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Risk-Management System for Infrastructure-Condition Assessment

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Abstract: Like other categories of the nation's infrastructure, offshore platforms are aging, and present a problem to owners and regulators with regard to the tracking of vital information and the management of risk. A prototype information management system for California's offshore platforms, the California Coastal Platform Information Management System, is presented. The system addresses the problems of both information management and risk management in an easy-to-use PC-based software package. The system incorporates level 1 analyses for the assessment of structural integrity, failure consequences, and risk. It also incorporates platform data-management features for tracking structure information as well as advanced environmental data management features for the probabilistic description of wind, current, wave, and seismic events.

INTRODUCTION

The California Coastal Platform Information Management System (CA IMS) is a software implementation of the first level of a screening system for the reassessment and requalification of offshore platforms, such as those proposed by Bea and Craig (1993) and Aggarwal (1991). The system uses existing methodologies (especially Bea and Craig's level 1 structural-integrity–assessment techniques and Aggarwal's level 1 consequence-assessment techniques) and is implemented in an easy-to-use software package. The CA IMS is a "proof-of-concept" prototype for more complete systems, which are planned to feature more levels of analysis, fully relational database management, and a focus on fleet management and the special problems that entails.

The system's features can be divided into three main functions: basic platform information-management operations, screening-cycle operations, and graphic platform information-management operations. Basic platform information-management operations involve the management of a flat-file database that includes such physical descriptors as platform name, location, water depth, and production. An unlimited number of platforms may be so described. Screening-cycle operations includes structural reliability, consequence, and risk assessment procedures; multiple methods of performing the latter two are provided. Although only level 1 screening-cycle procedures are incorporated at this stage, the system is designed to be the basis for more detailed screening-cycle analysis techniques as they are developed. Graphic platform information-management operations is primarily implemented for inputting probabilistic platform environmental data through direct graphic means.

Purpose

Regulators and fleet operators—and any group charged with the safe operation of large numbers of similar, existing structures—are increasingly faced with employing scarce resources to assess safety issues. The problems vary with the type of structure involved, the characteristic(s) of interest, and the authority having jurisdiction. Following are a few examples:

- For the Bureau of Indian Affairs to continue with its plans to assess the safety of its dams, it first has to find out how many dams it has (Slade 1994).
- A small staff of Minerals Management Service regulators is charged with ensuring the structural safety of 3,700 offshore oil platforms in the Gulf of Mexico, for which little historical information has been maintained (Dyhrkopp, personal communication 1994).
- There were approximately 577,000 bridges listed in the Federal Highway Administration (FHWA) National Bridge Inventory in 1988, and more than 238,000 were rated as deficient (Arockiasamy et al. 1993).

Clearly, these organizations and others like them are in no position to either perform or audit detailed safety assessments on each structure in their jurisdiction. Just as clearly, however, such assessments are needed for many of the structures.

Past solutions to managing safety-assessment processes have centered around screening systems. If the structure under consideration passes an initial, cursory level of analysis, it is considered "safe"; if not, more effort is devoted to more rigorous levels of analysis, until either the structure passes or it is reasonably certain that the structure is "unsafe." The initial level of analysis can be referred to as a level 1 analysis; subsequent, progressively more detailed analyses can use corresponding labels (thus, the most detailed analysis in a four-level scheme can be referred to as a level 4 analysis). "The Level 1 evaluations are intended to help screen large populations of structures, readily identifying those platforms that are not in need of extensive requalification analyses, and readily identifying those platforms that should be investigated in greater detail" (Bea 1993).

For buildings, Okada and Bresler (1976) proposed a screening methodology for seismic safety; Thurston et al. (1986) followed with one of their own. Bridge systems that moved beyond a focus on maintenance and cost management (based on databases of inspection reports, such as the FHWA's National Bridge Inventory) have included Weissmann et al.'s (1989) Texas bridge-management system module, and Miyamoto et al.'s (1993) fuzzy-logic–based expert system for bridge structural-safety assessment. For dams, McCann et al. (1985) put forth a screening methodology for failures stemming from a number of causes. Aggarwal (1991) proposed a methodology for Gulf of Mexico steel offshore platforms, and Bea and Craig (1993) did likewise for Gulf and West Coast platforms. The American Petroleum Institute (API) is currently developing its own screening methodology for U.S.

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offshore platforms ("Assessment" 1994). Few of these proposals were implemented in computerized form; fewer still addressed the consequence aspect of the risk-assessment problem.

The CA IMS described here is the first computerized implementation of a screening system for steel-jacketed offshore production and drilling platforms. It is a prototype of an enhanced screening system that combines previous systems' concepts of varying levels of analysis effort (and recognizing the trade-offs with accuracy that this entails) with a bridge-management system's concept of retaining information for future use. At present, the CA IMS incorporates only level 1 assessment techniques. Level 2 structural-assessment techniques (i.e., simplified ultimate limit-state analysis) are under development (Bea and Mortazavi 1995); level 3 (modified linear elastic analysis) and level 4 (nonlinear ultimate limit-state analysis) techniques exist but are as yet limited to advanced computer platforms.

SCREENING METHODOLOGIES EMPLOYED

The classical definition of risk for structures is that risk equals the probability of a structure's failure multiplied by the consequences of that failure. To serve the CA IMS's purpose of level 1 risk-based screening, methodologies for each area of structural assessment, consequence assessment, and risk assessment needed to be employed. These are described in the following.

