DRAFT submitted for possible publication in ASCE Journal of Performance of Constructed Facilities 5/2/95.

F PROJECT 223

A RISK MANAGEMENT SYSTEM FOR INFRASTRUCTURE CONDITION ASSESSMENT

By Stephen T. Staneff[1], C. William Ibbs[2], and Robert G. Bea[3]

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 (CA IMS), is presented. The system address the problems of both information management and risk management in an easy-to-use PC-based software package. The system incorporates Level One analyses for the assessment of structural integrity, failure consequences, and risk. It also incorporates platform data management features for tracking structure information, and 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 proposed by Bea and Craig (1993) and Aggarwal (1991). The system utilizes existing methodologies (especially Bea and Craig's Level One structural integrity assessment techniques and Aggarwal's Level One 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 upon fleet management and the special problems that entails.

[1] Graduate Student Researcher, Dept. of Civil Engr., University of California, Berkeley, CA, USA 94720.
[2] Professor, Dept. of Civil Engr., University of California, Berkeley, CA, USA 94720.
[3] Professor, Dept. of Civil Engr., University of California, Berkeley, CA, USA 94720.

The system's features can be divided into three main functions: basic platform information management operations, screening cycle operations, and graphical platform information management operations. The first item, basic platform information management operations involves the management of a flat-file database that includes such physical descriptors as platform name, location, water depth, production, etc. An unlimited number of platforms may be so described. The second main function, screening cycle operations, includes structural reliability, consequence, and risk assessment procedures; multiple methods of performing the latter two are provided. Although only "Level One" 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. The third item, graphical platform information management operations, is primarily implemented for inputting probabilistic platform environmental data through direct graphical 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 insuring the structural safety of 3,700 offshore oil platforms in the Gulf of Mexico, for which little historical information has been maintained (Dyhrkopp, 1994).

There were approximately 577,000 bridges listed in the Federal Highway Administration's (FHWA) National Bridge Inventory in 1988, over 238,000 of which 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 one" 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 four" 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 for West Coast platforms. The American Petroleum Institute (API) is currently developing its own screening methodology for US offshore platforms (API 1994). Few of the above proposals were implemented in computerized form; fewer still addressed the consequence aspect of the risk assessment problem.

The CA IMS described herein 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 One" assessment techniques. Level Two structural assessment techniques (i.e., simplified ultimate limit state analysis) are under development (Bea and Mortazavi 1995); Level Three (modified linear elastic analysis) and Level Four (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 One risk-based screening, methodologies for each of the areas of structural assessment, consequence assessment, and risk assessment needed to be employed. These are described below.

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):

$$\mathrm{RSR} = (R_1 \cdot R_2 \cdot R_3 \cdot R_4 \cdot R_5)/(S_1 \cdot S_2 \cdot S_3 \cdot S_4), \quad (1)$$

where RSR = Reserve Strength Ratio, and R_1 through S_4, listed in Table 1 below (Bea and Craig 1993), are factors meant to address structure capacities (R_i) and loadings (S_i).

[insert Table 1 here]

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

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

where

$$\sigma = \sqrt{\sigma_S^2 + \sigma_R^2}\,, \quad (3)$$

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

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),

loadings and capacities are assumed to be independently distributed,

T_S = the return period, in years, associated with the reference loading, and

$\Phi()$ = the cumulative standard normal distribution function.

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.

[Insert table 2 here]

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 above 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 then 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 then consolidated. For the individual consequence measures, an exponential utility form is used (modified from Marshall and Oliver, 1993):

$$U(x_i) = \begin{cases} \frac{\beta_i}{\beta_i - 1}\left\{1 - \left[\left(\frac{1}{\beta_i}\right)\right]^{\frac{(x_i - x_{min})}{(x_{max} - x_{min})}}\right\}, & \beta_i \neq 1 \\ 1 - \left[\frac{(x_i - x_{min})}{(x_{max} - x_{min})}\right], & \beta_i = 1 \end{cases} , \tag{5}$$

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 is 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):

$$U_c = \frac{U_1 k_1}{\sum_i k_i} + \frac{U_2 k_2}{\sum_i k_i} + \frac{U_3 k_3}{\sum_i k_i} , \tag{6}$$

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

$$C_f = 5 - (5\, U_C). \tag{7}$$

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 utilized 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.

