AND JETTIES Page __1__ of __2__

PROJECT: ____Plotkin Bay Resort Harbor______________ REACH: __4A___ STA: _20+20_ TO __24+00_

DESCRIPTION OF STRUCTURE: ___North Jetty________________________________

INSPECTED BY: __Joe Kubinski______________________________ DATE: __10-22-04_ TIME: __0900____

WEATHER: ____windy____

WAVE CONDITIONS: ________1-3 ft waves, low tide_______________________________ SWL: __________
(water level, wave height, etc.)

INSPECTION PROCEDURE: ____Walked length of jetty, viewed from opposite jetty also___________________________
____
(walking, boating, other)

RATING TABLE

RATING CATEGORIES	DEFICIENCIES	SUPER-STRUCTURE Rating (0-100)	SUPER-STRUCTURE Comment Number	SUB-STRUCTURE Rating (0-100)	SUB-STRUCTURE Comment Number	FOUNDATION Rating (0-100)	FOUNDATION Comment Number
Elevation/Alignment	B	9	1	95			
Structural	B, E, F	9	1	60	4	95	
Material		95		95		95	
Fill	D			50	1		
Scour/Wave Protection	B					10	2
Foundation						95	

KEY TO DEFICIENCIES:
Elevation/Alignment: a) Settlement; b) Displacement; c) Out of Plumb; d) Loss of Units; e) Other
Structural: a) Fractures; b) Holes; c) Connection/Interlock Loss; d) Member Loss; e) Poor Connections; f) Load Damage/Deformation; g) Impact Damage; h) Vandalism; i) Other
Material: a) Nonstructural Cracks; b) Spalls; c) Corrosion; d) Rot/Borers; e) Checks/Splits; f) Scaling, g) Other
Fill: a) Settlement; b) Voids; c) Degradation; d) Loss of Fill; e) Other
Scour/Wave Protection: a) Settlement; b) Displacement; c) Degradation; d) Other
Foundation: a) Settlement; b) Displacement; c) Degradation; d) Other

INTEGRATED OR APPURTENANT STRUCTURES
Some deficiencies may be caused by the existence or condition of **integrated or appurtenant structures**. If that is the case, describe the impact that the integrated or appurtenant structure has on the inspected structure in the comments. Major integrated or appurtenant structures which could have an impact on the inspected structure should be inspected separately.
Items which should be inspected and commented on include: **Aids to Navigation, Warning Signs, Gates, Walkways, Stairs, Railings, Mooring Structures,** etc.
Comment Numbers
_____3_________ WARNING SIGNS/GATES
_____1_________ AUXILIARY STRUCTURES (**walkways**, stairs, **railings**, aids to navigation, fender piles, fendering etc.)

Figure 37. Completed structural rating form (front).

COMMENTS/RECOMMENDED ACTIONS

Action Key: **IA** = Immediate Action; **A** = Action; **M** = Monitor; **I** = Investigate; **N** = No Action

Comment Number	Action	Location (Stations)	Comments and Sketches
1	A	20+40 to 23+40	Reach 3A has a breach of the cap down to LWD 0.0 from Station 20+40 to 23+40. The concrete cap, foot blocks and cap blocks are now located on the lakeside rock armor and some 2-3 ft of quarry run stone fill of the core is also missing. The timber piles, wales, tie rods and timber sheeting seem to be in good shape. The lake side toe and wave absorbing armor is in good shape. Excessively steep waves impact the channel side.
2	A	20+20 to 23+60	A scour hole has been noted for the last 2 annual surveys on the channel side and a re-survey is called for. The thalwag seem to be shifting toward the jetty. The channel side toe protection and wave absorbing armor is largely missing.
3	A	At beach approach	Warning signs are called for to alert the public of the danger until the damage is repaired.
4	A	20+40 to 23+40	Top of wales and timbers suffered minor damage when cap blocks were removed by excessive wave impact forces.

Figure 38. Completed structural rating form (back).

STRUCTURAL RATING FOR NON-RUBBLE-MOUND BREAKWATERS AND JETTIES Page 1 of 2

PROJECT: Portland Harbor REACH: 3A STA: 18+00 TO 23+00

DESCRIPTION OF STRUCTURE: South jetty

INSPECTED BY: Don Plotkin DATE: 5-22-05 TIME: Afternoon

WEATHER: Calm

WAVE CONDITIONS: None SWL: __________
(water level, wave height, etc.)

INSPECTION PROCEDURE: Walked length of jetty, viewed from opposite jetty also. Divers performed underwater inspection
(walking, boating, other)

RATING TABLE

RATING CATEGORIES	DEFICIENCIES	SUPER-STRUCTURE		SUB-STRUCTURE		FOUNDATION	
		Rating (0-100)	Comment Number	Rating (0-100)	Comment Number	Rating (0-100)	Comment Number
Elevation/Alignment		100		100			
Structural	B,D,F	55	2	60	1	100	
Material		100		100		100	
Fill				100			
Scour/Wave Protection						65	3
Foundation						100	

KEY TO DEFICIENCIES:
Elevation/Alignment: a) Settlement; b) Displacement; c) Out of Plumb; d) Loss of Units; e) Other
Structural: a) Fractures; b) Holes; c) Connection/Interlock Loss; d) Member Loss; e) Poor Connections; f) Load Damage/Deformation; g) Impact Damage; h) Vandalism; i) Other
Material: a) Nonstructural Cracks; b) Spalls; c) Corrosion; d) Rot/Borers; e) Checks/Splits; f) Scaling, g) Other
Fill: a) Settlement; b) Voids; c) Degradation; d) Loss of Fill; e) Other
Scour/Wave Protection: a) Settlement; b) Displacement; c) Degradation; d) Other
Foundation: a) Settlement; b) Displacement; c) Degradation; d) Other

INTEGRATED OR APPURTENANT STRUCTURES
Some deficiencies may be caused by the existence or condition of **integrated or appurtenant structures**. If that is the case, describe the impact that the integrated or appurtenant structure has on the inspected structure in the comments. Major integrated or appurtenant structures which could have an impact on the inspected structure should be inspected separately.
Items which should be inspected and commented on include: **Aids to Navigation, Warning Signs, Gates, Walkways, Stairs, Railings, Mooring Structures** etc.

Comment Numbers
__________ WARNING SIGNS/GATES
__________ AUXILIARY STRUCTURES (**walkways**, stairs, **railings**, aids to navigation, fender piles, fendering etc.)

Figure 39. Completed structural rating form (front, second example).

COMMENTS/RECOMMENDED ACTIONS

Action Key: **IA** = Immediate Action; **A** = Action; **M** = Monitor; **I** = Investigate; **N** = No Action

Comment Number	Action	Location (Stations)	Comments and Sketches
1	C	23+10 – 23+16	Four damaged panels above MHHW. Cracked but not holed or missing. Not affecting beach sands or sediment transport. Not of significance relative to wave energy transmission. Looks like vessel or floating log impact cause likely.
2	C	23+00 – 23+16	Rebar in area of impact damage at junction of cap and sheets and cap and buttressing piles have epoxy coating of rebar broken and rebar is rusting leaving heavy rust staining evidence.
3	C	20+25 – 20+45	Diver survey on 10-15-98 at tide stage +6' MLLW found 20 foot stretch where half of the quarry run stone toe protection blanket width was missing. Divers (J. Oliver & D. Pirie) found evidence of the channel moving closer to the toe of the channel. They also reported that the ebb current could be also be affecting this loss of channel side toe blanket.

Figure 40. Completed structural rating form (back, second example).

STRUCTURAL FEATURE CHECKLIST FOR NONRUBBLE BREAKWATERS & JETTIES Page _____ of _____

PROJECT: ____ REACH: _______ STA: _______ TO _______

DESCRIPTION OF STRUCTURE: ____

INSPECTED BY: ____ DATE: __________ TIME: __________

WEATHER: ______________________________ WAVE CONDITIONS: ________________________ SWL: __________

INSPECTION PROCEDURE: ____

____

FEATURE TABLE

	Steel Sheet Pile			Timber	
FEATURES	**Rating (0-100)**	**Comment Number**	**FEATURES**	**Rating (0-100)**	**Comment Number**
Alignment			Alignment		
Parapet			Parapet		
Concrete Cap			Concrete Cap		
Stone Cap			Stone Cap		
Sheet Pile Cap			Cap Blocks		
Sheet Piling			Foot Blocks		
Tees & Special Piles			Timber		
Seat Angles			Piles		
Tie Rods			Planks (Sheeting)		
Connections			Wales		
Fill			Tie Rods		
Scour Protection			Connections		
			Fill		
			Scour Protection		
			Foundation Mattress		
			Bearing Piles/Batter Piles		

	Concrete			Concrete	
FEATURES	**Rating (0-100)**	**Comment Number**	**FEATURES**	**Rating (0-100)**	**Comment Number**
Parapet			Fill		
Concrete Cap			Scour Protection		
Concrete Walls			Foundation Mattress		
Joints			Bearing Piles/Batter Piles		
Connections					

Figure 41. Structural Feature Rating Checklist (front).

Key to Deficiencies:

Loss of Alignment: a) Settlement; b) Displacement; c) Out of Plumb; d) Other

Structural Defects/Damage: a) Fractures; b) Holes; c) Interlock Loss; d) Poor Connections; e) Deformed Members; f) Displaced Members; g) Member Loss; h) Load Damage; g) Impact Damage; h) Vandalism; i) Other

Material Defects/Deterioration: a) Nonstructural Cracks; b) Spalls; c) Corrosion; d) Rot; e) Scaling f) Other

Loss of Fill Level: a) Settlement; b) Voids; c) Degradation; d) Other

COMMENTS AND RECOMMENDED ACTIONS

Key to Actions: A) Immediate Action; B) Action Soon; C) Watch; D) Defer; E) Investigate Further

Figure 42. Structural Feature Rating Checklist (back).

For rating purposes, each reach or subreach cross section is divided into three areas: the superstructure, substructure, and foundation. Each cross sectional area is given 0 to 100 ratings in six rating categories, as shown in the center of the form. All categories must be rated (otherwise, an SI cannot be calculated).

Next to each rating block on the inspection form is a space for a comment number. This number may be keyed to a comment given in the bottom section, explaining the reason for the rating and describing what was observed, as well as the station (or station range) for the defect location, and a column for "Suggested Action," referring to one of the five lettered actions listed above the comment block.

The six rating categories have a list of descriptors following them that serve to further characterize the defects found within a reach. If applicable, the inspector should circle one (or more) descriptor(s) that best characterizes the existing defects. Further description may be supplied by the inspector in the comment space.

Below the rating block are additional items that should also be observed while inspecting a structure. The foundation fault items may require additional work before they can be completed. Related comments should be recorded in the comment section at the bottom of the form.

The importance of providing thorough comments cannot be overemphasized. Comments should note the location, character, size, and actual or potential effects of structure defects. The comments serve as backup and explanation for the ratings and suggested actions chosen by the inspector. Comments also provide a good record for future reference.

Five Suggested Actions are given on the structural rating form, just above the comment block. The inspector may use these to suggest what action may be appropriate for the recorded defects. (A) Immediate Action means that repairs are required right away to preserve structural integrity in an emergency. (B) Action Soon means defects should be corrected during the next budget cycle. (C) Watch means no repairs are required currently, but the condition may be unstable or subject to rapid change and should be monitored regularly. (D) Defer means that the affected area of the reach appears stable and does not appear to threaten structural integrity, even if condition should worsen somewhat. (E) Investigate Further means more detailed inspection and analysis are needed to determine or verify the severity of the condition or the appropriate action to be taken.

Inspectors are encouraged to suggest an action for each defect area on the reach, but should follow local guidance in applying and reporting these. The action items do not affect ratings or index values.

The Inspection Process

Completion of the structural rating form is intended to be part of a regular, periodic structure inspection program conducted by the Coastal Engineer Districts. The field observations and recorded information needed to produce CI values are nearly the same as would be required as part of any routine inspection.

Preparation for determining structure ratings should be the same as for any regular, thorough inspection. The inspector (or inspection team) should be familiar with the structure and past inspection reports before the inspection begins. The beginning and end of each reach should also be known. A copy of the latest inspection report should be brought to the work site to help judge changes in condition.

Other items to help conduct an effective inspection and to document findings include: project maps and photographs, still and video cameras, tape measures, hand levels, and tidal information.

Ratings may be determined best by first walking the length of the structure and making notes of observed defects, their station location, and their severity. On the return walk, ratings may then be selected based on having seen the whole structure and on a second opportunity to observe defect sites.

Determining Structural Ratings

Structural ratings are selected from the appropriate rating table (Tables 4 through 9). These ratings are based on a comparison of the existing condition (at the time of inspection) with an “ideal” or “perfect” condition. Thus, even a brand new structure may not warrant ratings of 100 if, for example, some armor units were damaged during placement or armor placement did not fully meet design specifications.

When assigning ratings, choosing numbers in multiples of five is usually preferred. Ratings at the top or bottom end of a condition level may also be appropriate. The descriptions in the tables correspond to ratings at the center of the value range for each level. *All ratings must be based on the condition of the structure at the time it was inspected.*

For any rating category, it will be quite common that none of the condition levels lists a case exactly matching the situation found in the field. In such cases, the inspector selects the appropriate rating by first narrowing the choice to the most appropriate one or two condition levels, and then selecting the final rating. The general SI scale (Table 2) should also be used to help judge the relative severity of the defect. The two most common situations are:

a. The choice is narrowed to one condition level. The inspector must then determine if the most appropriate rating is near the top, bottom, or middle of the condition level. (Examining the condition levels just above and below will help in deciding.)

b. Two adjacent condition levels look possible. The inspector must determine if the rating is most appropriate near the bottom of the higher condition level or near the top of the lower level.

For conditions or unique situations not covered in the rating tables, the general SI scale should be used to determine the most appropriate rating. The following two examples illustrate the thought process for selecting SI ratings.

Example 1

Reach 3A, between Station 20+20 to 24+00, of the example shown on Figure 10, is part of a simple concrete sheetpile structure buttressed with concrete batter piles on the channel side every 50 feet from 0+00 to 24+00. The narrow concrete cap with a top elevation of +12 MLLW, was poured in place around the epoxy coated rebar network connecting the sheets, buttressing, and cap. An aid to navigation is located at the jetty tip with power and control wiring being provided by submerged cables at the structure toe. A full jetty length blanket of quarry run toe protection is augmented with 5-ton stone to MLLW for a slight wave absorber for the outer 50 feet of the jetty tip.

This reach was inspected at a minus tide and found to be in relatively good condition except for four damaged concrete sheet panels above MHHW from Station 23+10 to 23+16. No wave energy is bypassing the structure and the damage is too high above MHHW to affect sediment transport or beach elevations. Here, the concrete was cracked but not broken from what looks like vessel impact or floating log impact, and the joints between the buttresses, cap, and panels are weeping rust sweat from what looks like rusting rebar that has had its epoxy coating disturbed. The other aspect of the reach, found by divers, was that the toe protection blanket of quarry run was missing half of its width between Station 20+25 and 20+45. Either the ebb current is excessively swift at this area of the structure and scouring away the toe protection or the channel is migrating toward the structure.