Level 1 Structural Assessment

The structural-reliability–assessment procedure employed in the CA IMS follows Bea and Craig (1993). A qualitative scoring factor model, it results in an approximation of reserve strength ratio (RSR), the quotient of the structure's ultimate lateral-load capacity divided by its design or "reference" lateral loading:

$$\mathrm{RSR} = \frac{R_1 \cdot R_2 \cdot R_3 \cdot R_4 \cdot R_5}{S_1 \cdot S_2 \cdot S_3 \cdot S_4} \tag{1}$$

where R_1–S_4 = subjective factors meant to address structure capacities (R_i) and loadings (S_i), and are listed in Table 1 (Bea and Craig 1993).

RSR may be related to the probability of failure (P_f) by the following:

$$\mathrm{RSR} = \exp[\Phi^{-1}(1 - P_f)\sigma - K\sigma_S] \tag{2}$$

where

$$\sigma = \sqrt{\sigma_S^2 + \sigma_R^2} \tag{3}$$

$$K = \Phi^{-1}(1 - T_S^{-1}) \tag{4}$$

and σ_S = the standard deviation of the (lognormal) distribution of the annual maximum expected loadings (commonly assumed to be about 0.3 for wave loadings); σ_R = the standard deviation of the (lognormal) distribution of the platform capacity, or strength (commonly assumed to be about 0.1); T_S = the return period, in years, associated with the reference loading; and $\Phi(\ )$ = the cumulative standard normal distribution function. Loadings and capacities are assumed to be independently distributed.

Bea and Craig (1993) compares actual level 1 results with those of higher-level analyses, and examines some of level 1's experiential assumptions. Extreme results toward the unsafe (lower) limit of (1) will cause a risk assessment indicating to the user that the structure should be temporarily rejected until more detailed analysis techniques have been employed.

TABLE 1. RSR Scoring Factor Guidelines

Factor (1)	Definition (2)	Guideline (3)	Score (4)
R_1	Structure and foundation design and construction criteria	1947–59	0.5–0.8
		1960–64	0.6–1.2
		1965–75	0.7–1.3
		1976–93	0.9–1.5
R_2	Structure condition: corrosion, dented and bent members, dropped objects, fouling, and scour	Poor	0.3–0.8
		Good	0.8–1.0
		Excellent	1.0–1.2
R_3	Structure and foundation modifications developed during installation, operations, or reassessment that result in increases or decreases in capacity	Decreases	0.5–0.9
		No changes	1.0
		Increases	1.1–1.5
R_4	Structure and foundation configuration	Low robustness (e.g., caisson)	1.0–1.1
		Moderate robustness (e.g., four-leg platform nonductile bracing)	1.2–1.3
		High robustness (e.g., eight-leg platform with ductile bracing)	1.4–1.5
		Very high robustness (e.g., eight-leg platform with ductile bracing and excess capacity)	1.6–2.0
R_5	Loading-capacity effects factor, F_v	Storm waves	1.0–1.5
		Earthquakes	1.0–4.0
S_1	Storm loadings design criteria ("Assessment" 1994)	$(H_{\mathrm{API}}/H_{\mathrm{design}})^2$	1.0–1.5
		$(Cd_{\mathrm{API}}/Cd_{\mathrm{design}})$ × (directional spread, shielding, blockage, and current corrections)	1.0–1.5
S_2	Lower equipment deck elevation (not in design wave loading)	$\mathrm{Elevation}_{\mathrm{API}}/\mathrm{Elevation}_{\mathrm{present}}$	1.0–1.5
S_3	Loading modifications: elements added or removed, and marine growth management	$\mathrm{Area}_{\mathrm{modified}}/\mathrm{Area}_{\mathrm{design}}$	0.5–1.5
S_4	Operating/gravity loading modifications	$\mathrm{Weight}_{\mathrm{modified}}/\mathrm{weight}_{\mathrm{design}}$	0.5–2.0

Level 1 Consequence Assessment

The default consequence-assessment method in the CA IMS is based on a qualitative procedure outlined by Aggarwal (1991) for Gulf of Mexico platforms. This modified version of Aggarwal's method involves using the answers to a number of questions to generate consequence measures in each of three categories: loss of life, environmental consequences, and economic consequences. The implemented logic for consequence assessment may be seen in Table 2.

Consequence assessment is largely a subjective matter. For this reason, alternative methods are provided in the CA IMS. The first is a duplicate of the preceding procedure, but is provided in a form that allows easy modification by the user, for instances where consequence criteria differ. The second is a simple, direct input form: The user is asked to supply values of "very low," "low," "medium," "high," or "very high" for each of the three consequence measures.

Once determined, qualitative consequence measures are converted into numerical values and integrated into one combined consequence measure, C_f. In the CA IMS, numerical values are assigned to individual consequence measures (C_i) on a scale of zero to five: "very low" = 0.5, "low" = 1.5, "medium" = 2.5, "high" = 3.5, and "very high" = 4.5. The default method of determining C_f is through utility functions, which use utility theory to express the user's risk aversion. Utility functions are first defined for each of the three consequence measures and consolidated. For the individual consequence measures, an exponential utility form is used [modified from Marshall and Oliver (1995)].