[Insert Table 3 here]

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). Bea evaluated an "acceptable" standard of practice for the industry, relating the probability of failure to the consequence of that failure, as

$$P_{fa} = 10^{-(0.74 \, Log_{10}[C_M] + 1.12)}, \quad (8)$$

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

$$P_{fm} = 10^{-(0.60 \, Log_{10}[C_M] + 0.95)}. \quad (9)$$

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).

Equations (8) and (9) are generally presented in graphical form, per Figure 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 fall above the "marginal" line, it is considered to be unacceptable.

[Insert Figure 1 here]

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

$$C_f = \frac{4}{5}\log_{10}(C_M). \tag{10}$$

Figure 2 is an example of such a graph. Equation (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 Figure 4 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.

[Insert figure 2 here.]

The implementation of the above was left to further development efforts. The CA IMS, a demonstration program, presents the user with a graph similar to Figure 2 and allows the user to shift the risk guidelines according to the user's own standards.

SOFTWARE IMPLEMENTATION

The CA IMS is provided as a set of files written in a popular PC spreadsheet program (Microsoft Excel v. 4.0 for Windows). The choice of format was guided by a desire to maximize the software's potential distribution, to minimize associated hardware costs, and to 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 assessment and consequence assessment procedures prior to performing a risk analysis procedure on any given platform.

Level 1 structural assessment

Implementation of the Level One Structural Assessment procedure is straightforward - a worksheet, very similar to Table 1, is provided for user input of factors R_1 through 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 above, 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 vs. structural integrity measure RSR (Figure 2). The location of the plotted 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 one of the individual consequence measures against RSR.

Information storage

All inputs and outputs developed in the above 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 Figure 3. This form aids in tracking platform data such as name, location (in latitude/longitude or Lambert coordinates), operator name, lease #, wells, water depth, miles to land, installation date, date of first production, type, regional location, status, and daily production.

[Insert Figure 3 here.]

The CA IMS features an advanced method for entering probabilistic environmental data, which is helpful in subsequently calculating loadings. Figure 4 illustrates the first screen in a series of screens for the graphical 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 Figure 4 is redrawn to show the H_{max} vs. return 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} vs. RP curve. Next, the user selects a distribution to represent the bias inherent in the determination of the H_{max} vs. RP curve, in terms of both the assessment and the modeling of natural processes. Figure 5 shows the maximum wave height bias curve screen overlain by the dialog box for changing the shape of its distribution.

[Insert Figures 4 & 5 here.]

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

[Insert figures 6 & 7 here.]

The distribution in the final graph is calculated as follows:

$$\text{Mean(Final Hmax)} = \text{Mean(Hmax)} + \text{Mean(Bias)} + \text{Ln}(H/\text{Hmax}) \qquad (11)$$

$$\text{StDev(Final Hmax)} = \sqrt{(\text{StDev(Hmax)})^2 + (\text{StDev(Bias)})^2 + \left(\text{Ln}(1+(\text{COV}(H/\text{Hmax}))^2\right)^2} \qquad (12)$$

where the first term on the right-hand side of each equation comes from the "Maximum Wave Height vs. Return Period" chart, the second term comes from the "Maximum Wave Height Bias" chart, and the third term comes from the "Wave Height/Depth Adjustment" chart (see Figures 4, 5, 6, and 7).

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

In practice, 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 below show the input values and intermediate results.

[insert Tables 4 and 5 here]

Instead of proceeding directly to costly Level Two (if available) or higher level analyses, however, the user could perform iterative Level One analyses on the platform to determine which, if any, of the underlying factors 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 vs. RSR risk assessment graph, which might be acceptable to the owner and to the authority having jurisdiction. Note that 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 which included repairing all dents, fouling, scour, etc. (R_2 = 1.1), increasing the structure's capacity (perhaps through leg grouting: R_3 = 1.2), 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 default risk guidelines) shows that the second alternative's result is closer to the "marginal" guideline than is the first alternative's. Independent of other concerns, therefore, the first alternative is to be 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 other platforms 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.

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 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 authors 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 3700), 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 it arrives, 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 which 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.