The damage to the sheetpiles above MHHW is addressed in Table 5, **Rating Guidance for Structural Damage or Defects**. The sheets are not significantly damaged where "units are missing," so the rating should be above 40. The description for a rating of "good" is not quite bad enough to describe the cracked, but not lost, sheeting. The stains from cracked and rusting epoxy coated rebar is more than "some signs of stain." To determine whether the sheet damage is "fair" or "marginal," consider that the damaged components are critical components but have not yet been holed. The damage is restricted to a noncritical elevation on the sheeting, so the rating should be higher and in the 55-69 range. A rating of 60 is selected to represent the rating of the four cracked sheet panels.

The damage to the connecting rebar, which is seen to be rusting in the area above the impact area, is also rated using Table 5. Table 6 would be used if the rusting had not been caused by impact and instead had been caused by "environmental wear and tear or material deficiencies." From Table 5 find that the rebar is a critical connecting component and that the rating should be placed at the high end of "marginal" or the low end of "fair." Because loss of the connections would likely lead to loss of the reach and the belief that localized corrosion of epoxy coated rebar could lead to catastrophic corrosion rates of the cracked joints, a rating of 55 is assigned.

The loss of toe scour protective stone of a half width loss over a 20 foot length, is rated on Table 8. Although the scour has not reached the location of the sheeting toe, the loss of protective material is a concern. None of the descriptions fit exactly, but one can infer that the "threat to stability" factors of "fair" and "marginal" ratings are to be considered. The structural stability is not yet threatened. Therefore, a “fair” rating is suggested. If this loss is something that has been slow to materialize, a rating toward 65 would be appropriate. If it is something that happened over a few episodic events and could be expected to become a serious problem more quickly, a rating of 60 would be attached. For this example, consider that the problem has been watched for a number of years and is progressing slowly, so a rating of 65 is given. The CI results are tabulated in Figures 37–39.

Example 2

A timber pile and plank structure, with a cross section as shown in Figure 7e, is similar to those commonly found along the Great Lakes, in breakwaters and jetties. The typical construction includes protection by stone armor acting both as a scour protection and a partial wave absorber. Since the armor does not come up to an elevation that would classify this structure as a rubble mound with a timber pile and plank core, we should consider it instead as a timber pile and plank with supplemental armor wave protection. Reach 3A has a breach of the cap down to LWD 0.0 from Station 20+40 to 23+40. The concrete cap, foot blocks and cap blocks are now located on the lakeside bottom and some 2 to 3 feet of elevation of the core’s quarry run stone fill is also missing. The timber piles, walers, tie rods, and timber sheeting seem to be in reasonably good shape considering the loss of the cap. The lakeside toe protection/wave absorbing armor also is in good shape. A scour hole has been noted for the last two annual surveys on the channel side and has eliminated most of the wave armor and toe scour protection. A re-survey is called for. The thalweg seems to be shifting. The loss of wave protection from the loss of the channel side armor has led to increased wave action on the structure and loss of the cap. Warning signs are needed to alert the public of the danger until the damage is repaired.

The ratings for this example are again from Tables 4–9. Loss of elevation in the form of loss of the entire cap rates a “failed” rating of 9. Cap structural damage rating of 9 is from Table 5’s “failed” classification of “General structural failure.” The substructure’s structural damage rating of 60 resulted from a “minor deformation of connections. Walers may show significant wear or some damage, but members are still sound.” The 50 rating for the loss of fill are from the determination that large sections of the sidewalls are beginning to lose support. The 10 rating for scour is from a determination that the wave energy absorbing aspect of the combined toe/protection and stone armor have been minimized to a point where steep waves are impacting the structure even on the “fair” day of the inspection.

This loss of protection has also led to a general failure of the jetty superstructure.

6 Functional Rating Procedures

Introduction

The structure's functional performance is the most critical portion of the CI for coastal structures, with the measure of physical condition (SI values) playing a subordinate role. As previously shown in Figures 2 and 3, the SI values supply information to assist in determining functional ratings, which then lead to functional index (FI) values and to the final CI. FI values are expressed as numbers from 0 to 100 and have the general interpretation as shown in Table 10.

Part of implementing the CI system is determining which major functions and, in turn, which rating categories apply to each reach of a structure. As with reach limits, once assigned, these functions should not change unless major changes are made to the structure or project. The FI for the reach will then be based on the same selected functional rating categories every time a functional rating is done.

Table 10. Functional CI rating scale.

Functional Loss Level	Zone	Functional Index	Condition Level	Description
Minor	1	85 to 100	EXCELLENT	Functions well, as intended. May have slight loss of function during extreme storm events.
		70 to 84	GOOD	Slight loss of function generally.
Moderate	2	55 to 69	FAIR	Noticeable loss of function, but still adequate under most conditions.
		40 to 54	MARGINAL	Function is barely adequate in general and inadequate under extreme conditions.
Major	3	25 to 39	POOR	Function is generally inadequate.
		10 to 24	VERY POOR	Barely functions.
		0 to 9	FAILED	No longer functions.

Functional ratings are produced using the rating tables (Tables 16 through 19) at the end of this chapter. While the wording in the descriptions for each rating table is specific to the category being rated, each table follows the format and general interpretation of the FI scale shown in Table 10. It is recommended that the functional rating form be brought to the field during the structural inspection for observations and comments that may affect the functional rating produced back in the office.

Functional Rating Categories

Structure functions are divided into 4 major areas containing a total of 11 rating categories. The four functional areas indicate how well the structure performs the following:

a. Controls waves and currents to permit full use of the harbor area.

b. Controls waves and currents to permit full use of the navigation channel and entrance.

c. Controls movement, build-up, and loss of sediment within navigation areas and along adjoining shorelines.

d. Protects nearby structures, or portions of itself, from wave attack or erosion damage.

The self-protection aspects of functional area (d) are not used in determining the CI, but are included as indicators of the potential for rapid loss of function in the other functional categories. Functional deficiencies that are not caused by structural deterioration are not included in the ratings. Design deficiencies should be identified in the development of the project spreadsheet and reported using the current guidance for that process.

When defining reaches (as outlined in Chapter 4), functions for each reach of a structure are determined from the 11 rating categories within the 4 main functional areas. A reach may have most of the 11 functions or only a few. (The rating process is covered in following sections.)

Tables 11 through 14 summarize the rating categories and corresponding process elements. Items in the Rating Categories column of the tables represent types of damage or adverse conditions (functional deficiencies). Items in the Process Elements column represent the potential causes of these conditions. When a functional deficiency is noted, an investigation of the process elements may help to further define the character and severity of the problem and to determine appropriate remedial actions.

In addition to the four major functional areas, there is a group called "Other Functions." These are considered secondary to the main functions and are not given numerical ratings, nor do they affect reach definitions or FI values. Instead, comments are provided when functional deficiencies exist in these categories.

Table 11. Rating categories and process elements for Harbor Areas.

Harbor Area Rating Categories	Process Elements
Harbor Navigation *Limitations on vessel size and draft *Vessel maneuvering difficulties	Wave Conditions *Long period fluctuations or oscillations: - Harbor resonance - Storm surge - Seiching
Harbor Use *Delays due to wave or current conditions *Limitations on vessel size and draft *Reduced usable mooring area *Reduced mooring density *Vessel maneuvering difficulties *Damage to structures *Damage to other facilities	*Storm waves: - Height - Period - Frequency *Wakes from vessels. *Wave transformation: - Diffraction - Reflection or standing waves - Wave/current interactions
a. Moored Vessels *Damage from waves, currents, seiches	
b. Harbor Structures *Damage or wear on piers, floating docks, and mooring systems *Overstressed mooring buoys and dolphins *Broken mooring lines *Vessels dragging anchors *Erosion or loss of backfill behind bulkheads, seawalls, revetments *Scour at toe or excessive leaning of structures *Direct structural damage *Use restrictions	Currents *Tidal or fluvial: - Training - Dispersion - Deflection *Alteration of natural flushing characteristics.
c. Other Facilities *Flooding *Erosion *Direct structural damage *Use restrictions	

Table 12. Rating categories and process elements for Navigation Channels.

Navigation Channel Rating Categories	Process Elements
Entrance Use *Delays due to wave or current conditions *Limited vessel size or draft, due to waves *Difficulty or damage while navigating entrance	Wave Conditions *Seiches of long period
Channel *Delays due to wave or current conditions *Limited vessel size or draft *Obstruction from displaced armor units *Migrating thalweg *Vessel collisions with structure or other vessels	*Storm waves: - Height - Period - Frequency *Wave transformation: - Refraction and focusing - Diffraction and crossing - Reflection - Breaking - Wave/current interactions - Waves at unfavorable angles
	Currents *Tidal or fluvial: - Training - Dispersion - Deflection *Excessive velocity *Cross-channel currents

Table 13. Rating categories and process elements for Sediment Management.

Sediment Management Rating Categories	Process Elements
Ebb Shoal *Delays due to wave or current conditions *Limited vessel size or draft, due to waves *Difficulty or damage while navigating entrance	Sediment *Shoaling: - Magnitude - Rate - Location
Flood Shoal *Change in navigation channel dimensions *Shift of channel location due to migrating thalweg Harbor Shoaling *Change in maneuvering channel dimensions *Loss of depth in mooring areas Shoreline Impacts *Downdrift Erosion: - Flanking - Interior bank erosion *Updrift Accretion *Adverse effect on sand bypassing operations *Sediment losses from system	*Loss of deposition *Transformation of bedforms: - Ebb or flood tidal shoals - Shore-parallel bars - Sand waves Wave Conditions *Direction *Refraction *Diffraction Currents *Training *Velocity

Table 14. Rating categories and process elements for Structure Protection.

Structure Protection Rating Categories	Process Elements
Nearby Structures *Inner side of jetties or breakwaters *Other jetties or breakwaters *Jetty itself, in some cases, when armor is breached Toe Erosion *At structure head *Seaward side *Channel side Trunk Protection (For Head or Root Only) *Damage to trunk due to inadequate protection from head or root reach	Wave Conditions *Wave transformation: - Diffraction - Refraction *Overtopping *Wave runup *Transmission through structure Current Conditions *Rip currents on seaward side *Ebb flow impingement *Flow separation during flood with eddy forming and developing a scour hole at the head
Flood Shoal *Change in navigation channel dimensions *Shift of channel location due to migrating thalweg Harbor Shoaling *Change in maneuvering channel dimensions *Loss of depth in mooring areas Shoreline Impacts *Downdrift Erosion: - Flanking - Interior bank erosion *Updrift Accretion *Adverse effect on sand bypassing operations *Sediment losses from system	*Loss of deposition *Transformation of bedforms: - Ebb or flood tidal shoals - Shore-parallel bars - Sand waves Wave Conditions *Direction *Refraction *Diffraction Currents *Training *Velocity

The 4 functional areas (Harbor Area, Navigation Channel, Sediment Management, and Structure Protection), and 11 rating categories are described as follows.

Harbor Area

Harbor protection structures (usually breakwaters) are designed to protect or shelter an area from large waves, currents, seiches, and sedimentation, thereby forming a safe, navigable harbor. (Typical break-water systems were illustrated previously in Figures 7 and 10.) Ratings within this main function are based on how well the structure provides and protects a harbor during all conditions and for all vessels, as compared with the design expectation or current requirements. Sedimentation is covered by the Sediment Management function under the Harbor Shoaling category.

Harbor Navigation

This category indicates how well navigable conditions are maintained within the harbor, as opposed to navigation outside the harbor. Difficulty in maneuvering and restrictions on vessel drafts or lengths are indications of problems. When these conditions are associated with waves or currents, in lieu of sedimentation, overcrowding, or designed channel width constraints, they indicate a deficiency in this category.

Harbor Use

Harbor use may be restricted by waves, currents, or seiches within the mooring area or at support facilities (i.e., fuel docks, unloading docks, dry docks, grids, etc). Use restrictions may occur during certain wave conditions, which tend to be seasonal. For instance, frequent winter storms may lead to wave conditions inside the harbor that make the harbor unsafe for normal operations.

There are several facets to restrictions on harbor use. These are sub-categorized in the following paragraphs and in the functional rating tables. The design storm events and structure performance expectations often differ among these subcategories, even though they are all part of harbor use. Likewise, all three subcategories may not apply to all harbors.

a. Moored vessels

This subcategory indicates how well moored vessels are protected from damage by waves, currents, and seiches. Functional deficiency may be measured by the frequency and degree to which moored vessels sustain damage due to excessive wave or current energy. Also, areas of the harbor that cannot be used to their full potential may have reduced mooring density or may have been abandoned by that part of the fleet sensitive to the problems being encountered.

b. Harbor structures

This subcategory indicates how well the harbor structures are kept usable and protected from damage. The berthing facilities used to dock or provide moorings for vessels are part of this subcategory. Berthing structures include fixed or floating docks, piers, mooring piles, dolphins or buoys, anchorages, and other areas set aside to receive vessels.

Functional deficiency may exist if waves or currents are strong enough to damage or impair the use of these facilities. Some indications of excessive wave and current energy are: damage or rapid wear to floating docks, chafing and wear on guide piles and mooring systems, overstressed mooring buoys and dolphins, and cases of vessels dragging their anchors.

Also included in this subcategory are those facilities which help form the harbor and allow its use for commercial and recreational navigation. Typical are structures that provide the land-water interface such as bulkheads, seawalls, and revetments. Certain kinds of repair facilities such as dry-docks may also be included in this category and, in some cases, even the breakwaters and jetties. Indications of damage by waves or currents include direct structural damage or erosion and loss of the backfill behind bulkheads and seawalls. Toe scour (determined from a diving inspection, sidescan, or other acoustic surveys) or excessive leaning of structures may also indicate damage by currents or seiches. Direct structural damage may not be the only indication of a problem. Use restrictions may indicate that waves and currents are excessive.

c. Other facilities

Other facilities are those which are set back from the land-water interface and which are part of the commercial and recreational activity surrounding the harbor. These facilities support cargo movements, commercial fishing, cruise vessels, recreational boating, etc. They include hard stand areas, transit sheds, warehouses, terminals, ship repair facilities, offices, stores, and restaurants. The condition of their foundations and surrounding property are indications of adequate or inadequate protection.

Navigation Channel

This functional area includes all entrances and navigation channels within harbors, channels, maneuvering areas, and mooring areas. Ratings within this main function are based on how well the structure controls waves and currents to provide safe navigation during all conditions and for all vessels, as compared with design expectations or current requirements. Sediment control aspects are rated under Sediment Management. The channel is separated into two segments: the entrance, including approaches, and the channel between the harbor and entrance, if that segment is separable.

Entrance Use

This category indicates the ability of the structure to maintain a safe channel or harbor entrance by controlling waves and currents within the limits provided in the authorizing documents or by economic reality. Functional deficiencies are indicated if certain sizes or types of vessels are unable to safely pass through the entrance, or are delayed in entering. Another indication is a limit on allowable vessel draft, which can exclude vessels in either extreme of the fleet for which the harbor was designed. The impact of the ebb shoal and flood shoal on wave transformation can be a major source of difficulty and is to be rated here.

If structures are performing poorly in controlling channel depth, that portion of the problem is to be rated under Sediment Management. (See Operations and Maintenance Items in Chapter 3.) If the entrance structures do not adequately reduce waves (or limit breaking wave conditions), the smallest vessels in the fleet may find it too hazardous to move through the entrance. Where the restriction is a function of wave activity and not caused by shoaling above project depth, it is properly rated here. Displaced armor from a structure may also create channel obstructions. (The angle that the entrance makes with prevailing winds and waves can also be a factor, particularly if recreational sailing is an important activity.)