TABLE 2. Default Consequence Evaluation Logic

Step (1)	Question (2)	If yes (3)	If no (4)
	(a) Loss of Life Consequence Measure (C_1)		
101	Is the platform permanently manned?	Go to question 102	C_1 = very low
102	Is an evacuation system provided for severe storms?	C_1 = high	C_1 = very high
	(b) Spillage Consequence Measure (C_2)		
201	Is crude stored on the platform?	C_2 = very high	Go to question 202
202	Does the platform have producing wells?	Go to question 203	Go to question 204
203	Do the wells have functioning SSSVs?	Go to question 204	C_2 = very high
204	Are any risers connected to the platform?	Go the question 205	C_2 = very low
205	Do the risers have functioning ESD valves?	C_2 = low	C_2 = very high
	(c) Economic Consequence Measure (C_3)		
301	Is the production level significant?	Go to question 309	Go the question 302
302	Is the platform multifunctional?	Go to question 305	Go to question 303
303	Will contractual obligations be affected by loss of the platform?	C_3 = medium to very high	Go to question 304
304	Will the platform be costly to replace?	C_3 = medium to very high	C_3 = low
305	Is it connected to other platforms?	Go the question 306	Go the question 309
306	Will the operation of other platforms be significantly affected?	Go the question 309	Go to question 307
307	Will contractual obligations be affected by loss of the platform?	C_3 = high to very high	Go to question 308
308	Will the platform be costly to replace?	C_3 = high to very high	C_3 = medium
309	Will contractual obligations be affected by loss of the platform?	C_3 = very high	Go the question 310
310	Will the platform be costly to replace?	C_3 = very high	C_3 = high

$$U(x_i) = \frac{\beta_i}{\beta_i - 1}\left[1 - \left(\frac{1}{\beta_i}\right)^{(x_i - x_{\min}/x_{\max} - x_{\min})}\right], \quad \beta_i \neq 1 \qquad (5a)$$

$$U(x_i) = 1 - \left(\frac{x_i - x_{\min}}{x_{\max} - x_{\min}}\right), \quad \beta_i = 1 \qquad (5b)$$

where i = consequence measure (1, 2, or 3, for loss of life, spillage, or economics); $x_{\min} = 0$; $x_{\max} = 5$; x_i = value of consequence measure i; and β_i = a user-defined attribute ($0 < \beta_i < \infty$). Adjusting β_i to above or below 1.0 modifies the concavity/convexity of the utility curve. The resulting three utilities U_i are combined into a consolidated utility U_c by the following (Ibbs and Crandall 1982):

$$U_C = \frac{\sum_{i=1}^{3} U_i k_i}{\sum_{i=1}^{3} k_i} \qquad (6)$$

where k_i = a user-defined attribute ($0 < k_i < \infty$) weighting the influence of each U_i utility. C_f is then determined from U_C by the relation

$$C_f = 5 - 5U_C \qquad (7)$$

Qualitative values for C_f are then based on the same scale as for C_i.

Two alternative methods for handling consequence measures may be used in the CA IMS. The first is an arbitrary example of a tabular method: The integer value of the final measure C_f is that of the highest of the individual C_i consequence measures, while the decimal portion of C_f is determined by the magnitude of the other two consequence measures (where C_i here are assessed as 1, 2, 3, 4, and 5 instead of the previous 0.5, 1.5, 2.5, 3.5, and 4.5). Table 3 is the look-up table employed for this alternative. The second alternative is to not combine the consequence measures at all, but to subject each individually to the risk assessment procedure.

TABLE 3. Lookup Table, Alternative Consequence Combination

Consequence measure values (1)	Corresponding value (2)
5, 5, 5	5.000
5, 5, 4	4.933
5, 5, 3	4.867
5, 5, 2	4.800
5, 5, 1	4.733
5, 4, 4	4.667
5, 4, 3	4.600
5, 4, 2	4.533
5, 4, 1	4.467
5, 3, 3	4.400
5, 3, 2	4.333
5, 3, 1	4.267
5, 2, 2	4.200
5, 2, 1	4.133
5, 1, 1	4.067
4, 4, 4	4.000
4, 4, 3	3.900
4, 4, 2	3.800
4, 4, 1	3.700
4, 3, 3	3.600
4, 3, 2	3.500
4, 3, 1	3.400
4, 2, 2	3.300
4, 2, 1	3.200
4, 1, 1	3.100
3, 3, 3	3.000
3, 3, 2	2.833
3, 3, 1	2.667
3, 2, 2	2.500
3, 2, 1	2.333
3, 1, 1	2.167
2, 2, 2	2.000
2, 2, 1	1.667
2, 1, 1	1.333
1, 1, 1	1.000

Level 1 Risk Assessment

The risk-assessment procedure employed in the CA IMS is modified from that of Bea (1990) and Bea and Craig (1993), which evaluated an "acceptable" standard of practice for the industry, relating the probability of failure to the consequence of that failure, as

$$P_{fa} = 10^{-(0.74\log C_M + 1.12)} \qquad (8)$$

where C_M = consequences, in millions of dollars (all consequences are converted into dollar terms); and P_{fa} = the maximum acceptable probability of failure for 1 year. P_{fm}, the maximum marginal probability of failure, is (Bea 1990):

$$P_{fm} = 10^{-(0.60\log C_M + 0.95)} \qquad (9)$$

Consequences, as used in the standard of practice procedure, are "based on the ranges of monetary costs, and/or fatalities that have been associated with the accidents. The monetary costs are based on actual costs, insurance payments, and judicial awards" (Bea 1990).