APPENDIX I. ACKNOWLEDGMENTS

This work is funded in part by a grant from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, under grant number NA89AA-D-SG138, project number R/OE-19 through the California Sea Grant College, and in part by the California State Resources Agency. The views expressed herein are those of the authors and do not necessarily reflect the values of NOAA or any of its sub-agencies. The U. S. Government is authorized to reproduce and distribute for governmental purposes.

Additional funding for this project was received from the California State Lands Commission, Norsk Hydro, and the U. S. Minerals Management Service (contract USDI-MMS 14-35-0001-30634).

Our Technical Advisory Committee consisted of representatives of the following organizations: ARCO Exploration and Production; California Coastal Commission; California Seismic Safety Commission; California State Lands Commission; Chevron Oil Company; Exxon Production & Research; Marathon Oil Company; Mobil Oil Company; Nippon Steel; Noble, Denton & Associates; Norsk Hydro; PMB Systems Engineering; Shell Oil Company; Texaco Oil Company; and UNOCAL Corporation.

The members of our Technical Advisory Committee provided invaluable assistance in the formulation and execution of this project.

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APPENDIX III. NOTATION

The following symbols are used in this paper:

C_i = individual consequence measure *i*, (*i* = 1, 2,or 3 for loss of life, spillage, or economic categories);

C_f = combined consequence measure;

C_M = combined consequence measure, monetary units;

F_v = loading capacity effects factor;

H = wave height;

H_{API} = API 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;

RP = return period;

RSR = reserve strength ratio;

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.

APPENDIX IV. KEYWORDS

Information management system, IMS, screening system, risk assessment, infrastructure, offshore platforms.

TABLE 1. RSR Scoring Factor Guidelines

Factor	Guideline	Score
R_1	Structure & foundation design and construction criteria	
	· 1947 - 1959	0.5 - 0.8
	· 1960 -1964	0.6 - 1.2
	· 1965 - 1975	0.7 - 1.3
	· 1976 - 1993	0.9 - 1.5
R_2	Structure condition: corrosion, dented & bent members, dropped objects, fouling, 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 & foundation configuration	
	· Low robustness (e.g., caisson)	1.0 - 1.1
	· Moderate robustness (e.g., 4-leg platform non-ductile bracing)	1.2 - 1.3
	· High robustness (e.g., 8-leg platform with ductile bracing)	1.4 - 1.5
	· Very high robustness (e.g., 8-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 (Ref. 1993 API RP 2A)	
	· $(H_{API} / H_{design})^2$	1.0 - 1.5
	· (Cd_{API} / Cd_{design}) x (dir. spread, shielding, blockage, & current corrections)	1.0 - 1.5
S_2	Lower equipment deck elevation (not in design wave loading)	
	· $Elevation_{API} / Elevation_{present}$	1.0 - 1.5
S_3	Loading modifications: elements added or removed, marine growth management	
	· $Area_{modified} / Area_{design}$	0.5 - 1.5
S_4	Operating / gravity loading modifications	
	· $Weight_{modified} / weight_{design}$	0.5 - 2.0

TABLE 2: Default Consequence Evaluation Logic

	Loss of Life Consequence Measure (C_1)	
101	Is the platform permanently manned? No ⇒ Yes ⇓	C_1 = Very low
102	Is an evacuation system provided for severe storms? Yes ⇒ No ⇒	C_1 = High C_1 = Very high
	Spillage Consequence Measure (C_2)	
201	Is crude stored on the platform? Yes ⇒ No ⇓	C_2 = Very high
202	Does the platform have producing wells? No ⇒ Yes ⇓	go to question 204
203	Do the wells have functioning SSSVs? No ⇒ Yes ⇓	C_2 = Very high
204	Are any risers connected to the platform? No ⇒ Yes ⇓	C_2 = Very low
205	Do the risers have functioning ESD valves? Yes ⇒ No ⇒	C_2 = Low C_2 = Very high
	Economic Consequence Measure (C_3)	
301	Is the production level significant? Yes ⇒ No ⇓	go to question 309
302	Is the platform multi-functional? Yes ⇒ No ⇓	go to question 305
303	Will contractual obligations be affected by loss of the platform? Yes ⇒ No ⇓	= Moderate to very high
304	Will the platform be costly to replace? No ⇒ Yes ⇒$_3$ = Moderate to very high	C_3 = Low
305	Is it connected to other platforms? No ⇒ Yes ⇓	go to question 309
306	Will the operation of other platforms be significantly affected? Yes ⇒ No ⇓	go to question 309
307	Will contractual obligations be affected by loss of the platform? Yes ⇒ No ⇓	C_3 = High to very high
308	Will the platform be costly to replace? No ⇒ Yes ⇒	C_3 = Moderate C_3 = High to very high
309	Will contractual obligations be affected by loss of the platform? Yes ⇒ No ⇓	C_3 = Very high
310	Will the platform be costly to replace? No ⇒ Yes ⇒	C_3 = High C_3 = Very high