Channel

This category indicates how well the structure controls waves and currents to provide a safe, navigable channel through which vessels may operate without difficulty, delay, or damage. Indications of functional deficiency include: strong cross channel currents or crossing wave trains that may delay vessels until more favorable conditions prevail; channel obstructions from displaced armor units; and reports of vessels impacting the bottom (grounding), vessels colliding with the navigation structures, or each other.

Sediment Management

The ratings in this main function indicate how well the structure controls the depth, character, and pattern of sedimentation in the navigation channel; the depth of ebb and flood shoals in tidal entrances; and the buildup or loss of sediments on nearby shorelines. For riverine or nontidal conditions, the rating should also cover the eddy shoal development that occurs at those entrances.

Breakwaters and jetties modify the pattern of sediment distribution in the waterways that are formed in conjunction with them and on the adjoining shorelines. A structure may cause ebb and flood shoals to shift dramatically and eventually stabilize in new locations if sediment supplies are stable. How well the structure is managing the depth of the ebb and flood shoal in the navigation channel can often be deduced by observing surveys and comparing them to dredging records. Secondary effects of ebb and flood shoals such as wave steepening, cross channel currents, and erosion impacts are rated under Navigation Channel or Structure Protection.

Poor sediment management can also be discerned by unpredictable channel locations and unstable channel depths and widths. Shoreline erosion or accretion and oversteepening of shorelines are other indications of sediment management problems.

Ebb Shoal

The ebb shoal forms seaward of the structures and is a product of longshore currents and sediments interacting with the ebb flow currents including riverine contributions and sediments. Its position can affect navigation negatively by focusing waves in the channel, decreasing navigable depths, forcing the channel thalweg to migrate, and forcing ebb flows to increase wave heights. The negative effects of in-channel sedimentation are largely managed by dredging, and a measure of the impact of the ebb shoal can often be partially deduced from dredging records. Other indications of ebb shoal impacts are vessel delays due to wave steepness or wave breaking in the entrance approach channel, vessel groundings, etc. To separate the Sediment Management portion of ebb shoal impacts from the Entrance Use category, only the loss of channel depth and width that can be corrected by dredging and the shift in thalweg requiring repositioning of aids to navigation are rated in this category. Other impacts of the ebb shoal are to be rated under Entrance Use and Structure Protection.

Flood Shoal

The flood shoal forms in the waterway landward of the structure head and, similar to the ebb shoal, is normally a product of longshore sediments and flood flow transfer of those sediments into the interior channel system. Riverine sediments may also contribute to this shoal. Deposition of the flood current sediments occurs at many locations and, to a large extent, is a product of loss of transport capacity at expansions. Normally the shoal can be found in two locations: immediately inside the contraction made by stagnation points at the jetty tips, and at the points where jetties terminate and an expansion occurs at the landward end.

The shoals can have significant affect on cross channel currents, waves in the channel, etc., even though they lie outside of the navigation channel. The only items that are rated in the Sediment Management functional area are a reduction in channel dimensions that impact navigation, and a shift in channel thalweg that requires changes in aids to navigation. The relationship can normally be deduced by examining dredging records and surveys. Both the ebb and flood shoal can also be related to some structural damage as currents are shifted and erosion occurs at the toes of the structures. The toe erosion or scour aspect is to be rated under Structure Protection. Cross channel currents, crossing wave trains, oversteepened waves, etc., caused by the flood shoal are to be rated in the Channel category. Focusing of waves to the extent they disrupt harbor use is to be rated under Harbor Use.

Harbor Shoal

Sediment buildup in a harbor may be independent from the ebb and flood shoals. Density, currents, upland runoff, winds, short waves, and vessel agitation of sediments combined with very low velocity currents can all create sediment deposit in maneuvering areas and mooring areas. Where structures were placed to limit these types of shoals, a functional rating should be developed.

Shoreline Impacts

Breakwaters and jetties modify the natural pattern of sediment distribution in the surrounding area. They also affect the sediment supply, its location, and distribution on adjacent beaches. When these changes occur, the adjoining shoreline tends to adjust to the new conditions created by the structure's presence. This rating category indicates the ability of the structure to maintain adjoining shoreline profiles within acceptable limits. The structures also force large amounts of sediment to transfer to their seaward tips, so that much of the sediments associated with the ebb and flood shoals are related to shoreline impacts.

Breakwaters built primarily for shore protection should be judged on how well they succeed in stopping erosion of the protected shoreline without causing undesirable erosion on the adjoining shoreline on either side of the project. If a recreational beach is a part of the project, then some judgment must also be made about how well the sand is being retained.

Measures to minimize shoreline impact include: mechanical sediment transport systems, weir jetties with sand traps (in combination with dredging of the sand trap), shoreline-to-shoreline dredge pumps, or on-shore or near-shore disposal areas. These systems are separate from the structures, and their performance is not considered here; however, a structure's adverse effect on these systems would be rated within this category.

Structure Protection

Ratings within this main function indicate how well the structure accomplishes the following, compared with design expectations, or in some cases, present requirements:

a. Minimizes wave energy levels on adjacent structures.

b. Protects itself from erosion (scour).

c. For head reaches (and sometimes for a root section), protects the trunk from structural deterioration.

These ratings are used to help assess which structural repair actions are needed. Only item [a] is included in calculating the functional index for the structure; items [b] and [c] are usually already accounted for, in more detail, in the structural ratings.

Nearby Structures

This category indicates how well the structure protects nearby structures. With parallel jetties, one jetty may protect the inner side of the other jetty. For example, at the Umpqua River in Oregon, the south jetty protects both an inner training jetty and the inner side of the north jetty. Jetties or breakwaters may also protect structures that are within their diffraction shadow. A prime example of this is the main breakwater protecting an inner breakwater at St. Paul Harbor in Alaska. A modest loss of main breakwater length can cause structural failure of the inner breakwater.

Toe Erosion

This category indicates how well reaches control excessive removal of sediments around the structure foundation. The flow contraction around the heads of structures often creates a stagnation area and eddy near the head of the structure. When this occurs large holes form, which can undermine the foundation. Interaction between tidal currents, coastal and longshore currents, coupled with surges, can also cause scour. Periodic seasonal surveys should be adequate to determine the size of the problem and, when coupled with a soils analysis, can be used to assess the severity of the condition.

Jetties and breakwaters are also subjected to flow concentrations at various locations throughout their length. Ebb flows may be shifted to the structure due to the relationship of its geometry to the tidal prism or to the flood shoal location. Conditions exist where both geometry and flood shoal combine to intensify the flow concentrations along the jetty and to minimize sediment entering the region. Under these conditions the depth of erosion can be severe. On the shore side of structures, rip currents and gyres form that can cause unexpected erosion or, in some cases, accretion. Wave turbulence combined with semi-steady state flows can intensify erosion. Erosion effects are sometimes visible on the structure as a breach due to settlement, or as slope defects. Side-scan sonar imaging may be able to detect scour before the structure is affected.

Trunk Protection

This category mostly applies to a structure head but may also apply to root sections in some cases. It indicates how well the head (or root, if applicable) prevents unraveling of the structure's trunk.

Other Functions

In addition to the main functions described above, breakwaters and jetties often have secondary functions, which are grouped together in this category. These categories are not given numerical ratings (and are not used in defining reaches), but are reported as comments on the functional rating form.

Public Access

Comments in this category should indicate any failure of structure features to permit safe public access as intended in the project plan, or to effectively limit public access where it is not desired. These features include walkways, handrails, bicycle paths, gates, barrier fences, warning signs, lights, markers, etc.

Recreational Use

Comments in this category should indicate any failure of the structure in permitting recreational use as intended in the project plan. These activities include: boating, fishing, swimming, etc. Conditions that degrade recreational use include dangerous wave or current conditions or shoals at a harbor entrance, or for shore protection structures, failure to maintain a stable public beach.

Environmental Effects

Comments in this category cover both positive and negative environmental impacts from a structure's presence. Negative impacts include any adverse effect the structure may have on the nearby environment or failure to provide expected environmental benefits. Such effects may include reduced water circulation and flushing in the protected area, resulting in poorer water quality. The structures may also degrade the local environment by accumulating trash and debris. In northern locations, particularly on the

Great Lakes, the harbor structures could impede the passage of ice floes if a major stream or river discharges into the harbor; in severe cases, ice jam flooding could occur.

Positive impacts may include the shelter provided by a breakwater that protects wetlands from wave attack and provides opportunities for habitat enhancement. Other positive impacts include attachment of organisms (habitat), increased diversity of environment, enhancement of fishing, diving, bird watching, etc.

Aids to Navigation

Comments in this category should indicate any damage, deterioration, or displacement of aids to navigation, deficiencies in access to them for maintenance and inspection, and damage to their mooring systems.

Storm Events

Performance in each functional rating category is measured in reference to three levels of storm events. Generally, ratings should be based on structure performance during storms of the greatest intensity that have occurred during the last rating period. Using three storm levels allows ratings to be produced during intervals when only storms of less than design intensity have occurred. Storms are to include the impacts of both local and distant events (sea and swell).

Design Storm

The design storm is the largest storm (or most adverse combination of storm conditions) that the structure (or project) is intended to withstand, without allowing disruption of navigation or harbor activities, or damage to the structure or shore facilities. For systems designed for seasonal use or for interrupted use, the expected nonuse periods must be allowed for in arriving at a design storm. Design storm conditions include: wave height, direction, and period; water level; storm duration; and combinations of these factors. The design storm is usually designated by frequency of occurrence or probability of occurrence.

The design storm typically varies from one project to another, and for different activities or areas within a single project. For example, disruption of cargo handling or limitations on channel entrance use might be tolerated more frequently than disruption in the harbor area. Thus the design storms for the navigation channel, damage to harbor facilities, vessel damage, and disruption of cargo handling are, or should be, at different return intervals.

Corps guidance is that channels and harbors will be safe and efficient. Safe implies that no vessel damage should occur when vessels are moored in accordance with good practice. Efficient implies reasonable economic tradeoffs. As an example, past Corps practice has often been to design small boat harbors to limit wave heights to 1.5 feet during storms that have a 50 percent probability of occurring during the economic life of the project. In this case, for a 50-year design life, the design storm would have a return interval of 73 years. Generally, the return interval allowed for facility or vessel damage is on the order of once every 50 to 100 years.

Authorizing documents, design notes, project history, and current requirements should be used to confirm the appropriate design storms for a project. Current requirements may show a need for new authorization to improve conditions, or current economic conditions may require dimensions and storm conditions that would decrease the use from the level anticipated during authorization.

For many harbor entrances, design depths and channel orientation are indications of design intent. For example, a 10-foot channel will have breaking waves at a wave height of 8 feet. At this wave height, about 4 feet of channel depth is lost at the wave trough and waves are steep enough to cause broaching of a craft with less than 5 feet of draft. Thus, with an 8-foot wave, the channel is impassable for all vessels due to either limited depth (for larger vessels) or excessive wave steepness (for smaller vessels). At this location, an 8-foot wave height can then be tied to a storm of a certain frequency or probability, and a tolerable frequency for closing the channel can then be determined. In a similar fashion, safety in the harbor berthing area and disruption to cargo handling could be analyzed.

Intermediate Storms (2X Design Storm Frequency)

This level refers to storms (or combinations of adverse conditions) of intermediate intensity that occur on the order of twice as often as the design storm. This level is intended to represent a midway point between the maximum storm levels (design storm) and small or minor intensity storms that may occur more frequently, especially during certain periods of the year.

Low Intensity Storm Conditions

This level refers to storms (or combinations of adverse conditions) of low intensity that may occur frequently throughout the year, and includes common rain storms or periods of above normal winds. This level is the next stage above normal nonstorm conditions.

Using the Functional Rating Form

The functional rating is made using the form shown in Figure 43 (front) and Figure 44 (back). Figures 45 (front) and 46 (back) show a completed form. One form is used for each reach in a structure. Numerical ratings are entered for those functional categories that apply to the reach. When a rating indicates a functional deficiency, a corresponding comment should be provided in the Comments and Sketches block at the bottom of the form to explain the rating.

As with the structural rating form, five suggested actions are listed above the comment block. (A) **Immediate Action** means that repairs or actions are required right away to preserve structure function or public safety in an emergency. (B) **Action Soon** means functional defects should be corrected during the next budget cycle. (C) **Watch** means no repairs are required currently, but the condition may be unstable or subject to rapid change and should be monitored regularly. (D) **Defer** means that the affected area of the reach appears stable and does not appear to threaten functional integrity, even if the condition should worsen somewhat. (E) **Investigate Further** means more detailed analysis is needed to determine the degree of functional loss or the appropriate action to be taken.

Inspectors are encouraged to suggest an action for each rated function, but should follow local guidance in applying and reporting these. The suggested actions do not affect ratings or index values.

<table>
<tr><td colspan="6">FUNCTIONAL RATING FOR BREAKWATERS AND JETTIES</td></tr>
<tr><td colspan="2">FUNCTION</td><td>RATING
0-100</td><td>COMMENT
NUMBER</td><td colspan="2">PROJECT</td></tr>
<tr><td rowspan="2">HARBOR AREA</td><td>Harbor Navigation</td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Harbor Use
a. Moored Vessels
b. Harbor Structures
c. Other Facilities</td><td></td><td></td><td colspan="2">STRUCTURE</td></tr>
<tr><td rowspan="2">NAVIGATION CHANNEL</td><td>Entrance Use</td><td></td><td></td><td colspan="2" rowspan="3">REACH</td></tr>
<tr><td>Channel</td><td></td><td></td></tr>
<tr><td rowspan="4">SEDIMENT MANAGEMENT</td><td>Ebb shoal</td><td></td><td></td></tr>
<tr><td>Flood Shoal</td><td></td><td></td><td colspan="2" rowspan="3">RATER</td></tr>
<tr><td>Harbor Shoal</td><td></td><td></td></tr>
<tr><td>Shoreline impacts</td><td></td><td></td></tr>
<tr><td rowspan="3">STRUCTURE PROTECTION</td><td>Nearby Structures</td><td></td><td></td><td colspan="2" rowspan="3">DATE OF RATING</td></tr>
<tr><td>Toe Erosion</td><td></td><td></td></tr>
<tr><td>Trunk Protection</td><td></td><td></td></tr>
<tr><td rowspan="4">OTHER FUNCTIONS</td><td>Public Access</td><td></td><td></td><td colspan="2" rowspan="3">Has a structural inspection been recently completed ?
YES NO</td></tr>
<tr><td>Recreational Use</td><td></td><td></td></tr>
<tr><td>Environmental Effects</td><td></td><td></td></tr>
<tr><td>Aids to Navigation</td><td></td><td></td><td></td><td>Comment No.</td></tr>
<tr><td colspan="4">Are there functional deficiencies which are <u>not</u> related to structural defects?</td><td>YES NO</td><td></td></tr>
<tr><td colspan="4">Is there risk of further <u>major</u> loss of function within the next budget cycle?</td><td>YES NO</td><td></td></tr>
<tr><td colspan="6">SUGGESTED ACTIONS: A) Immediate B) Soon C) Watch D) Defer E) Investigate Further</td></tr>
<tr><td>COMMENT NO.</td><td>ACTION</td><td colspan="4">COMMENTS AND SKETCHES</td></tr>
<tr><td></td><td></td><td colspan="4">11/2/98</td></tr>
</table>

Figure 43. Functional rating form (front).