Eqs. (8) and (9) are generally presented as in Fig. 1. A structure's failure probability P_f is plotted on the graph against its failure consequence C_M. Should the resulting point fall below the "acceptable" guideline, the platform is considered to be acceptable; should it fall between the acceptable and marginal guidelines, it is considered to be marginally acceptable and probably in need of further analysis; and should it

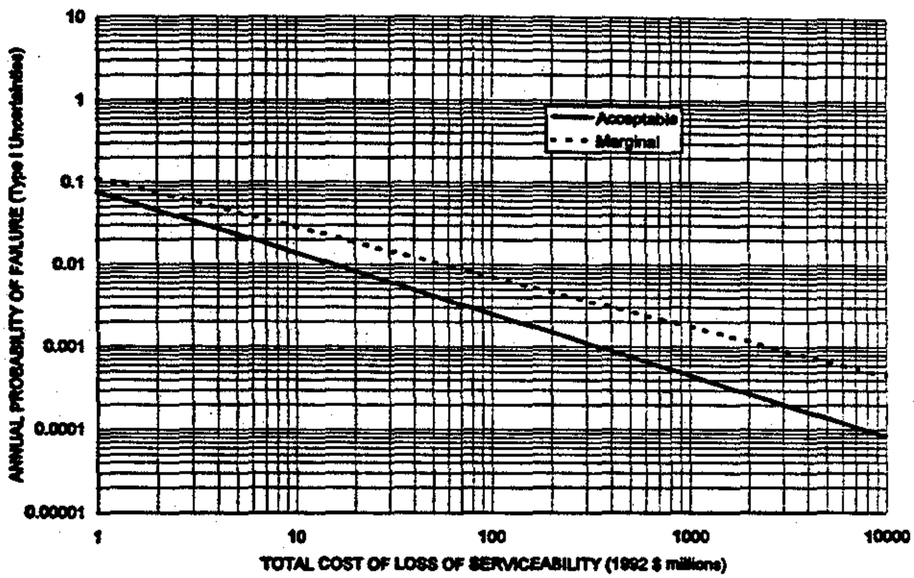

FIG. 1. "Acceptable" and "Marginal" Risk Guidelines

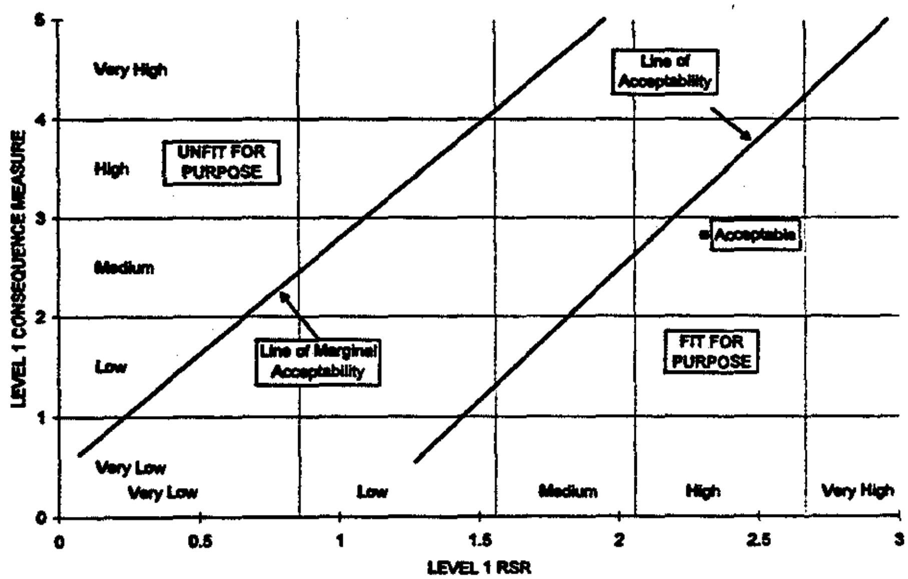

FIG. 2. Consequence Measure versus RSR

fall above the marginal line, it is considered to be unacceptable.

A graph of the RSR versus C_f form required by the CA IMS's structural and consequence assessment routines can be structured by relating P_f to RSR via (2), and roughly mapping monetary consequence C_M to consequence measure C_f by a relation similar to

$$C_f = \frac{4}{5} \log C_M \qquad (10)$$

Fig. 2 is an example of such a graph. Eq. (10) is applicable to C_f only when C_f is considered, as is C_M, as representing the total consequences of failure of a platform, including all loss of life, spillage, and economic costs (all expressed in monetary terms). Further, the risk guidelines in Fig. 2 are shifted according to the user's belief in the uncertainties involved in the structural integrity assessment, and in the desired likelihood of false positives (the chance that an unsafe structure might pass as acceptable) that the risk-assessment routine should incorporate.

The implementation of the preceding was left to further development efforts. The CA IMS, a demonstration program, presents the user with a graph similar to Fig. 2 and allows the user to shift the risk guidelines according to the user's own standards. Bea and Craig (1993) looks at the (thus far, limited) application of these risk assessment techniques to West Coast platforms; Bea (1990), Aggarwal (1991), and Staneff and Ibbs (1994), among others, examine various uses and implementations of the techniques.