TABLE 3: Lookup Table, Alternative Consequence Combination

For each consequence measure:

Assign value of 5 if "Very High"
Assign value of 4 if "High"
Assign value of 3 if "Medium"
Assign value of 2 if "Low"
Assign value of 1 if "Very Low"

Find combination of consequence measure values below, and assign corresponding values to combined consequence measure:

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

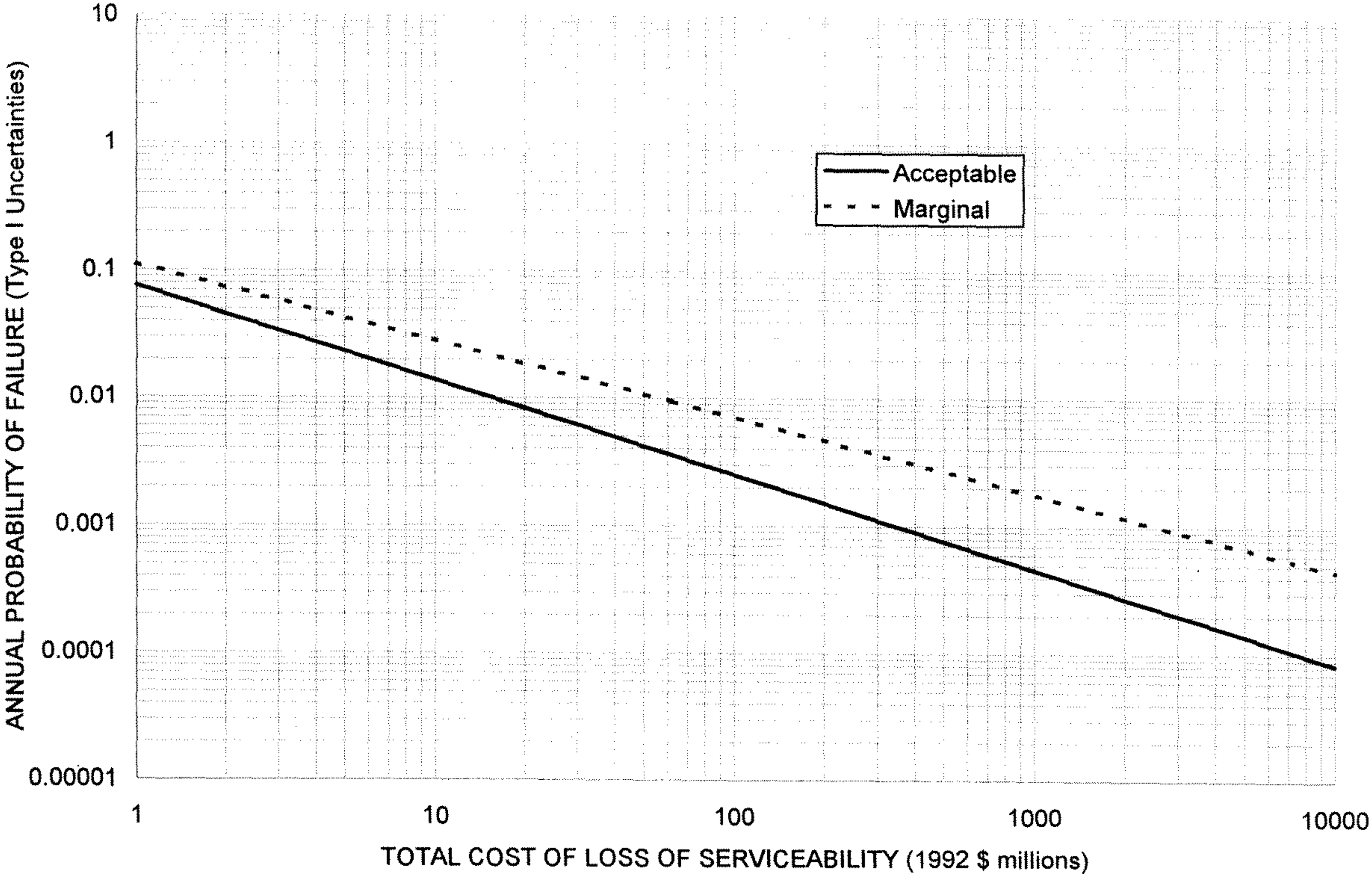
TABLE 4: Structural Integrity Assessment Inputs and Result