FUNCTIONAL RATING FOR BREAKWATERS AND JETTIES (CONTINUED)		
SUGGESTED ACTIONS: A) Immediate B) Soon C) Watch D) Defer E) Investigate Further		
COMMENT NO.	ACTION	COMMENTS AND SKETCHES
		8/6/98

Figure 44. Functional rating form (back).

<table>
<tr><td colspan="6">FUNCTIONAL RATING FOR BREAKWATERS AND JETTIES</td></tr>
<tr><td colspan="2">FUNCTION</td><td colspan="2">RATING
0-100</td><td>COMMENT
NUMBER</td><td>PROJECT
Plotkin Bay Resort Hbr</td></tr>
<tr><td rowspan="2">HARBOR AREA</td><td>Harbor Navigation</td><td colspan="2">20</td><td>8</td><td></td></tr>
<tr><td>Harbor Use
a. Moored Vessels
b. Harbor Structures
c. Other Facilities</td><td>30
35
35
35</td><td>30</td><td>9</td><td>STRUCTURE
South Jetty</td></tr>
<tr><td rowspan="2">NAVIGATION CHANNEL</td><td>Entrance Use</td><td colspan="2">100</td><td></td><td rowspan="2">REACH
3</td></tr>
<tr><td>Channel</td><td colspan="2">30</td><td>3,10</td></tr>
<tr><td rowspan="4">SEDIMENT MANAGEMENT</td><td>Ebb shoal</td><td colspan="2">85</td><td></td><td></td></tr>
<tr><td>Flood Shoal</td><td colspan="2">30</td><td></td><td rowspan="3">RATER
S. Foltz</td></tr>
<tr><td>Harbor Shoal</td><td colspan="2">85</td><td></td></tr>
<tr><td>Shoreline impacts</td><td colspan="2">75</td><td>6</td></tr>
<tr><td rowspan="3">STRUCTURE PROTECTION</td><td>Nearby Structures</td><td colspan="2">70</td><td>7</td><td rowspan="3">DATE OF RATING
11/02/98</td></tr>
<tr><td>Toe Erosion</td><td colspan="2">10</td><td>12</td></tr>
<tr><td>Trunk Protection</td><td colspan="2">-----</td><td></td></tr>
<tr><td rowspan="4">OTHER FUNCTIONS</td><td>Public Access</td><td colspan="2"></td><td>1</td><td rowspan="3">Has a structural inspection been
recently completed ?
<u>YES</u> NO</td></tr>
<tr><td>Recreational Use</td><td colspan="2"></td><td>2</td></tr>
<tr><td>Environmental Effects</td><td colspan="2"></td><td>none</td></tr>
<tr><td>Aids to Navigation</td><td colspan="2"></td><td>3</td><td>Comment No.</td></tr>
<tr><td colspan="4">Are there functional deficiencies which are <u>not</u> related to structural defects?</td><td>YES NO</td><td>4</td></tr>
<tr><td colspan="4">Is there risk of further <u>major</u> loss of function within the next budget cycle?</td><td>YES NO</td><td>5</td></tr>
</table>

<table>
<tr><td colspan="3">SUGGESTED ACTIONS: A) Immediate B) Soon C) Watch D) Defer E) Investigate Further</td></tr>
<tr><td>COMMENT NO.</td><td>ACTION</td><td>COMMENTS AND SKETCHES</td></tr>
<tr><td>1</td><td>A</td><td>Access to outer end of jetty (across this reach) is hazardous at all times.</td></tr>
<tr><td>2</td><td>B</td><td>Pedestrian access needs to be blocked and danger signs posted

11/2/98</td></tr>
</table>

Figure 45. Completed functional rating form (front).

FUNCTIONAL RATING FOR BREAKWATERS AND JETTIES (CONTINUED)

SUGGESTED ACTIONS: A) Immediate B) Soon C) Watch D) Defer E) Investigate Further

COMMENT NO.	ACTION	COMMENTS AND SKETCHES
3	A	Aids to navigation need to be shifted to identify channel location.
	E	
4		See project background information
	A	
5	A	Deterioration in function expected to increase
6	A	Assessment of design and impact of intermediate storm levels needed as structure may be lost if major breach recession occurs.
	A	
7	A	Rating based on low intensity storm experience. Further, evaluation may indicate a lower rating.
	A	Harbor navigation unsafe for small boats during low intensity storms.
8		
	E	Low intensity storms stop commercial activities and cause vessel and facility damage.
9		
	A	
		Thalweg migration caused channel shift.
10		
		Coast Guard is moving buoys periodically to indicate channel position.
11		The loss of toe protection has led to loss of wave armor which led to higher waves impacting jetty cap and loss of cap and some sub-structure cell fill of quarry-run stone. Sub-structure in now in danger of loss if impacted by minimal storm wave activity. Loss of toe protection caused by thalweg movement into the toe stone area and loss of toe blanket into channel. Dredging contractors should be advised that toe stone and armor stones are likely to be found in material to be dredged during next dredging cycle.
12		

Figure 46. Completed functional rating form (back).

The two questions above the comment block should be answered by circling Yes or No. When answering “Yes” to the first question, a corresponding comment should be made to identify the deficiency or changed conditions or requirements that support the response. A “Yes” answer to the second question also requires a comment and should correspond to a Suggested Action of (A) Immediate Action or (B) Action Soon.

Steps in the Functional Rating Process

Background/Data Collection

Obtain the information required for the functional analysis:

Items (a) through (c) of the following list establish baseline performance expectations for the project and structures:

a. Review the original intent or expectation of the design as described in the authorizing documents (or as subsequently modified).

b. Review the descriptions for the functions assigned to the different reaches.

c. Review the structure's functional performance requirements and structural requirements (as outlined in Chapter 4).

Items (d) through (h) establish evidence of existing performance deficiencies and risk of near-term functional deterioration. (Use the lists in Tables 10 through 13 as a guide on what information to look for, what observations to make, and what questions to ask):

d. Examine inspection reports, dredging records, project history, and other office records relating to project performance.

e. Review the structural ratings, SI values, and comments made during the structural inspection. Note the lower ratings and any suggestion or evidence of structural instability.

f. Examine the project site. Look for evidence of navigation difficulties or functional deficiencies (such as those listed in the descriptions of the functional categories above).

g. Gather information from vessel operators, harbor masters, the Coast Guard, Corps staff, etc. on any known navigation difficulties, facility damage, or other project deficiencies.

h. Review the environmental setting in and around the project: wave energy, water level variability, sediment transport, etc.

Analysis

Use the information obtained in the previous steps to analyze the structure's functional performance. Filling in a spreadsheet, as shown in Table 15, is recommended — one for each reach.

a. Document the performance expectations and the actual structure performance, when no structural defects have been present.

b. Estimate the minimum cross-sectional dimensions, crest elevation, and level of structural integrity needed to meet the performance requirements for the reach being examined. The center columns of Table 15 are used to first estimate the impact on structure performance if the reach were destroyed and, secondly, to record the minimum reach dimensions necessary to provide acceptable performance.

c. Determine for each reach which functional deficiencies exist and estimate their severity. Use a table (similar to Table 15, in the following rating example) to compare performance with no structural defects to performance in the present condition.

d. Determine the extent to which the structure's physical condition is responsible for functional deficiencies. (This is the criterion on which numerical ratings will be based.)

e. Determine if changed requirements, site conditions, or design inadequacies have adversely affected structure performance. (This is used in responding to the questions below the rating section.)

f. Determine if there is a significant risk of further functional deterioration before the next budget cycle can be completed. (This is used in responding to the questions below the rating section.)

Functional Rating

Determine the functional ratings and complete a functional rating form for each reach:

a. Based on the functional analysis performed, the guidance presented in the next section, and Tables 16 through 19, determine the appropriate numerical rating for each function assigned to the reach.

b. Check to ensure that each rating is made based only on a reduced performance due to structural deterioration. (As a reminder: desired structure or project modifications due to design deficiencies, major changes in usage, etc., are beyond the scope of maintenance and repair, and thus are not considered here.)

c. Provide comments on the rating form to explain the reason for choosing the ratings and select the appropriate Suggested Actions.

d. Answer the two questions above the comment block.

Determining Functional Ratings

Functional ratings are made in reference to structure performance criteria, either design intent or current requirements, as discussed in Chapter 4 and in the previous section. Design deficiencies are not rated here but should become evident in the development of spreadsheets for the project and are to be noted there. The reporting of design deficiencies should then follow current guidance and be separated from this report.

Thus, to affect the ratings, functional deficiencies must be caused by structural deterioration or, in some cases, changed requirements. In any case, situations that a structure could not reasonably correct or control should not be taken into account. In addition, ratings must be based on the condition of the structure at the time it was inspected.

Ratings are made using the rating tables that appear in the following section. A rating of 100 indicates the structure is performing as well as it would when no structural defects are present. When assigning ratings, choosing numbers in multiples of five is preferred. Ratings at the top or bottom end of a condition level may also be appropriate. The descriptions in the tables correspond to ratings at the center of the value range for each level.

For any rating category, it will be quite common that none of the condition levels lists a case exactly matching the situation found in the field. In such cases, the inspector selects the appropriate rating by narrowing the choice to the most appropriate one or two condition levels, and then selecting the final rating. The general FI scale (Table 10) should also be used to help select the most appropriate rating. The two most common situations are:

a. The choice can be narrowed to one condition level. The inspector must then determine if the most appropriate rating is near the top, bottom, or middle of the condition level. (Examining the condition levels just above and below will help in deciding.)

b. Two adjacent condition levels look possible. The inspector must determine if the rating is most appropriate near the bottom of the higher condition level or near the top of the lower level.

For conditions or unique situations not covered in the rating tables, the general FI scale should be used to determine the most appropriate rating. The following example illustrates the process for selecting FI ratings.

Example

This example illustrates the type of information and observations needed to determine functional ratings, how the ratings are selected, and using a spreadsheet similar to Table 15 to aid in the analysis.

Background. A functional evaluation is being done for reach 3 (offshore trunk) of a jetty similar to the one in Figure 9. The jetty protects the shallow draft entrance and channel of a small commercial and recreational harbor, as shown in Figure 47. The dredged channel is maintained to -15 feet LWD. Commercial vessels that use the channel are primarily fishing trawlers with the largest having a draft of 11 feet. In addition, the channel is heavily used on weekends by recreational sail and powerboats that originate from marinas within the harbor. The bulk of these pleasure craft have drafts of 6 feet or less. A few fixed-keel sailboats have drafts of up to 10 feet.

Field Observations of Structural Integrity and Functional Performance. A 300-foot breach has developed in reach 3, which was given a structural rating of 10, representing major damage. The cap has been swept into the lakeside waters and large sections of substructure core are exposed. It is easy to imagine that another major storm could devastate a much greater portion of the jetty in reach 3 and adjoining reaches. Waves overtop the jetty through the breach and spill over into the navigation channel extensively several times a year. When this happens, the wave conditions in the channel are too dangerous to navigate for most of the vessels in the harbor. In addition, sand is carried over the breakwater through the breach so that a large shoal has developed in the entrance. The shoal impinges on the channel, and groundings are probable when care is not exercised. Strong currents through the entrance have distributed the sand across broad areas of the channel, causing the channel thalweg to migrate. It should be noted that sand is available for transport across the jetty because of a large deposit on the updrift side of the project. The deposit is larger than expected during design. There has also been erosion on the downdrift side of the project, and additional sand was previously added to the north beach to prevent undermining of seawalls at one or two locations and to protect existing homes.

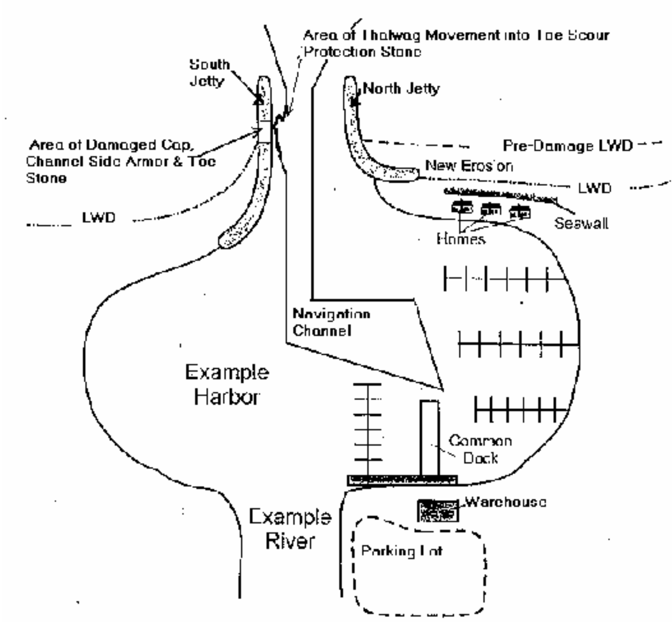


Figure 47. Example commercial and recreational harbor.

Prior to the breach, wave conditions could be severe within the entrance channel, but these conditions did not extend beyond the entrance except under unique storm events. Project history indicates that the unique events have been associated with long period swells approaching in a manner such that the crests of the swells are almost parallel to the shoreline and perpendicular to the jetty entrance. When these conditions occur, the waves have translated up the entrance channel and into the harbor. This creates a general disturbance within about 25 percent of the berths in the harbor that are the closest to the entrance channel. At the time of final project design, these areas of the harbor were identified as likely to experience disturbances during certain design conditions and moorings were excluded from the area. Despite recommendations otherwise, mooring facilities were later built and have, in fact, experienced the predicted disturbances. During these events, mooring lines quickly become chafed and occasionally break. The boats, if unattended, will then drift from their moorings or be damaged within their berths.

Wave reflection has historically been an occasional problem at one exposed bulkhead during the unique events, and "green" water and large amounts of white spray have overtopped the wall, particularly when wind conditions are right. No serious toe erosion or other problems have occurred during these conditions.

Shorter period storm waves may sometimes approach from the same direction. For small storms expected to occur every few years, there is not much difficulty except for vessels moving into the harbor through the entrance channel. The harbor area itself is fairly well protected because diffraction and refraction effects cause these waves to dissipate before they reach the inner harbor.

Since the breach in the structure, waves from storms frequently enter the channel, reflect and translate up the channel, and cause severe disturbances in the harbor. During these periods, recreational vessels cannot leave their slips, even to cruise only within the protected portion of the harbor. Vessel damage occurs, mooring lines chafe through, and docks are damaged. Commercial fishermen who might return to the harbor ahead of the storm have difficulty unloading their catch at the commercial dock and usually are hindered until conditions subside.

The exposed bulkhead area that faces the entrance channel is now subjected to heavy wave pounding on a more frequent basis. In these cases, larger amounts of green water overtop the wall and flood the area behind the bulkhead. Vehicles that normally park behind the bulkhead must be moved to avoid damage, and a material storage area has to be emptied.