SOFTWARE IMPLEMENTATION

The CA IMS is provided as a set of files written in a popular PC spreadsheet program (Microsoft Excel version 4.0 for Windows). The choice of format was guided by a desire to maximize the software's potential distribution, minimize associated hardware costs, and provide a prototype that would be easy to modify. In addition to the screening methodologies outlined in the previous section, the software provides information management tools to the user.

The user must first set up a new information file for each platform to be assessed (this may be performed from within the CA IMS program). From there, the user can move through the various assessment procedures as required. The only caveat is that the user must perform the structural- and con-

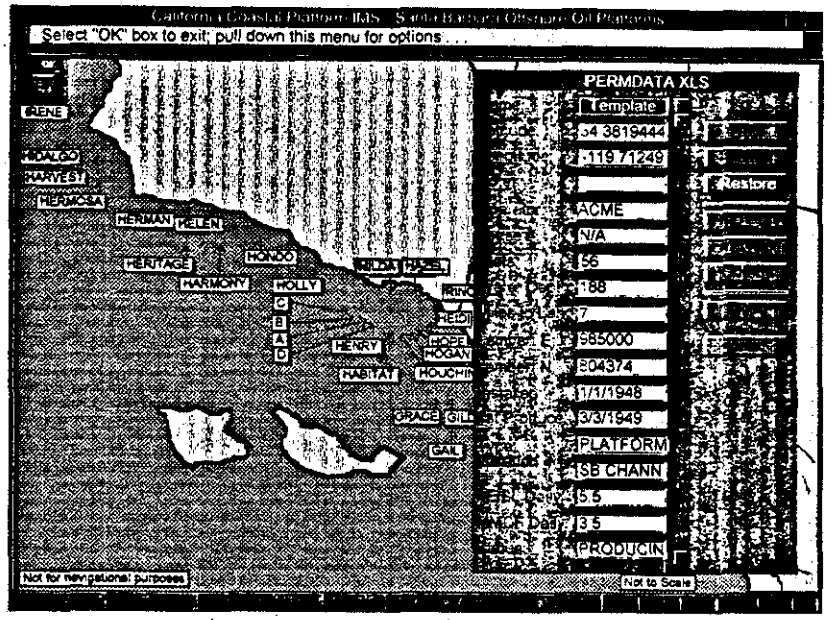

FIG. 3. Data-File Access Form

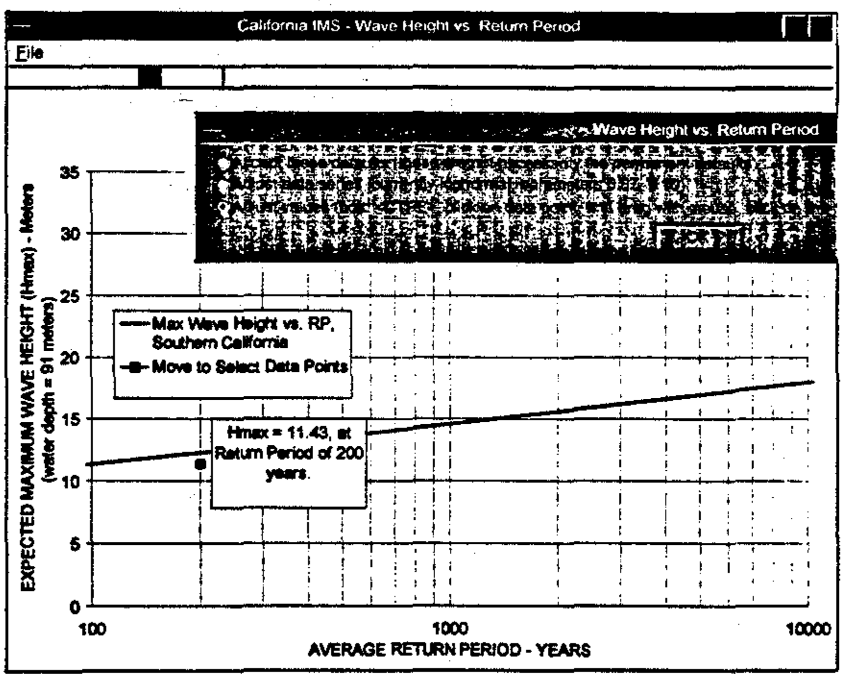

FIG. 4. Maximum Wave Height versus Return Period Input

sequence-assessment procedures prior to performing a risk-analysis procedure on any given platform.

Level 1 Structural Assessment

Implementation of the level 1 structural-assessment procedure is straightforward; a worksheet, very similar to Table 1, is provided for user input of factors R_1–S_4. The CA IMS then calculates RSR and stores that output, as well as all inputs, in the platform information file.

Level 1 Consequence Assessment

The default and each of the two alternative consequence assessment procedures are provided in spreadsheet form. After choosing "Consequence Assessment" from the main dialog box, the "Settings" item on the menu bar allows the user to choose the appropriate assessment worksheet. After the first question in each of the three consequence categories is answered, subsequent questions will appear on the worksheet as appropriate (as mentioned earlier, the alternative worksheets provide for user modification of questions or results, or for the elimination of questions altogether). Once all pertinent questions have been answered, ratings of "very low," "low," "medium," "high," or "very high," as appropriate, will appear in each of the three results box at the top of the sheet.