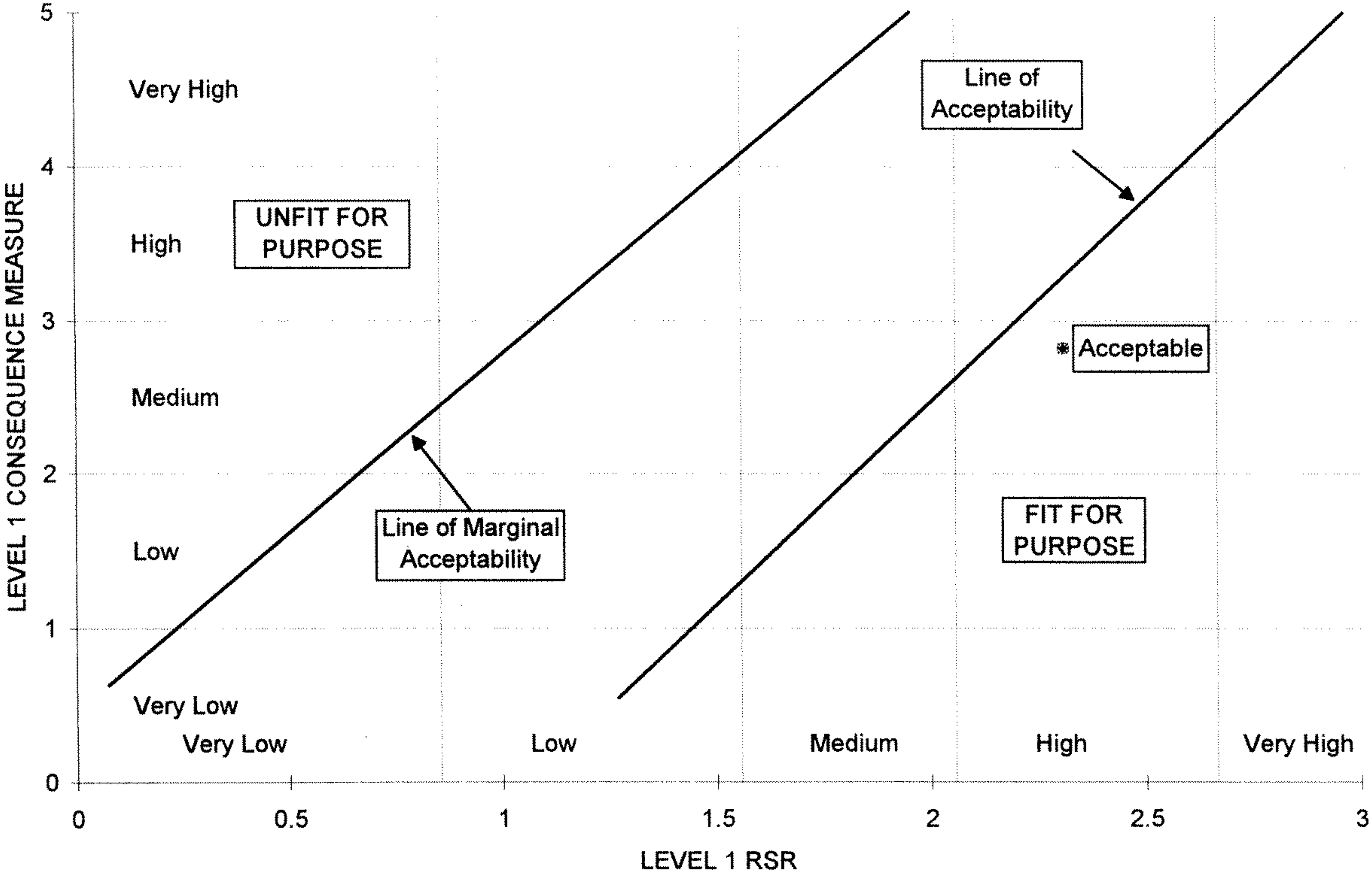
R_1	R_2	R_3	R_4	R_5	S_1	S_2	S_3	S_4
0.65	0.9	1.0	1.25	2.5	1.25	1.25	1.0	1.25