Functional Rating. Functional ratings are performed separately for the harbor area itself, the navigation channel, sediment management, for self-protection of the jetty, and for other functions. The resulting functional ratings appear in the example completed functional rating form, shown as Figures 48 and 49.

FUNCTIONAL RATING FOR BREAKWATERS AND JETTIES

FUNCTION		RATING 0-100		COMMENT NUMBER
HARBOR AREA	Harbor Navigation	20		8
	Harbor Use	80	30	9
	a. Moored Vessels	55		
	b. Harbor Structures	35		
	c. Other Facilities	35		
NAVIGATION CHANNEL	Entrance Use	100		
	Channel	80		3, 10
SEDIMENT MANAGEMENT	Ebb shoal	85		
	Flood Shoal	30		
	Harbor Shoal	85		
	Shoreline Impacts	75		6
STRUCTURE PROTECTION	Nearby Structures	70		7
	Toe Erosion	90		
	Trunk Protection	—		
OTHER FUNCTIONS	Public Access			1
	Recreational Use			2
	Environmental Effects			None
	Aids to Navigation			3

PROJECT	Example Harbor
STRUCTURE	South Jetty
REACH	3
RATER	J. O.
DATE OF RATING	9/8/95
Has a structural inspection been recently completed?	(YES) NO

			Comment No.
Are there functional deficiencies which are not related to structural defects?	(YES)	NO	4
Is there risk of further major loss of function within the next budget cycle?	(YES)	NO	5

SUGGESTED ACTIONS: A) Immediate B) Soon C) Watch D) Defer. E) Investigate Further

COMMENT NO.	ACTION	COMMENTS AND SKETCHES
1	A	Access to outer end of jetty (across this reach) is hazardous at all tide levels.
2	A	Pedestrian access needs to be blocked and danger signs posted.

4/22/96

Figure 48. Example completed FI form (front).

FUNCTIONAL RATING FOR BREAKWATERS AND JETTIES (CONTINUED)		
SUGGESTED ACTIONS: A) Immediate B) Soon C) Watch D) Defer E) Investigate Further		
COMMENT NO.	ACTION	COMMENTS AND SKETCHES
3	A	Aids to navigation need to be shifted to identify channel location.
4	E	See project backround information
5	A	Deterioration in function expected to increase.
6	A	Assessment of design and impact of intermediate storm levels needed as structure may be lost if major breach recession occurs.
7	A	Rating based on low intensity storm experience. Further, evaluation may indicate a lower rating.
8	A	Harbor navigation unsafe for small boats during low intensity storms
9	A	Low intensity storms stop commercial activities and cause vessel and facility damage.
10	A	Thalweg migration causes channel shift.
11	E	Coast Guard is moving buoys periodically to indicate channel position.
		4/22/96

Figure 49. Example completed FI form (back).

The ratings were determined after completing a Spreadsheet for Functional Evaluation, shown as Table 15. This spreadsheet is used initially to guide the choice of ratings from the functional rating tables (Tables 16 through 19), and then again, if the initial rating process indicates the need for further analysis in any of the rating categories.

The spreadsheet summarizes structural performance under three conditions: when there are no structural defects present (in a like new condition), if the reach were substantially destroyed, and under current conditions when structural defects are present. The first column lists the functional rating categories. The left-hand section (Without Structural

Defect) summarizes structure performance as intended when designed and then as experienced when built. This section also includes a column (Non Str. Def.) to indicate if there are functional deficiencies that are not related to structural deterioration.

The center section (If Reach Were Destroyed), not used in this example, is intended to aid in evaluating the With Structural Defect case and for determining reach functions when the system is first implemented. It can also aid in cross checking for correct reach functional assignments and in determining (in the column to the right) the minimum structure dimensions needed to provide satisfactory functional performance.

The right-hand section (With Structural Defect) summarizes structural performance as presently experienced and, as needed, when recent changes in physical condition have occurred and analysis is required to estimate current performance. The column titled Analyzed Storm Disruption Period is not used in the initial analysis but is reserved for times when additional analysis is suggested. If suggested actions are undertaken, the performance effects are entered in this column, and a revised rating is then determined for that functional category.

The right-hand column is used to show the increase in frequency of disruptions compared to the performance of the structure when in excellent condition. This entry assists the rater in locating the appropriate rating in the functional rating tables (Tables 16–19). The disruption frequency increase is based on the Analyzed Storm Disruption Period whenever this additional analysis is done for a functional category.

If the numbers shown in the last column indicate >>2, disruptions are said to occur even in low intensity storms. If the disruption frequency is about 2, then intermediate storm conditions must be present to cause disruption. A 0 or 1 entry would indicate that design storm conditions are required to cause disruption.

Table 15 shows no problems under Without Structural Defect conditions, except when long period swells are approaching directly in line with the entrance channel. However, damage under these conditions was anticipated during design and should not affect the rating. Jetties were not intended to offer complete protection when waves approach in line with the opening between the structures. The other project defect under Shoreline Impacts has been remedied by a project modification made in 1989. In all cases, functional defects not associated with structural defects are not to be considered in the ratings.

To determine proper ratings, it is necessary to consider existing conditions when structural deterioration is present. Since actual experience of the impact of the structural defects is often limited, it may be necessary to expand the database through analysis estimating the probable effects in cases where structure performance in present condition is not well known. If estimated impacts are used, the If Reach Were Destroyed section must be filled in before judgments on these impacts are made. The example uses only experienced impacts, as should be the case for all projects during the first iteration of the rating. The need for further analysis is a local decision and should be based on economic, environmental, safety, and other factors.

In the example, the data from Table 15 suggest ratings from 10 to 54 for Harbor Area categories (Table 16). Harbor Navigation is curtailed to a large extent and receives a rating of 20 due to virtual cessation of use by pleasure craft during low intensity storm conditions. (Table 17 shows a Disruption Frequency Increase of much greater than 2.) In the Harbor Use category and its three subcategories, several evaluations must be made. In the general paragraph describing harbor use, it is noted that cargo handling is hindered during storms of 2X the design storm frequency, which would put the rating between 25 and 39. A value of 30 is assigned. Moored vessels are suffering damage during low intensity storm events, but curtailment of operation is not yet being experienced. This would suggest a rating between 25 and 39 (say 35). Some evaluation of the expected damage during a design storm and intermediate level storm is appropriate as those conditions could control the rating. This is also true for the remaining categories under Harbor Use. Harbor structures are being damaged but the damage is moderate. This places the Harbor Structure subcategory in the 25 to 39 range and 35 is chosen. Other facilities are being damaged to a moderate degree and this category is also given a rating of 35. As the lowest rating found under the Harbor Use category is 30, the overall rating for Harbor Use is 30.

Under Navigation Channel, Entrance Use has not been affected and is given a rating of 100 from Table 17. The channel inside the entrance has certainly been affected by waves, resulting in two to three closures per year. Even though these closures exceed twice the frequency of the design storm, they are not frequent enough to be considered as low intensity storm events. Therefore, the intermediate storm level is appropriate, and this column (in Table 17) is used to evaluate the Channel rating category. Delays and nonuse periods appear best described by the 25 to 39 range. The lower end of this range is used and the Channel category is rated at 30.

Sediment Management (Table 18) has been compromised, but only for the Flood Shoal. Ratings for Ebb Shoal and Harbor Shoal remain high and are given an 85. From the description of the project, updrift shoreline impacts should be significant during major and intermediate storm levels, but no impact of consequence is evident at this time other than minor shore recession as material is taken out of storage and deposited in the navigation channel. This suggests a rating for Shoreline Impacts in the 70 to 84 range, and a 75 is chosen. A note is added to the evaluation indicating immediate need to evaluate higher intensity storms. The rating should be modified if the evaluations indicate that a problem will occur with higher level storms. The Flood Shoal rating falls in the 25 to 39 range. A rating of 30 is given, as the shoaling requires significant effort to keep track of the migrating thalweg and significant effort by navigators to avoid vessel damage.

Under Structure Protection (Table 19), the evidence of toe erosion is significant and has led to the loss of channel side supplemental wave armor and the complete loss of the super-structure. Consequence Toe Erosion is rated at 15. Protection of nearby harbor structures may have been seriously compromised. The rating of 70 for Nearby Structures is based on the observed low intensity storm experience, and it is noted that the impacts of more severe storms should be evaluated. (The final rating for Nearby Structures could be as low as 20 after these evaluations are made.)

Although Other Functions are not given numerical ratings, these items should be given considerable thought and attention as they concern public safety and environmental effects of the project. As noted in the comments section, immediate action to alleviate public hazard may be needed.

Rating Tables

Tables 16 through 19 on the following pages are used to select the appropriate functional ratings. The descriptions in the tables correspond to ratings at the center of the value range for each level. Ratings should be selected with respect to the worst storm or wave/current/wind conditions experienced at the project.

Table 15. Example functional evaluation spreadsheet.

SPREADSHEET FOR FUNCTIONAL EVALUATION	Structure/Reach: Example Jetty - Reach 3						Date: 3/26/96 Evaluator: J. O.		
	WITHOUT STRUCTURAL DEFECT			IF REACH WERE DESTROYED		ESTIMATED DIMENSIONS WHEN STRUCTURE FUNCTION IS DISRUPTED	WITH STRUCTURAL DEFECT		
FUNCTION	EXPECTED DESIGN STORM DISRUPTION PERIOD	REALIZED STORM DISRUPTION PERIOD	NON STR. DEF.*	EXPECTED DESIGN STORM DISRUPTION PERIOD	DISRUPTION FREQUENCY INCREASE	ELEVATION, WIDTH, OR OTHER DIMENSIONS	OBSERVED STORM DISRUPTION PERIOD OR CONDITION	ANALYZED STORM DISRUPTION PERIOD	DISRUPTION FREQUENCY INCREASE
HARBOR AREA									
Harbor Navigation	70-year event	70 year event	No				2 to 3 per year	Analysis suggested	>>2
Harbor Use	1 per year for cargo unloading	1 per year for cargo unloading	No				2 to 3 per year for cargo unloading		2
a. Moored Vessels	70-year event	70 year event	No				2 to 3 per year	Analysis suggested	>>2
b. Harbor Structures	70-year event except at harbor bulkhead where wave reflection problems were anticipated on a 1 to 3 year basis	70 year event except at harbor bulkhead where wave reflection occur 1 to 3 times per year	No				2 to 3 per year	Analysis suggested	>>2
*Are There Functional Deficiencies That Are Not Related To Structural Defects?									

[1] Ratings to be based on worst conditions found in the three levels of storms.

SPREADSHEET FOR FUNCTIONAL EVALUATION				Structure/Reach: Example Jetty - Reach 3			Date: 3/26/96	Evaluator: J. O.	
	WITHOUT STRUCTURAL DEFECT			**IF REACH WERE DESTROYED**		**ESTIMATED DIMENSIONS WHEN STRUCTURE FUNCTION IS DISRUPTED**	**WITH STRUCTURAL DEFECT**		
FUNCTION	EXPECTED DESIGN STORM DISRUPTION PERIOD	REALIZED STORM DISRUPTION PERIOD	NON STR. DEF.*	EXPECTED DESIGN STORM DISRUPTION PERIOD	DISRUPTION FREQUENCY INCREASE	ELEVATION, WIDTH, OR OTHER DIMENSIONS	OBSERVED STORM DISRUPTION PERIOD OR CONDITION	ANALYZED STORM DISRUPTION PERIOD	DISRUPTION FREQUENCY INCREASE
c. Other Facilities	10-year event except where wave over-splash was anticipated on a 1 to 3 year basis	10-year event except where wave oversplash was anticipated on a 1 to 3 year basis	No				2 to 3 times per year	Analysis suggested	>>2
NAVIGATION CHANNEL									
Entrance Use	5 times per year	5 times per year	No				5 times per year		0
Channel	1 per year	1 per year	No				3 to 4 per year		>2
SEDIMENT MANAGEMENT									
Ebb Shoal	Annual dredging cycle	Annual dredging cycle	No				Annual dredging cycle		0
Flood Shoal	Annual dredging cycle	Annual dredging cycle	No				Dredging cycle must be modified or navigation aids moved on a frequent basis to maintain safe navigation		Severe change
Harbor Shoal	10-year cycle	10 year cycle	No				10-year cycle anticipated		No observed change

[1] Ratings to be based on worst conditions found in the three levels of storms.

SPREADSHEET FOR FUNCTIONAL EVALUATION	Structure/Reach: Example Jetty - Reach 3				Date: 3/26/96		Evaluator: J. O.		
	WITHOUT STRUCTURAL DEFECT			**IF REACH WERE DESTROYED**		**ESTIMATED DIMENSIONS WHEN STRUCTURE FUNCTION IS DISRUPTED**	**WITH STRUCTURAL DEFECT**		
FUNCTION	EXPECTED DESIGN STORM DISRUPTION PERIOD	REALIZED STORM DISRUPTION PERIOD	NON STR. DEF.*	EXPECTED DESIGN STORM DISRUPTION PERIOD	DISRUPTION FREQUENCY INCREASE	ELEVATION, WIDTH, OR OTHER DIMENSIONS	OBSERVED STORM DISRUPTION PERIOD OR CONDITION	ANALYZED STORM DISRUPTION PERIOD	DISRUPTION FREQUENCY INCREASE
Shoreline Impacts	50-year project life	Project modified for beach nourishment at 5-year interval in 1989	No				50-year project life with beach nourishment as undertaken in 1989		No change
STRUCTURE PROTECTION									
Nearby Structures	Minor damage in project life	Minor	No				Significant change in the level of protection	Analysis suggested	Significant change in frequency of structural stress
Toe Erosion	Minor	Minor	No				Minor		No change
Trunk Protection									
OTHER FUNCTIONS									
Public Access	2 per year	2 per year	No				Continuous		>>>2
Recreational Use	2 per year	2 per year	No				Continuous		>>>2
Environmental Effect	None	None	No				None		0
Aids To Navigation	None	None	No				None		0

[1] Ratings to be based on worst conditions found in the three levels of storms.

Table 16. Rating Guidance For: HARBOR AREA

RATING*	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2x Design Storm Frequency	LOW INTENSITY STORM CONDITIONS
		MINOR OR NO FUNCTIONAL LOSS		
85 to 100	HARBOR NAVIGATION	Recreational boats and other vessels can be maneuvered without interruption in the protected part of the harbor. Vessels can enter of leave the harbor immediately when outside conditions warrant.	Recreational boats and other vessels can be maneuvered without interruption in the protected part of the harbor. Vessels can enter or leave the harbor immediately when outside conditions warrant.	No difficulties or impacts for navigation.
	HARBOR USE	Cargo loading operations, and other maritime activities can continue without interruption.	Cargo loading operations and other maritime activities can continue without interruption.	Operations within the harbor occur at optimum design levels at all locations.
	a. Moored Vessels	Vessels at moorings, at berths, or within slips experience no difficulty.	Vessels at moorings, at berths, or within slips experience no difficulty.	There are no problems at mooting, berths, or within slips.
	b. Harbor Structures	The harbor structures and docks can remain fully occupied without jeopardizing vessels.	The harbor structures and docks can remain fully open with no damages to structures or vessels.	The harbor structures and docks are in optimum condition and occupancy is not limited.
		No erosion, toe scour, wave overtopping, or other problems.	No erosion, toe scour, wave overtopping, or other problems.	No erosion, toe scour, wave overtopping, or other problems.
	c. Other Facilities	No erosion or flood damages to facilities within the harbor.	No erosion or flood damages to facilities within the harbor.	No erosion or flood damages to facilities in the harbor.
70 to 84	HARBOR NAVIGATION	Recreational boats, and other vessels can be maneuvered without interruption within the protected portion of the harbor. Minor problems may exist at a few spots. Nearly all vessels can enter or leave the harbor immediately when outside conditions warrant, although the deepest draft vessels may have to exercise some caution in a few isolated locations. Waves or currents may cause difficult maneuvering conditions in one or two places within the harbor.	Recreational boats and other vessels can be maneuvered without interruption within the protected portion of the harbor. Vessels can enter or leave the harbor immediately when outside conditions warrant. There are no limitations on vessel draft throughout the harbor and there are no maneuvering difficulties that could be attributable to wave or current conditions.	Navigation within the harbor is close to design levels at all locations. No difficulties, due to waves or currents are generally evident. Nearly everyone interviewed about local conditions would praise the harbor.