The "Consolidation" menu item is then used to choose among the three methods of combining (or not combining) the individual consequence measures into a single value.

Level 1 Risk Assessment

Upon entering the risk-assessment module, if either the "Utility Functions" or "Tabular Consolidation" option was chosen in the consequence-assessment routine, the user will see a chart plotting consequence measure C_f versus structural-integrity measure RSR (Fig. 2). The location of the plotted

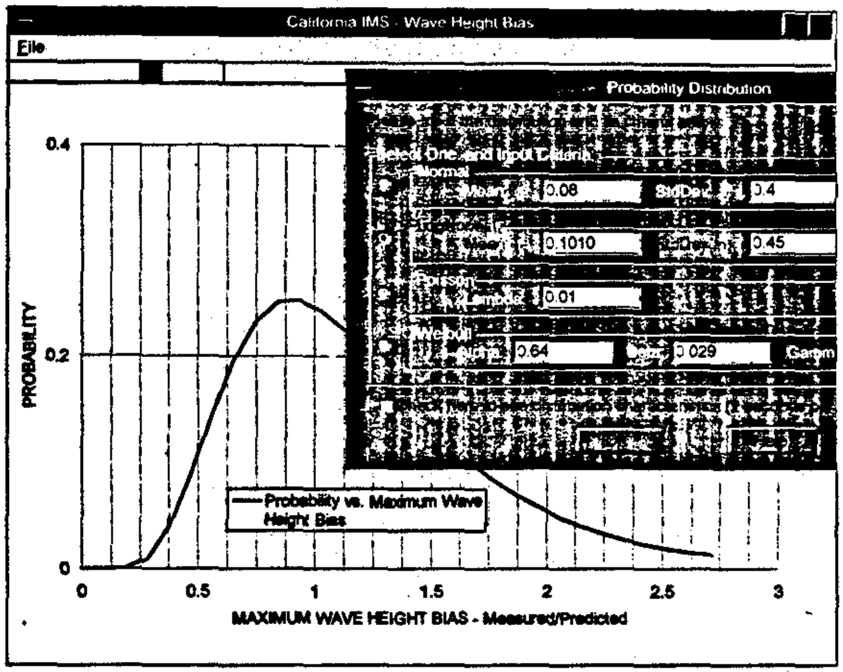

FIG. 5. Maximum-Wave-Height Bias Input

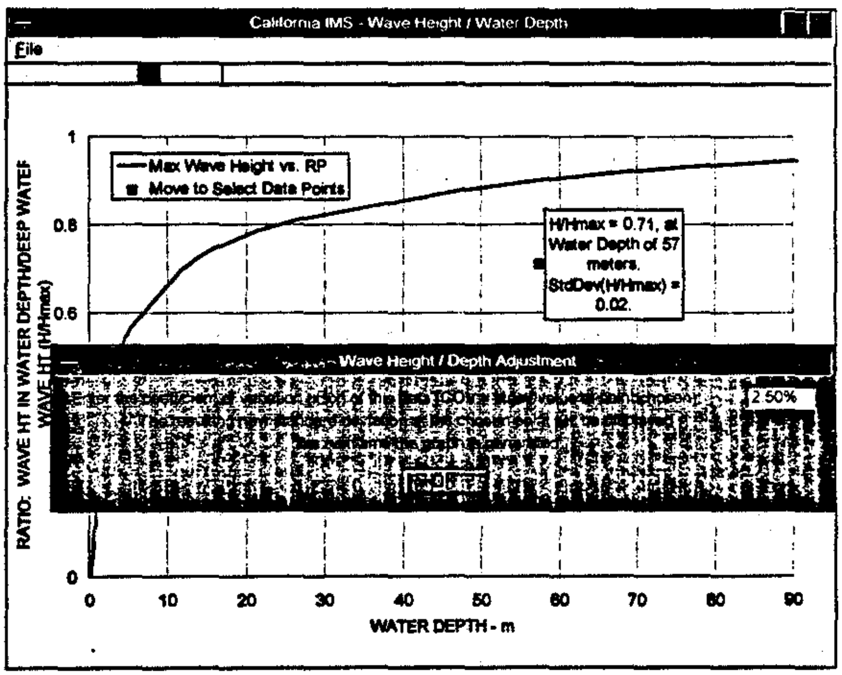

FIG. 6. Wave-Height/Depth-Adjustment Input

point in relation to the risk-acceptance guidelines (which the user may change by moving the endpoints with the mouse) determines the acceptability of the platform in question. If the "Don't Combine" option was chosen, the user will be presented with three charts, each plotting an individual consequence measure against RSR.

Information Storage

All inputs and outputs developed in these procedures are stored in the appropriate data file for the platform in question. This is one form of information management provided by the CA IMS. Two others are also featured: the tracking of general platform data, and an advanced method of entering environmental data.

Platform data may be entered or reviewed for each platform via a data-file access form, shown against the system's start-up screen in Fig. 3. This form aids in tracking platform data such as name, location (in latitude/longitude or Lambert coordinates), operator name, lease number, wells, water depth, distance to land, installation data, date of first production, type, regional location, status, and daily production.