RSR =	**0.94**

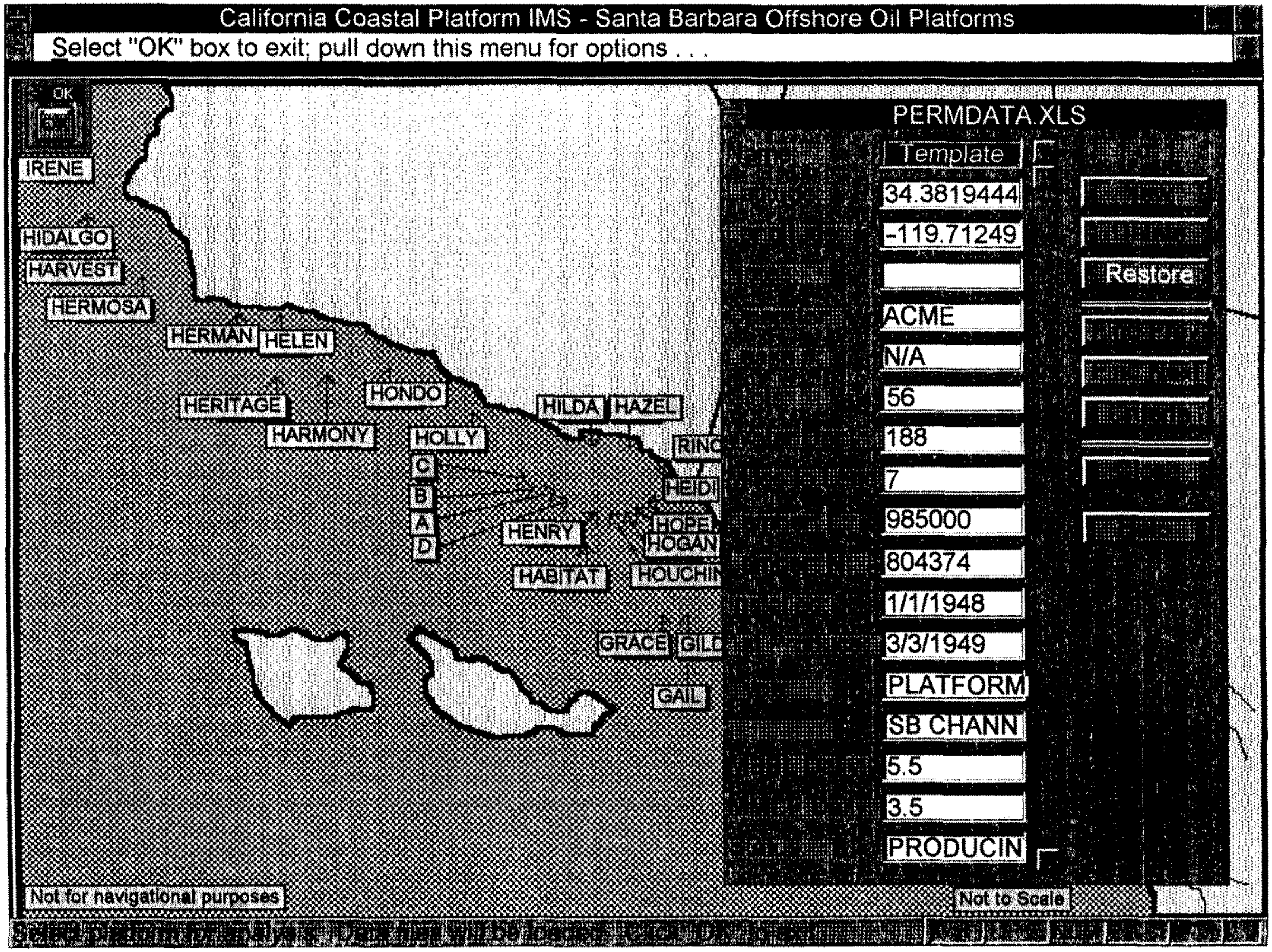
TABLE 5: Consequence/Risk Assessment Inputs and Results