1 Ratings to be based on worst conditions found in the three levels of storms.

RATING*	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2x Design Storm Frequency	LOW INTENSITY STORM CONDITIONS
		MINOR OR NO FUNCTIONAL LOSS		
	HARBOR USE	Cargo loading operations and other maritime activities can continue without interruption within the protected portion of the harbor. Minor problems may exist at a few spots.	Cargo loading operations and other maritime activities can continue without interruption within the protected portion the harbor.	Operations within the harbor are close to design levels at all locations during normal conditions. No difficulties, damages, or impacts due to waves or currents are generally evident. Nearly everyone interviewed about local conditions would praise the harbor.
	a. Moored Vessels	A few vessels may experience minor damages while in the harbor. An occasional vessel may drag anchor.	Generally, there will be no damages to moored vessels within the harbor.	Moored vessels in the harbor have no problems and would not suffer damages.
	b. Harbor Structures	Moorings, berths, slips and other facilities within the harbor can remain fully occupied without jeopardizing structures. In a few cases, some minor damages to docks or mooring systems may occur. No erosion, toe scour, wave overtopping, with the exception of minor amounts at scattered locations.	No erosion, toe scour, wave overtopping, or other problems.	No erosion, toe scour, wave overtopping, or other problems.
	c. Other Facilities	No erosion or flood damages to facilities within the harbor, except minor problems at scattered locations.	No erosion or flood damages to facilities within the harbor.	No erosion or flood damages to facilities within the harbor.

[1] Ratings to be based on worst conditions found in the three levels of storms.

RATING*	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X Design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MODERATE FUNCTIONAL LOSS		
55 to 69	HARBOR NAVIGATION	The smaller boats in the recreational fleet would not leave their slips in such conditions. Nearly all vessels can enter or leave the harbor immediately when outside conditions warrant although many vessels may have to exercise caution in a few isolated locations. Waves or currents may cause difficult maneuvering conditions in one or two places within the harbor.	Recreational boats can continue without interruption. Nearly all vessels can enter or leave the harbor immediately when outside conditions warrant, although the deepest draft vessels may have to exercise some caution in a few isolated locations. Waves or currents may cause difficult maneuvering conditions in one or two places within the harbor.	Vessels can enter or leave the harbor freely. There are no limitations on vessel draft throughout the harbor and there are no maneuvering difficulties that could be attributable to wave or current conditions. Recreational boating can continue without interruption.
	HARBOR USE	Generally, there are only minor damages within the harbor. In one or two isolated locations, more damage may occur. Cargo loading operations can largely continue without interruption within the protected portion of the harbor.	Generally, there are no damages within the harbor, except in one or two isolated locations. Cargo loading operations, other maritime activities can continue without interruption within the protected portion of the harbor, although minor problems may exist at a few spots.	There are no damages within the harbor. Cargo loading operations and other maritime activities operate daily without interruption within the protected portion of the harbor.
	a. Moored Vessels	Some berths may have to curtail operations because of excessive vessel movements or difficulties in remaining at the mooring. Many vessels may suffer minor or incidental damage. A few vessels may have more damage. No vessel would be expected to have severe damage.	A few vessels may suffer minor damages. The majority of vessels would be unscathed.	No damages to moored vessels would be expected.
	b. Harbor Structures	Moorings, berths and slips within the harbor can remain fully occupied with only minor damages during major storms. In a few cases, more than minor damages to docks or mooring systems may occur. An occasional vessel may drag anchor. Minor erosion, toe scour, wave overtopping, or other problems throughout the harbor. Problems can be more important in localized areas.	The mooring area can remain fully open with only minor damages occurring occasionally to moorings or vessels. No erosion, toe scour, wave overtopping, or other problems, although localized minor problems may exist.	The mooring areas or berths would not be expected to suffer damages and occupancy is not limited by wave or current conditions. No erosion, toe scour, wave overtopping, or other problems.

[1] Ratings to be based on worst conditions found in the three levels of storms.

RATING*	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X Design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MODERATE FUNCTIONAL LOSS		
	c. Other Facilities	Minor erosion or flood damages within the harbor. Damages can be more important in localized locations.	No erosion or flood damages to facilities within the harbor. Minor localized damages could occur in a few areas.	No erosion or flood damages to facilities within the harbor.
40 to 54	HARBOR NAVIGATION	Most boats in the recreational fleet would avoid going out in such conditions. Maneuvering conditions are difficult in number of places within the harbor.	The smallest boats in the recreational fleet would not leave their slips in such conditions. Maneuvering conditions may be difficult in one or two places within the harbor.	Vessels can generally enter or leave the harbor freely. There are some limitations on vessel draft within the harbor and there are a few places where maneuvering is difficult.
	HARBOR USE	Generally, some damage occurs throughout the harbor. In several locations, moderate damage may occur. Cargo loading operations can continue in most berths but are somewhat hindered.	Generally there are only minor damages within the harbor. In one or two locations more extensive damage may occur. Cargo loading operations can continue without interruption in most instances.	There are few damages within the harbor. Cargo loading operations and other maritime activities generally operate without interruption. There are however a few locations where operations are often limited. A few recreational boat slips may be unusable because of wave action.
	a. Moored Vessels	Many berths may have to curtail operations because of excessive vessel movement. Some vessels may experience moderate levels of damage while at moorings or within berths. Large numbers of recreational craft could suffer significant damages.	Some berths may have to curtail operations because of excessive vessel movements or difficulty in remaining at the mooring. A few vessels may suffer minor damages. Some recreational craft could suffer moderate damages.	Vessels within the harbor could suffer minor damage. The majority of damage would be to smaller boats. Incorrectly moored recreational boats would be the most susceptible to damage.
	b. Harbor Structures	Mooring, berths and slips can remain fully occupied with some damage. Moderate damages to docks or mooring systems may occur in a few cases. An occasional vessel may drag its anchor or a mooring line may part. Some erosion, toe scour, wave overtopping, or other problems that can threaten structural stability of bulkheads, revetments, wharves and other structures may occur in a few locations.	Minor damage to mooring systems within the harbor should be expected. In some cases damages could be more than minor. Minor erosion, toe scour, wave overtopping or other problems can occur at a few locations.	The moorings systems may suffer minor damages at times in a few isolated cases. No erosion, toe scour, wave overtopping or other problems except for minor problems in isolated locations.

[1] Ratings to be based on worst conditions found in the three levels of storms.

RATING*	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X Design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MODERATE FUNCTIONAL LOSS		
	c. Other Facilities	Some erosion or flood damage to facilities including moderate damages in some areas.	Minor erosion or flood damage to facilities, which can be moderate at a few locations.	No erosion or flood damage to facilities within the harbor with the exception of minor problems at a few locations.
		MAJOR FUNCTIONAL LOSS		
25 to 39	HARBOR NAVIGATION	Difficult maneuvering conditions prevail throughout the harbor.	Most boats in the recreational fleet would avoid going out in such conditions. Difficult maneuvering conditions are common in a number of places within the harbor.	Vessels must generally exercise care when entering or leaving the harbor. There are limitations on vessel draft and many places where maneuvering difficulties occur.
	HARBOR USE	Generally, moderate damage occurs throughout the harbor. In several locations, damage is significant. Cargo loading operations can continue in some berths, but are significantly hindered.	Generally, some damage occurs throughout the harbor. In several locations, moderate damage may occur. Cargo loading operations can continue in most berths, but are somewhat hindered.	Minor damage often occurs within the harbor. Cargo loading operations and other maritime activities can usually operate daily without interruption. In a few places wave action often limits operations. Conditions are normally poor for recreational vessels and many slips cannot be leased. Damage to mooring lines and docks is common and persistent.
	a. Moored Vessels	Most berths have to curtail operations because of excessive vessel movements or difficulties in remaining at the mooring. Most recreational boats have problems at the slips. Some may be lost and many boats will suffer significant damage.	Many berths may have to curtail operations because of excessive vessel movements or difficulties in remaining at the mooring. Overall, a large number of vessels, particularly recreational craft, suffer moderate damage. In a few cases, this damage is significant.	Vessels within the harbor suffered only minor to moderate damage. The majority of damage is to smaller boats, particularly recreational vessels whose lines are not closely tended.

[1] Ratings to be based on worst conditions found in the three levels of storms.

RATING*	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X Design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MODERATE FUNCTIONAL LOSS		
	b. Harbor Structures	Moorings, berths and slips within the harbor can remain fully occupied, but with moderate damage. In a few cases, significant damage to docks or mooring systems may occur. Some vessels may drag their anchors, mooring buoys may be displaced, and parted mooring lines may be common. Moderate erosion, toe scour, wave overtopping, or other problems occur, which can be significant in places.	Moderate damage to mooring systems within the harbor is common. A few vessels may drag their anchors and there may be occasional parting of mooring lines or displacement of mooring buoys. Some erosion, toe scour, wave overtopping, or other problems occur, which can, in a few locations, threaten structural stability of bulkheads, revetments, wharves and other structures.	The mooring systems may suffer minor damages. It would be unusual, however, for a vessel to drag anchor, a mooring line to part, or similar incidents to occur. Minor erosion toe scour, wave overtopping, or other problems, which can, in a few locations, threaten structural stability of bulkheads, revetments, wharves and other structures.
	c. Other Facilities	Moderate erosion or flood damage occurs to facilities within the harbor, which can be significant in places.	There is some erosion or flood damage to facilities within the harbor. In a few locations, the level of damage can be moderate.	Minor erosion or flood damage occurs to facilities within the harbor. In a few locations, moderate levels of damage may occur.
10 to 24	HARBOR NAVIGATION	Maneuvering conditions are hazardous throughout the harbor.	Maneuvering conditions are difficult throughout the harbor.	Vessels must always exercise care when entering or leaving the harbor. There are significant limitations on vessel draft and maneuvering difficulties prevail.
	HARBOR USE	Generally, significant damage occurs throughout the harbor. In several locations, damage is severe. Cargo loading operations cease because of excessive vessel movements or difficulties in remaining at the mooring. Any recreational boats within their slips would be in extreme jeopardy. Most or nearly all would be lost as well as the docks.	Generally, significant damage would occur throughout the harbor. Cargo loading operations cease with the possible exception of one or two berths. Most berths have to curtail operations because of excessive vessel movements or difficulties in remaining at the mooring. Most recreational boats have problems at their slips. Some will be lost and many boats and docks will suffer significant damage.	Moderate damage often occurs within the harbor. Cargo loading operations and other maritime activities must usually be timed to allow for favorable conditions. Most berths are normally vacant. Permanently occupied recreational ships are out of the question in nearly all cases. Docks are in poor condition.
	a. Moored Vessels	Nearly all vessels within the harbor suffer significant to major damage and there would be a number of total losses. Smaller craft would be particularly hard hit.	Most vessels within the harbor suffer significant damage, and there would be occasional total losses of smaller vessels.	Damage to vessels within the harbor is common. Damage is so severe that few, if any, small recreational boats use the harbor.
	b. Harbor Structures	Moorings, berths and slips within the harbor suffer significant damage. In a few cases,	Significant damage to mooring systems within the harbor occurs. Vessels dragging anchors,	The mooring systems may suffer moderate damage. It would be common for a

[1] Ratings to be based on worst conditions found in the three levels of storms.

RATING*	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X Design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MODERATE FUNCTIONAL LOSS		
		major damage or complete losses to docks or mooring systems occur. Vessels dragging anchors, displacement of mooring buoys and parted mooring lines are a widespread problem.	displacement of mooring buoys, and parted mooring lines are a common problem. Significant erosion, toe scour, wave overtopping, or other problems occur, which can, in a few locations, threaten the structural stability of bulkheads, revetments, wharves and other structures. Structural failures can be expected in a few locations.	vessel to drag anchor, a mooring line to part, or other similar incidents to occur. Moderate erosion, toe scour, wave overtopping, or other problems occur, which can, in a few locations, threaten the structural stability of bulkheads, revetments, wharves and other structures. Structural failures can be expected in a few locations.
	c. Other Facilities	Significant erosion or flood damage occurs to facilities within the harbor. In a few locations, the damage is severe and total losses to some facilities may occur.	Significant erosion or flood damage occurs to facilities within the harbor.	Moderate erosion or flood damage occurs to facilities within the harbor. Significantly greater damage may occur in a few locations.
0 to 9	HARBOR NAVIGATION	Navigation extremely hazardous.	Navigation is generally hazardous.	Navigation is possible at some risk.
	HARBOR USE	No prudent mariner would remain in this harbor. Massive damage to vessels and facilities would be expected and losses would be catastrophic.	Remaining in or using this harbor would be hazardous. Virtually no essential activities could occur and severe damage would be expected.	This is a minimal harbor that supports few activities, and those inadequately. From a functional viewpoint, it is barely superior to no harbor at all.
	a. Moored Vessels	Damage or losses to moored vessels would be catastrophic.	Damage or losses to moored vessels would be severe. Many vessels would be lost.	Any boat that uses this harbor would be subject to damage whenever wave activity picks up.
	b. Harbor Structures	Damage to mooring systems would be heavy. Total destruction of various elements would be expected. Severe erosion, toe scour, wave overtopping, or other problems occur in the harbor. Structural failures can be expected in many locations throughout the harbor.	Damage to mooring systems would be heavy. Total destruction of various elements would be expected. Severe erosion, toe scour, wave overtopping, or other problems occur in the harbor. Structural failures can be expected in many locations throughout the harbor.	Mooring systems are in poor condition. Fendering systems, mooring dolphins, lines, buoys, and other elements are distressed and heavily worn due to excessive working hand movements of vessels when secured. Persistent erosion, toe scour, wave overtopping, or other problems occur in the harbor. Structural failures in locations throughout the harbor are not uncom-

[1] Ratings to be based on worst conditions found in the three levels of storms.

RATING*	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X Design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MODERATE FUNCTIONAL LOSS		
				mon.
	c. Other Facilities	Severe erosion or flood damage occurs to facilities within the harbor. Destruction of some facilities may be expected.	Severe erosion or flood damage occurs to facilities within the harbor. Destruction of some facilities may be expected.	Persistent erosion or flood damage to facilities occurs within the harbor. Many locations throughout the harbor can no longer support these facilities because of the threat of damage.

[1] Ratings to be based on worst conditions found in the three levels of storms.