The CA IMS features an advanced method for entering probabilistic environmental data, which is helpful in subsequently calculating loadings. Fig. 4 illustrates the first screen in a series of screens for the graphic determination of the required design maximum wave height resulting from storm events. The user first chooses a lognormal distribution to represent the yearly expected maximum wave height (H_{max}). The curve in Fig. 4 is redrawn to show the H_{max}–versus–turn–period (RP) curve implicit in the chosen distribution. The user then moves the platform data point horizontally to select the design return period, and from there moves it vertically until the point lies on the H_{max}-versus-RP curve. Next,

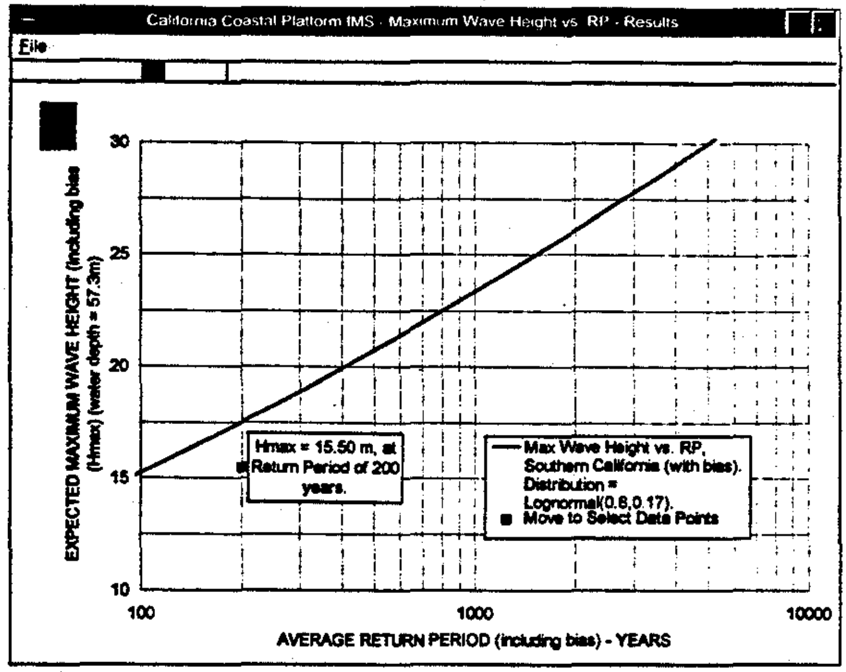

FIG. 7. Maximum Wave Height versus RP Output

the user selects a distribution to represent the bias inherent in the determination of the H_{max}-versus-RP curve, in terms of both the assessment and the modeling of natural processes. Fig. 5 shows the maximum-wave-height bias-curve screen overlain by the dialog box for changing the shape of its distribution.

After thus establishing the shape of the H_{max}-versus-RP curve, which is evaluated at a water depth of 91 m, the user must next pick a value for the water-depth adjustment factor, H/H_{max}, at the pertinent water depth. This is accomplished through the chart illustrated in Fig. 6, in which the H_{max}–versus–water-depth curves is seen. The platform data point is established horizontally by the system to match the structure's water depth, then must be moved vertically till it rests on the adjustment curve. This sets H/H_{max}. Finally, the user moves on to the maximum-wave-height–versus–return-period-output chart (Fig. 7). The curve in Fig. 7 is determined through the values established in the prior three charts (see later). By moving the platform data point vertically (the horizontal criterion, return period, was established in the first chart of the series) to the curve, the final design value of H_{max} is established.

The distribution in the final graph is calculated as follows:

$$\text{mean(final } H_{max}) = \text{mean}(H_{max}) + \text{mean(bias)} + \ln\left(\frac{H}{H_{max}}\right) \tag{11}$$

$$\text{stdev(final } H_{max}) = \sqrt{[\text{stdev}(H_{max})]^2 + [\text{stdev(bias)}]^2 + \ln\left\{1 + \left[\text{COV}\left(\frac{H}{H_{max}}\right)\right]^2\right\}^2} \tag{12}$$

where the first term on the right-hand side of each equation comes from Fig. 4, the second term comes from Fig. 5, and the third term comes from Fig. 6.

Similar series of charts reside in the CA IMS for the determination of design values of wind velocity, current velocity, and seismic spectral acceleration.

PRACTICAL APPLICATIONS

The CA IMS may be used by regulators, operators of large fleets, and others (including consultants) to quickly determine which of the platforms under their jurisdiction need more detailed analysis effort. For example, if an otherwise average, hypothetical, four-legged platform off the California coast was built in 1953, permanently staffed, lacked a storm evacuation system, regularly stored crude, produced significant amounts, and was laboring under significant contractual obligations, the CA IMS would quickly reveal that this platform is probably in need of further attention to ascertain its worthiness (using the default consequence and risk analysis methodologies). Tables 4 and 5 show the input values and intermediate results.