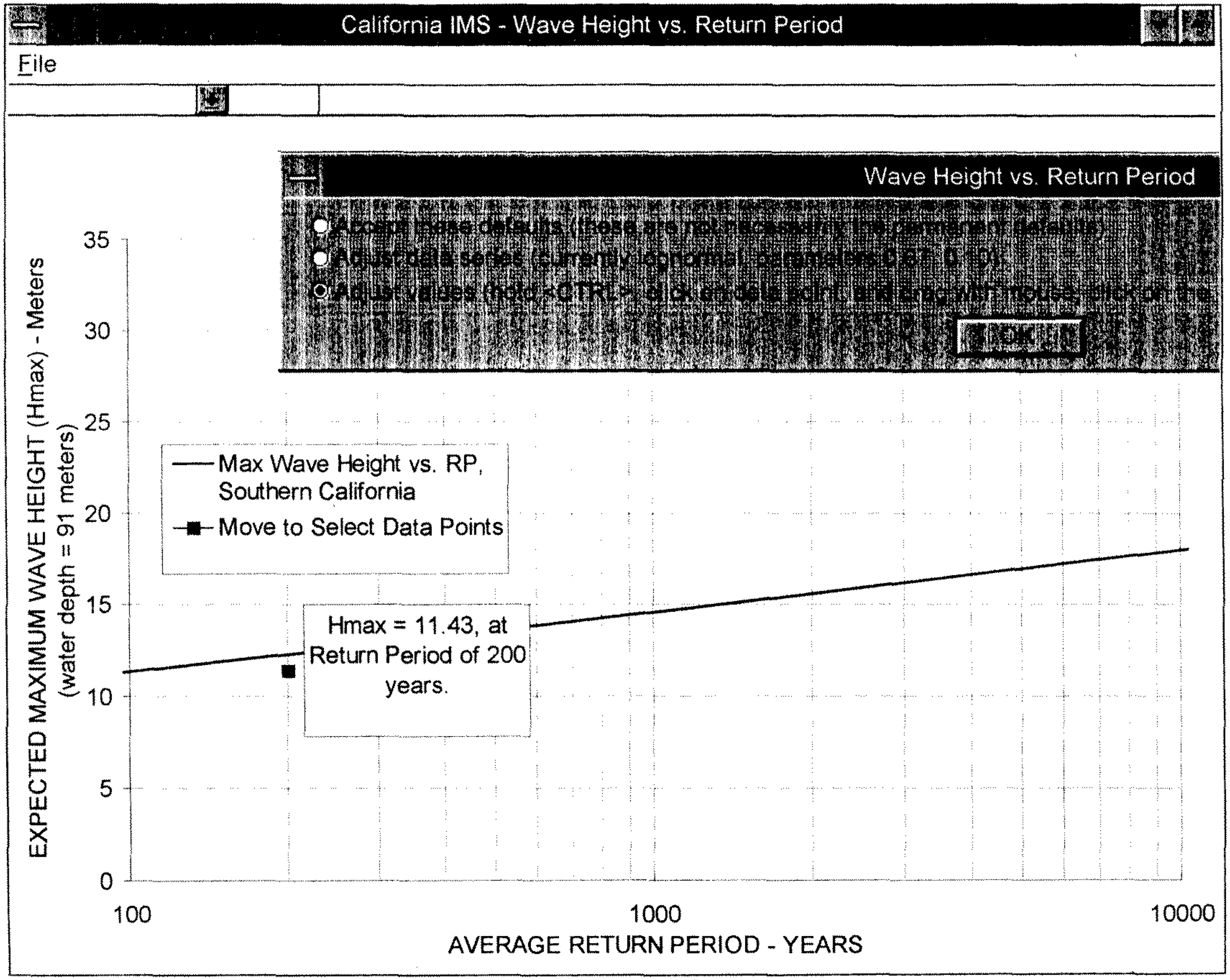
Category:	Loss of Life	Spillage	Economics
	Very High	Very High	Very High
β	10	5	1
k	7	5	3
C_f =	**Very High**		