Table 17. Rating Guidance For: NAVIGATION CHANNEL

RATING*	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X Design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MINOR OR NO FUNCTIONAL LOSS		
85 to 100	ENTRANCE USE	There are no delays. The largest and smallest vessels may transit without broaching or touching bottom. Vessels experience no difficulties in the entrance.	There are no delays. Vessels experience no difficulty in the entrance.	There are no delays. Vessels experience no difficulty in the entrance.
	CHANNEL	There are no delays, in the channel, within the shelter of the breakwaters or jetties. The largest and smallest vessels using the harbor are not limited by insufficient depth or severe wave conditions.	There are no delays in the channel within the shelter of the breakwater or jetties. The largest and smallest vessels using the harbor are not limited by either insufficient depth or severe wave conditions.	There are no delays in the channel within the shelter of the breakwaters or jetties. Vessel operations are not limited by either depths or hazardous wave conditions.
70 to 84	ENTRANCE USE	Vessels generally have no difficulty in the entrance when seeking shelter in the harbor.	Vessels normally experience no difficulty in the entrance.	Vessels experience no difficulty in the entrance.
	CHANNEL	There are generally no vessel delays in the channel within the shelter of the breakwater or jetties. Small vessels may have some problems with wave conditions within exposed parts of the harbor.	There are no vessel delays in the channel within the shelter of the breakwater or jetties. The largest and smallest vessels using the harbor are not limited by either insufficient depth or severe wave conditions with only a few exceptions in unusual circumstances.	There are no vessel delays in the channel within the shelter of the breakwater or jetties.

[1] Ratings to be based on worst conditions found in the three levels of storms.

RATING*	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MODERATE FUNCTIONAL LOSS		
55 to 69	ENTRANCE USE	Vessels generally have little difficulty in the entrance when seeking shelter.	Vessels generally have no difficulty in the entrance when seeking shelter.	Vessels experience no difficulties in the entrance.
	CHANNEL	There are generally few vessel delays in the channel within the shelter of the break-waters or jetties, except in a few exposed locations. Some vessels using the harbor do not have enough water under the keel to go safely. Small vessels have some prob-lems with conditions at exposed locations.	There are generally no vessel delays in the channel within the shelter of the breakwater or jetties, except at ex-posed locations.	There are no vessel delays in the channel within the shelter of the break-waters or jetties. No vessels using the harbor are limited by either insufficient depth or by severe wave conditions.
40 to 54	ENTRANCE USE	Vessels generally have some difficulty in the entrance when seeking shelter. Vessel entrance may be delayed until flood tide.	Vessels generally have no difficulty in the entrance when seeking shelter.	Vessels have little or difficulty in the entrance.
	CHANNEL	There are vessel delays, in the channel, within the shelter of the breakwaters or jetties. In a few locations the delays can be significant for larger vessels that do not have enough water under the keel to pro-ceed safely. Small vessels have problems with wave conditions at a number of loca-tions. In a few exposed locations condi-tions may be too hazardous for small ves-sels to safely venture.	There are some vessel delays in the channel within the shelter of the break-waters or jetties. A few vessels that would normally use the harbor are lim-ited by either insufficient depth or se-vere wave conditions.	Vessels experience little or no difficulty in the channel.

[1] Ratings to be based on worst conditions found in the three levels of storms.

RATING*	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X Design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MAJOR FUNCTIONAL LOSS		
25 to 39	ENTRANCE USE	Vessels often have difficulty in the entrance when seeking shelter in the harbor. Crossing during ebb tide is seldom a possibility.	Vessels generally have some difficulty in the entrance while seeking shelter. Entry may be delayed until flood tide.	Vessels generally have no difficulty in the entrance when seeking shelter.
	CHANNEL	There are vessel delays in the channel within the protected areas of breakwater and jetties that may continue for a considerable period before and after the peak of the storm. In several locations in the harbor the delays can be significant, especially for larger vessels. Larger vessel may not have enough water under the keel to proceed safely. Small vessels have problems with wave conditions within the harbor and channel before, during, and after storm peaks. In many locations conditions may be too hazardous for small vessels to safely venture.	There are vessel delays in the channel within the shelter of the breakwater or jetties leading up to, during, and after storm peaks. Numerous vessels using the harbor may not have enough water under the keel to proceed safely during the storm. Small vessels generally have problems with wave conditions within the shelter of the harbor.	There are occasional vessel delays. A few large vessels using the harbor may have to wait for favorable tide conditions before proceeding. Wave conditions may limit use of exposed portions of the channel by small craft on some days.
10 to 24	ENTRANCE USE	Vessels generally seek shelter in other harbors. Entrance is hazardous even during flood tide. Ebb shoal may be focusing waves. Flood shoal may be focusing currents.	Vessels often have difficulty in the entrance when seeking shelter. Crossing during ebb tide is seldom a possibility. Ebb shoal may be focusing waves. Flood shoal may be focusing currents.	Vessels generally have some difficulty in the channel while seeking shelter. Entrance must often be delayed until flood tide.
	CHANNEL	The channel is hazardous for all vessels for a long time before and after the peak of the storm. Throughout the harbor there are normally significant delays after the passage of the storms before it is again safe to enter or leave. Many vessels have problems with wave conditions in the harbor and channels. In most locations the wave conditions are too hazardous for small vessels. Ebb and flood shoal may be influencing wave and current regime.	Delays are common leading up to, during, and immediately after the peaks of storms. Many vessels using the harbor may not have enough water under the keel to proceed safely. Small vessels generally have problems with wave conditions throughout the harbor and channels. In some locations conditions may be too hazardous for small vessels to safely venture. Ebb and flood shoal may be influencing wave and current regime.	Delays are common. Most of the larger vessels using the harbor have to wait for more favorable tide conditions before entering or leaving the harbor. Wave conditions limit use of the channel by small craft on many days.

[1] Ratings to be based on worst conditions found in the three levels of storms.

RATING*	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X Design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MAJOR FUNCTIONAL LOSS		
0 to 9	ENTRANCE USE	Vessels avoid the harbor. Entrance is extremely hazardous. Wave steepness makes small boat broaching a possibility during all tide phases. Ebb shoal focuses waves.	Vessels generally seek shelter in other harbors. Entrance is hazardous even during flood tide. Ebb shoal has an impact on wave focusing.	Vessels often have difficulty in the entrance when seeking shelter. Crossing during ebb tide is seldom possible.
	CHANNEL	The channel is extremely hazardous for all vessels. Most vessels have problems with wave conditions within the channels. Flood shoal impacts wave and current regime.	Long delays are normal and extend through the period leading up to, during, and immediately after the peaks of storms. Many vessels using the harbor will not have enough water under the keel to proceed safely. Many vessels will have problems with wave conditions. Flood shoal has an impact on wave and current regime.	Delays are the normal mode of operation. Most vessels must await favorable tide conditions before entering or leaving the harbor. Wave conditions limit use of exposed portions of the channel by small craft on most days.

1 Ratings to be based on worst conditions found in the three levels of storms.

Table 18. Rating Guidance For: <u>SEDIMENT MANAGEMENT</u>

RATING*	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X Design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MINOR OR NO FUNCTIONAL LOSS		
85 to 100	EBB SHOAL	The channel is stable, does not migrate and is not deflected or impaired. Shoals that would threaten navigation safety do not form in the channel.	The channel is stable, does not migrate, and is not deflected or impaired. Shoals that would threaten navigation safety do not form in the channel.	The channel is stable, does not migrate, and is not deflected or impaired. Maintenance dredging requirements are minimal and infrequent. T here are no hidden or dangerous shoals in the channel.
	FLOOD SHOAL	The channel is stable, does not migrate and is not deflected or impaired. Shoals that would threaten navigation safety do not form in the channel.	The channel is stable, does not migrate, and is not deflected or impaired. Shoals that would threaten navigation safety do not form in the channel.	The channel is stable, does not migrate, and is not deflected or impaired. Maintenance dredging requirements are minimal and infrequent. There are no hidden or dangerous shoals in the channel.
	HARBOR SHOAL	Shoaling is insignificant and does not affect harbor navigation or mooring areas. Build-up is very gradual and easy to manage with widely time-spaced periodic dredging.		
	SHORELINE IMPACTS a. Navigation Structures OR	The project has had no discernible impact on littoral processes. There is no unexpected accretion on the updrift side of the project and no unexpected erosion on the downdrift side. If there is a sand management plan in place for the project, the amount of material that needs to be moved to maintain shoreline equilibrium is well within the projected amount. Sediment is not being lost from littoral system (e.g., no offshore dumping of material dredged from the channel).		
	b. Shoreline Protection Structures	Adequate amount of sediment is maintained to prevent upland structure or flood damage from a subsequent intermediate level storm. Recovery of beach to original conditions is expected.	Insignificant sediment loss.	No indication of shoreline distress.
70 to 84	EBB SHOAL	The channel is generally stable, does not migrate significantly, and is not deflected or impaired significantly by large storms. Dangerous shoals generally do not form in the channel.	The channel is generally stable, does not migrate significantly, and is not deflected or impaired significantly by large storms. Dangerous shoals generally do not form in the channel.	The channel is stable, does not migrate, and is not deflected or impaired. Shoals or shifting bars are not an important concern since they are minor in size and area. Channel maintenance requirements are minimal in quantity but occasionally are needed.

1 Ratings to be based on worst conditions found in the three levels of storms.

RATING*	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X Design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MINOR OR NO FUNCTIONAL LOSS		
	FLOOD SHOAL	The channel is generally stable, does not migrate significantly, and is not deflected or impaired significantly by large storms. Dangerous shoals generally do not form in the channel.	The channel is generally stable, does not migrate significantly, and is not deflected or impaired significantly by large storms. Dangerous shoals generally do not form in the channel.	The channel is stable, does not migrate, and is not deflected or impaired. Shoals or shifting bars are not an important concern since they are minor in size and area. Channel maintenance requirements are minimal in quantity but occasionally are needed.
	HARBOR SHOAL	Shoaling is evident but has no impact on harbor navigation and is only a minor inconvenience in the mooring area.		
	SHORELINE IMPACTS a. Navigation Structures OR	The project has had a barely discernable impact on littoral processes. On the updrift side there may be a small amount of accretion beyond what was expected, but this presents no problem. The downdrift side of the project may be experiencing a small amount of localized erosion, but it is inconsequential. If there is a sand management plan in place for the project, the amount of sand that needs to be moved annually to maintain shoreline equilibrium is close to design projections. No important losses of sand from the system are occurring (e.g., offshore dumping of hopper dredged material).		
	b. Shoreline Protection Structures	Amount of sediment maintained is barely adequate to prevent upland structure or flood damage from a subsequent low intensity storm. Beach recovery without damage is expected.	Adequate sediment is maintained to prevent upland structure or flood damage from a subsequent design storm. Full recovery of the beach is expected.	Sediment loss is not significant.

[1] Ratings to be based on worst conditions found in the three levels of storms.

RATING*	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X Design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MODERATE FUNCTIONAL LOSS		
55 to 69	EBB SHOAL	The channel is fairly stable, does not seriously migrate, deflect, or become impaired. Some potentially hazardous shoals often form in or along the channel, but these are in isolated locations and can be readily avoided by most mariners.	The channel is generally stable and does not migrate significantly. A few minor shoals may for in or along the channel, but these are not a significant problem for prudent mariners.	The channel is generally stable and does not migrate significantly. Small shoals form over time and these are removed from the channel through maintenance dredging operations that are small in scale, but are needed on an annual basis.
	FLOOD SHOAL	The channel is fairly stable, does not seriously migrate, deflect, or become impaired. Some potentially hazardous shoals often form in or along the channel, but these are in isolated locations and can be readily avoided by most mariners.	The channel is generally stable and does not migrate significantly. A few minor shoals may for in or along the channel, but these are not a significant problem for prudent mariners.	The channel is generally stable and does not migrate significantly. Small shoals form over time and these are removed from the channel through maintenance dredging operations that are small in scale, but are needed on an annual basis.
	HARBOR SHOAL	There is some impact on navigation. Spot shoals may require periodic removal and avoidance by deeper draft vessels in the navigation fairways. Shoaling at docks may require shifting of vessels between maintenance cycles.		
	SHORELINE IMPACTS			
	a. Navigation Structures OR	The project has had a minor affect on littoral processes. There has been a little more accretion on the updrift side than expected but this presents only a minor problem (e.g., slightly more channel maintenance dredging due to sand bypassing the end of the updrift jetty). The downdrift side of the project has experienced some localized erosion, but it can be handled by adding small quantities of additional sand at the impacted area. There is still enough beach width to provide for recreation and storm protection. If there is a sand management plan in place for the project, the amount of sand to be moved annually is larger than design projections. Some sand is periodically lost from the system by offshore dumping of dredged material.		
	b. Shoreline Protection Structures	Supplemental beach nourishment would be needed to prevent upland structure or flood damage from a following low intensity storm.	Sediment maintenance is barely adequate to prevent structure or flood damage if a subsequent intermediate level storm occurs.	Adequate sediment is maintained to prevent upland structure or flood damage if a design storm should occur.

1 Ratings to be based on worst conditions found in the three levels of storms.

RATING*	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X Design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MODERATE FUNCTIONAL LOSS		
40 to 54	EBB SHOAL	The channel tends to migrate so that care is required to be taken by mariners. Hazardous shoals and bars are numerous.	The channel is fairly stable and does not migrate, deflect, or become impaired. A few potentially hazardous shoals often form in or along the channel, but are usually in isolated locations and can be readily avoided by most mariners.	The channel is stable, does not migrate, and is not deflected or impaired. Shoals are a persistent problem in a few sections of the channel. A moderate amount of maintenance dredging is needed on an annual basis.
	FLOOD SHOAL	The channel tends to migrate so that care is required to be taken by mariners. Hazardous shoals and bars are numerous.	The channel is fairly stable and does not migrate, deflect or become impaired. A few potentially hazardous shoals often form in or along the channel, but these are usually in isolated locations and can be readily avoided by most mariners.	The channel is stable, does not migrate, and is not deflected or impaired. Shoals are a persistent problem in a few sections of the channel. A moderate amount of maintenance dredging is needed on an annual basis.
	HARBOR SHOAL	Shoals are an encumbrance to navigation. Minor loss of facility use occurs between dredging cycles.		
	SHORELINE IMPACTS a. Navigation Structures OR	The project has had a moderate affect on littoral processes. More accretion than expected has occurred on the updrift side, creating a problem. (e.g., channel maintenance requirements are increasing because sand is bypassing the end of the updrift jetty). The downdrift side has measurable erosion over a long length of shoreline, with some pockets of moderate erosion. Trouble spots have demanded occasional remedial filling with sand. Beach width is barely adequate for recreation and some storm protection. If a sand management plan exists for the project, the annual movement of sand for maintaining shoreline equilibrium is significantly larger than design projections. Sand may be periodically lost from the system in offshore dumping of hopper-dredged material.		
	b. Shoreline Protection Structures	Supplemental beach nourishment is required to prevent upland structure and flood damage from a subsequent low intensity storm.	Supplemental beach nourishment is required to prevent upland structure and flood damage from a subsequent intermediate level storm.	Sediment maintenance is barely adequate to prevent upland structure or flood damage if a design storm should occur.

[1] Ratings to be based on worst conditions found in the three levels of storms.