Instead of proceeding directly to costly level 2 (if available) or higher-level analyses, however, the user could perform iterative level 1 analyses on the platform to determine which underlying factors, if any, might be easily changed (relative to decommissioning) to produce an improvement. For example, switching over to automatic equipment to eliminate full-time staffing and storing crude on adjacent facilities (using appropriate safety devices on all risers and pipelines) would reduce loss of life consequences to "very low" and spillage consequences to "low." This would yield an overall consequence measure C_f of "medium," and bring the platform into the "marginal" range on the C_f-versus-RSR risk-assessment graph, which might be acceptable to the owner and to the authority having jurisdiction. This plan would entail neither loss of production nor significant alterations to the structure itself—although it would mean large expenditures for process equipment.

An alternative would be to examine the effects of improving the structure's physical condition. A plan—included repairing all dents, fouling, scour, and so on (R_2 = 1.1); increasing the structure's capacity (perhaps through leg grouting, R_3 = 1.2); and removing equipment from the lower equipment deck and cleaning the legs of all marine growth (S_3 = 0.7)—would result in an RSR of 1.96. Combined with the unaltered C_f of "very high," this would yield a risk-assessment result of "marginal," as did the first alternative.

Comparing the results for the two alternatives (using the

TABLE 4. Structural-Integrity–Assessment Input and Results (RSR = 0.94)

Input (1)	Result (2)
R_1	0.65
R_2	0.9
R_3	1.0
R_4	1.25
R_5	2.5
S_1	1.25
S_2	1.25
S_3	1.0
S_4	1.25

TABLE 5. Consequence/Risk-Assessment Inputs and Results (C_r = Very High)

Category (1)	Value (2)	β (3)	k (4)
Loss of life	Very high	10	7
Spillage	Very high	5	5
Economics	Very high	1	3

default risk guidelines) shows that the second alternative's result is closer to the marginal guideline than the first. Independent of other concerns, therefore, the first alternative is preferred. A combination of the two alternatives might produce a better result with possibly less implementation cost: Switching over to automatic equipment but retaining crude storage, while cleaning and repairing the structure and removing equipment from the lower equipment deck, will also produce a marginal rating. In this way, results from the CA IMS can be used to guide further risk-management work on the platform.

Comparing the results of this platform with those of others in the owner's fleet will enable risk management to take place on the entire fleet without the prerequisite time and expense of a detailed structural analysis for each platform. The writers feel that a computerized, simplified risk-assessment process, used either in an iterative fashion on single structures or for the prioritization of structures within a fleet, is a tool that can and should be applied to a wide variety of infrastructure-management problems. The CA IMS, based on a common spreadsheet program, illustrates that the implementation of such a tool is readily accomplished.

In current practice, neither the CA IMS nor any of its component methodologies [the Bea and Craig (1993) level 1 structural analysis and the Aggarwal (1991) consequence analysis] is employed; this is due in large part to the small number of platforms on the West Coast, which enables operators and regulators to perform detailed analyses. The system's successor, described in the following, will be oriented toward the Gulf of Mexico, where the automatic performance of detailed analyses is seldom economically viable.

CONCLUSIONS

This paper describes a computer-based system for the simultaneous data management and rapid risk screening of production platforms located in California offshore waters. [The manual for the software used is available in Staneff et al. (1994).] The system is a proof-of-concept prototype for advanced civil engineering information systems operating on minimal computer platforms. It incorporates simplified structural-integrity, failure-consequence, and risk-assessment routines, as well as platform data management and an advanced probabilistic environmental data mechanism.

The writers are continuing to develop information-management systems for offshore platforms. Currently under way are a level 2 structural-integrity program (Bea and Mortazavi 1995), and an expanded Gulf of Mexico Information Management System (GOM IMS). The GOM IMS will incorporate the level 2 analysis routine, will be built on a relational database engine, and will focus on fleet risk management rather than individual platform management. Tools will be included to allow users to compare the results of risk assessment on multiple platforms (up to the Gulf's full complement of 3,700), and to examine the policy effects of alternative safety standards upon the fleet. The GOM IMS will also allow the calibration of structural analysis routines against real data as they arrive, through a Bayesian mechanism.

The GOM IMS is also projected to serve as a model for other types of structural fleets: Structural assessment and consequence assessment methodologies that exist or are being developed for wharves, piers, pipelines, dams, and other structures will be easily adaptable to the IMS format. If successful, this will result in more efficient risk management and information management for a major segment of the nation's infrastructure.

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APPENDIX II. NOTATION

The following symbols are used in this paper:

C_f = combined consequence measure;
C_i = individual consequence measure i (i = 1, 2, or 3 for loss of life, spillage, or economic categories);
C_M = combined consequence measure, monetary units;
F_v = loading-capacity effects factor;
H = wave height;
H_{API} = American Petroleum Institute reference maximum expected wave height;
H_{design} = design value, maximum expected wave height;
$H_{\max}$ = maximum expected wave height;
k_i = weighting attribute, utility i;
P_{fa} = maximum acceptable probability of failure per safety standard;
P_{fm} = maximum marginally acceptable probability of failure per safety standard;
R_i = structure capacity scoring factor;
S_i = structure loading scoring factor;
T = structure period;
T_S = return period, in years, associated with reference loading;
U_C = utility, combined consequence measure C_f;
U_i = utility, consequence measure i;
x_i = value of consequence measure i;
β_i = risk aversion factor, consequence measure i;
σ_S = standard deviation of (lognormal) distribution of annual maximum expected loadings;
σ_R = standard deviation of (lognormal) distribution of platform capacity, or strength; and
$\Phi(\ )$ = cumulative standard normal distribution function.