RATING[*]	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X Design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MAJOR FUNCTIONAL LOSS		
25 to 39	EBB SHOAL	The channel tends to migrate significantly so that care is required to be taken by most mariners. Hazardous shoals and bars are widespread.	The channel tends to migrate and develop shoals. Mariners must proceed with caution.	The channel tends to migrate. Shoals are a fairly widespread problem. Channel maintenance dredging is needed annually.
	FLOOD SHOAL	The channel tends to migrate significantly so that care is required to be taken by most mariners. Hazardous shoals and bars are widespread.	The channel tends to migrate and develop shoals. Mariners must proceed with caution.	The channel tends to migrate. Shoals are a fairly widespread problem.
	HARBOR SHOAL	Shoaling trends require significant effort by the harbormaster to prevent vessel damage. Significant loss of facility use between dredging cycles is common.		
	SHORELINE IMPACTS a. Navigation Structures OR	The project has had a significant impact on littoral processes. There has been more accretion on the updrift side than expected. Channel maintenance dredging requirements have increased significantly because sand is bypassing the end of the updrift jetty. The downdrift side of the project is experiencing significant erosion over a long length of shoreline, with some pockets of intense erosion. Trouble spots have demanded emergency remedial filling with sand after low intensity storms. Beach width is less than desirable. Recreation use has been compromised and the storm protection properties have suffered. Private property owners have begun trying to build bulkheads and revetments to protect waterfront property where permitted. If there is a sand management plan in place for the project, the amount of sand that needs to be moved annually to maintain shoreline equilibrium is much larger than design projections. Operational or budgetary reprogramming is required to meet project needs. A significant volume of sand may be lost from the system during offshore dumping of dredged material.		
	b. Shoreline Protection Structures	Some structural damage or flooding occurs. Supplemental beach nourishment is needed to prevent continued damage and flooding in upland area from a low intensity storm.	Significant supplemental beach nourishment is needed to prevent damage and flooding in upland area from an intermediate level storm.	Supplemental beach nourishment is needed to prevent damage and flooding in upland area from a design storm. Chronic sediment deficit is evident.
10 to 24	EBB SHOAL	The channel migrates widely after large storms. Shifting shoals are common and dangerous. Great care is required to negotiate the channel.	Storms cause the channel to shift significantly and shoals are common.	The channel tends to migrate and hazardous shoals appear in numerous places. Extensive channel maintenance dredging is needed annually.
	FLOOD SHOAL	The channel migrates widely after large storms. Shifting shoals are common and dangerous. Great care is required to negotiate the channel.	Storms cause the channel to shift significantly and shoals are common.	The channel tends to migrate and hazardous shoals appear in numerous places. Extensive channel maintenance dredging is needed annually.

[1] Ratings to be based on worst conditions found in the three levels of storms.

RATING[*]	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X Design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MAJOR FUNCTIONAL LOSS		
	HARBOR SHOAL	Shoaling is extensive and management by the harbormaster can no longer prevent navigation conditions from becoming hazardous. Major loss of facility use between dredging cycles is common.		
	SHORELINE IMPACTS a. Navigation Structures OR	The project has had a major impact on littoral processes. There is major accretion on the updrift side, which presents a problem (e.g., intense channel maintenance dredging efforts are needed to offset the sand bypassing at the end of the updrift jetty). These efforts are not enough to maintain a safe open channel in the aftermath of storm events. There has been serious erosion on the downdrift side of the project over a long length of shoreline. Trouble spots have demanded emergency filling with sand after low intensity storms. There is little beach width remaining to provide for recreation and storm protection. Existing dune systems have been over washed and destroyed. Private property owners have begun trying in earnest to build bulkheads and revetments where permits for structures can be obtained. Homes and other shorefront structures have been lost in storms and some existing bulk-heads and revetments have been destroyed. If there is a sand management plan in place for the project, the amount of sand that needs to be moved annually to maintain shoreline equilibrium far exceeds design projections. An important volume of sand may be lost from the system during the offshore dumping of dredged material.		
	b. Shoreline Protection Structures	Significant flooding and damage occur on shore. Significant supplemental beach nourishment is needed to prevent damage and flooding in upland area from a low intensity storm.	Some flooding and damage occur on shore. Major supplemental beach nourishment is needed to prevent damage and flooding in upland area from an intermediate level storm.	Significant supplemental beach nourish-ment is needed to prevent damage and flooding in upland area from a design storm. Large, chronic sediment deficit is evident.
0 to 9	EBB SHOAL	The main body of the channel may mi-grate dramatically, or close entirely.	Storms cause the channel to shift dramati-cally or to close. As a minimum, dangerous shoals are widespread.	The channel is difficult to maintain. Haz-ardous shoals occur in many places. Extraordinary maintenance dredging effort is needed to keep the channel open.
	FLOOD SHOAL	The channel thalweg may shift, requiring repositioning of navigation aids and/or emergency dredging before the channel can be safely navigated.	Dangerous shoals are widespread.	The channel is difficult to maintain and there are hazardous shoals in many places. Extraordinary maintenance dredging effort is needed to keep the channel open.
	HARBOR SHOAL	Dredging cycles are repetitive and interfere with normal harbor use. The harbor may not be economically competitive without modification.		
	SHORELINE IMPACTS	The project has had a catastrophic impact on littoral processes. Enormous accretion of sand has occurred on the updrift side, stretching far upcoast. Intense channel maintenance dredging efforts are needed to offset the sand bypassing the end of the updrift jetty. Low intensity storms move enough sand to close or seriously impair use of the entrance channel. There has been major ero-		

[1] Ratings to be based on worst conditions found in the three levels of storms.

RATING[*]	RATING CATEGORY	DESIGN STORM CONDITIONS	INTERMEDIATE STORMS (2X Design Storm Frequency)	LOW INTENSITY STORM CONDITIONS
		MAJOR FUNCTIONAL LOSS		
	a. Navigation Structures OR	sion on the downdrift side of the project along vast lengths of shoreline. Trouble spots have routinely demanded emergency filling with sand and revetment stone following low intensity storms. There are no beaches left at high tide and beach storm protection properties are negligible. The dune system has overwashed and is almost destroyed. Private property owners have armored the shoreline with bulkheads and revetments where not constrained by permit processes. Houses have been moved back from the shoreline and/or abandoned. Numerous homes and other shorefront structures have been lost in storms and bulkheads and revetments have been destroyed. If a sand management plan exists, the annual volume of sand required to maintain shore equilibrium far exceeds design projections. Huge volumes of sand may be lost from the system during offshore dumping of dredged material.		
	b. Shoreline Protection Structures	Structures are ineffective. Major damage occurs to upland areas. Major beach nourishment or other remedies are needed.	Significant flooding and damage occurs. Significant supplemental beach nourishment is needed to protect against a subsequent low intensity storm.	Significant supplemental beach nourishment is needed to prevent damage and flooding in upland area from a subsequent intermediate level storm.

[1] Ratings to be based on worst conditions found in the three levels of storms.

Table 19. Rating Guidance For: STRUCTURE PROTECTION

RATING	RATING CATEGORY	DESCRIPTION OF CONDITION
MINOR OR NO FUNCTIONAL LOSS		
85 to 100	NEARBY STRUCTURES	Wave energy levels on adjacent structures are within design intent, and nearby structures are fully protected.
	TOE EROSION	No erosion at the toe or adjacent to the structure.
	TRUNK PROTECTION	Head reach fully protects structure trunk.
70 to 84	NEARBY STRUCTURES	Wave energy passing structure is somewhat higher than intended, but nearby structures are still fully protected.
	TOE EROSION	Only minor erosion at the toe or adjacent to the structure. Structural stability is not threatened.
	TRUNK PROTECTION	Condition of the head reach has resulted in minor super-structure or wave armor movement or shifting on the trunk, but the trunk is still considered to be fully protected.
MODERATE FUNCTIONAL LOSS		
55 to 69	NEARBY STRUCTURES	Segments of the structure allow enough wave energy to pass to be of concern. Some minor damage to nearby structures has resulted.
	TOE EROSION	Erosion is clearly evident along the toe or adjacent to the structure, but has not resulted in damage higher up on the structure. Structural stability is not seriously threatened.
	TRUNK PROTECTION	Condition of the head reach has resulted in minor damage to the trunk.
40 to 54	NEARBY STRUCTURES	Nearby structures are suffering moderate damage, but their functions are not yet compromised.
	TOE EROSION	Moderate erosion along the toe or adjacent to the structure has resulted in some damage to the cap or sub-structure. Structural stability is still considered adequate.
	TRUNK PROTECTION	Condition of the head reach has resulted in moderate level damage to the trunk.
MAJOR FUNCTIONAL LOSS		
25 to 39	NEARBY STRUCTURES	Nearby structures have incurred significant damage from lack of protection, and as a result, their functions have been moderately compromised.
	TOE EROSION	Significant erosion along the toe or adjacent to the structure has resulted in significant damage to the primary structure. Core is exposed or structural stability is marginal. Structure is vulnerable to heavy damage from subsequent intermediate level or design storm.
	TRUNK PROTECTION	Condition of the head reach has resulted in moderate level damage to the trunk. Trunk receives direct wave attack due to improper protection from head.

RATING	RATING CATEGORY	DESCRIPTION OF CONDITION
10 to 24	NEARBY STRUCTURES	Nearby structures have incurred major damage from lack of protection, and as a result, their functions have been seriously compromised.
	TOE EROSION	Widespread erosion along the toe or adjacent to the structure has resulted in cap and sub-structure failures along the structure. Undermining has occurred and foundations are unstable. Structure is vulnerable to additional damage from subsequent low intensity storm.
	TRUNK PROTECTION	Condition of the head reach has resulted in major damage to the trunk. Trunk receives little protection from head.
0 to 9	NEARBY STRUCTURES	Nearby structures are being destroyed from lack of protection, and as a result, their functions have been largely lost.
	TOE EROSION	Toe erosion has undermined most the structure, resulting in massive structural failure. Sub-structure has been seriously damaged and the crest is below the waterline. The whole structure is compromised.
	TRUNK PROTECTION	Head reach no longer provides any protection to the trunk.

7 How Index Values Are Calculated

The BREAKWATER Computer Program

The BREAKWATER computer program was developed to calculate index values for each reach or subreach and structure in rubble mound structures. The program accepts all information (including comments) from the structural and functional inspection forms. The input screens are set up much like the field forms to simplify the transfer of information from the forms to the computer. The index values are obtained when creating the desired reports from the Reports menu. The software has not been modified to accept nonrubble inspection data that are collected according to the procedures in this report.

Structural Index

The ratings are used to calculate the SI values as follows.

Cross-Section Component Index

The 0 to 100 ratings assigned by the inspector for the structural rating categories are weighted as follows to produce an SI for the superstructure, substructure, and foundation for each reach or subreach:

$$SP = R_3 + 0.3(R_1 - R_3)[\frac{R_2}{100}]$$

$$SB = R_4 + 0.3(R_1 - R_3)[\frac{R_2 + R_3}{200}]$$

where:

SP = Structural index for Superstructure

SB = Structural index for Substructure or for Foundation
R_4 = Lowest of the four ratings for the rating category
R_1 = Highest of the four ratings for the rating category
R_2,R_3 = Values for the second and third highest ratings.

$$(0 \leq \text{All Variables} \leq 100)$$

Reach/Subreach Index

The cross-sectional indexes will be combined as follows to create an SI for the reach or subreach:

$$SI = I_L + 0.3(I_H - I_L)[\frac{I_M}{100}]$$

SI = Structural index for the reach or subreach
I_L = Lowest of the three rating category indexes
I_M = Middle of the three rating category indexes
I_H = Highest of the three rating category indexes

$$(0 \leq \text{All Variables} \leq 100)$$

Structure Index

The SI for a whole structure is determined from the reach and subreach SI values in the following manner:

$$SI = I_L + 0.3(I_H - I_L)[\frac{\%1}{100} * \frac{S1}{100} + \frac{\%2}{100} * \frac{S2}{100} + \frac{\%3}{100} * \frac{S3}{100} ...(etc.)]$$

SI = Structural index for the structure
I_L = Lowest of the reach or subreach SIs
I_H = Highest of the reach or subreach SIs
%1, %2, %3, ... = Percentage of the structure length occupied by reaches or subreaches 1, 2, 3, etc.
S1, S2, S3, ... = SI for reaches or subreaches 1, 2, 3, etc.

$$(0 \leq \text{All Variables} \leq 100)$$

Functional Index

After the functional rating forms are completed, the ratings are entered into the BREAKWATER computer program, which will calculate the FI values as shown below. Only the ratings for categories within Harbor Area, Navigation Channel, Sediment Management, and Nearby Structures (within Structure Protection) are used to produce FI values.

Reach Index

The functional ratings will be combined as follows to create an FI for the reach:

$$SI = R_L + 0.3(R_H - R_L)\frac{[R_2/100 + R_3/100 + R_4 + /100 + ...(etc.)]}{N}$$

FI = Functional index for the reach

R_L = Lowest of the functional ratings for the reach

R_H = Highest of the functional ratings for the reach

$R_2, R_3, R_4, ...$ = Values for the second, third, and fourth, etc., highest ratings (maximum is 7).

N = Number of rated functions for the reach (maximum is 9).

$$(0 \leq \text{All Variables Except N} \leq 100)$$

Structure Index

The FI for each reach will be combined as follows to create an FI for the whole structure:

$$SI = I_L + 0.3(I_H - I_L)\frac{[I_2/100 + I_3/100 + I_4 + /100 + ...(etc.)]}{N}$$

FI = Functional index for the structure

I_L = Lowest of the reach FIs

I_H = Highest of the reach FIs

I2,I3,I4,... = Values for the second, third, and fourth, etc., highest reach indexes

N = Number of reaches in structure

$$(0 \leq \text{All Variables Except N} \leq 100)$$

Condition Index

The CI for a reach or structure is the same as its FI.

8 Summary and Recommendation

The general intent of REMR Management Systems is to provide maintenance managers with tools to promote easier and more effective maintenance and budget planning. This report contains a rational, standard method for evaluating the physical condition and performance of nonrubble breakwaters and jetties. The method includes processes to determine numerical condition and performance ratings that are used to produce an overall CI, which indicates the relative need for structural repair.

It is recommended that this method be distributed and applied Corps-wide. It is further recommended that the method periodically be reevaluated and refined to incorporate improvements suggested by users.

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14. ABSTRACT

Within the REMR program is a group of projects dedicated to the development of computerized maintenance management systems for coastal and waterway navigational structures. The general intent of these REMR Management Systems is to provide maintenance managers at all levels with tools to promote easier and more effective maintenance and budget planning.

One objective of these REMR Management Systems is to create uniform procedures for assessing the condition of structures, and further to create assessment methods which will allow the condition of structures, and their parts, to be expressed numerically to take best advantage of the benefits available from the use of microcomputers in maintenance management. This "numerical language" for expressing the condition of facilities is the Condition Index (CI).

For coastal structures, the CI is determined from a Functional Index (FI) and a Structural Index (SI). The FI indicates how well a structure (or reach) is performing its intended functions, while the SI for a structure or structural component indicates its level of physical condition and structural integrity. This report describes a procedure for evaluating the condition and performance of coastal structures and for determining CI values.

15. SUBJECT TERMS
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