ANNUAL PROBABILITY OF FAILURE (Type I Uncertainties)
10
1
0.1
0.01
0.001
0.0001
0.00001
Acceptable
Marginal
1
10
100
1000
10000
TOTAL COST OF LOSS OF SERVICEABILITY (1992 $ millions)

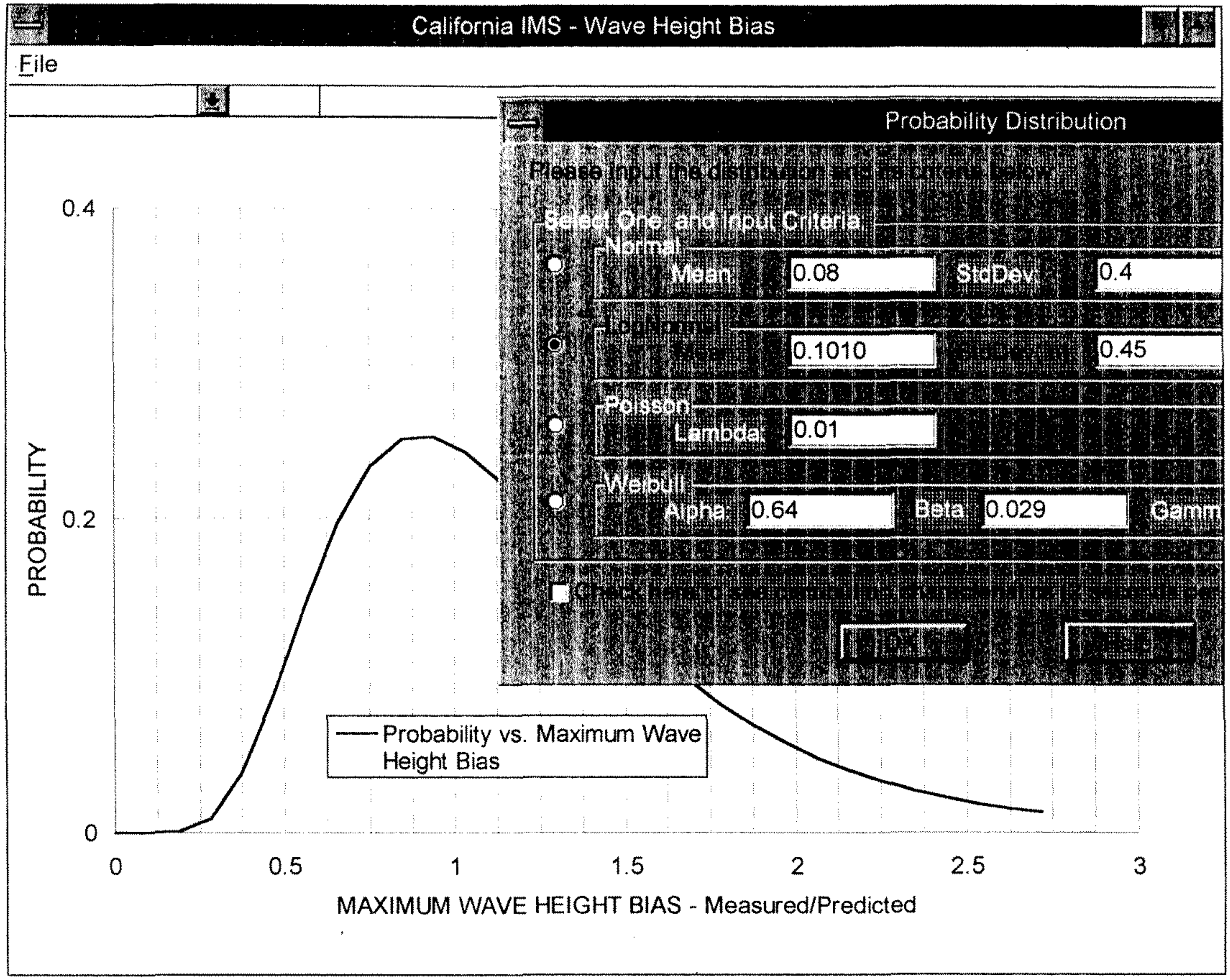


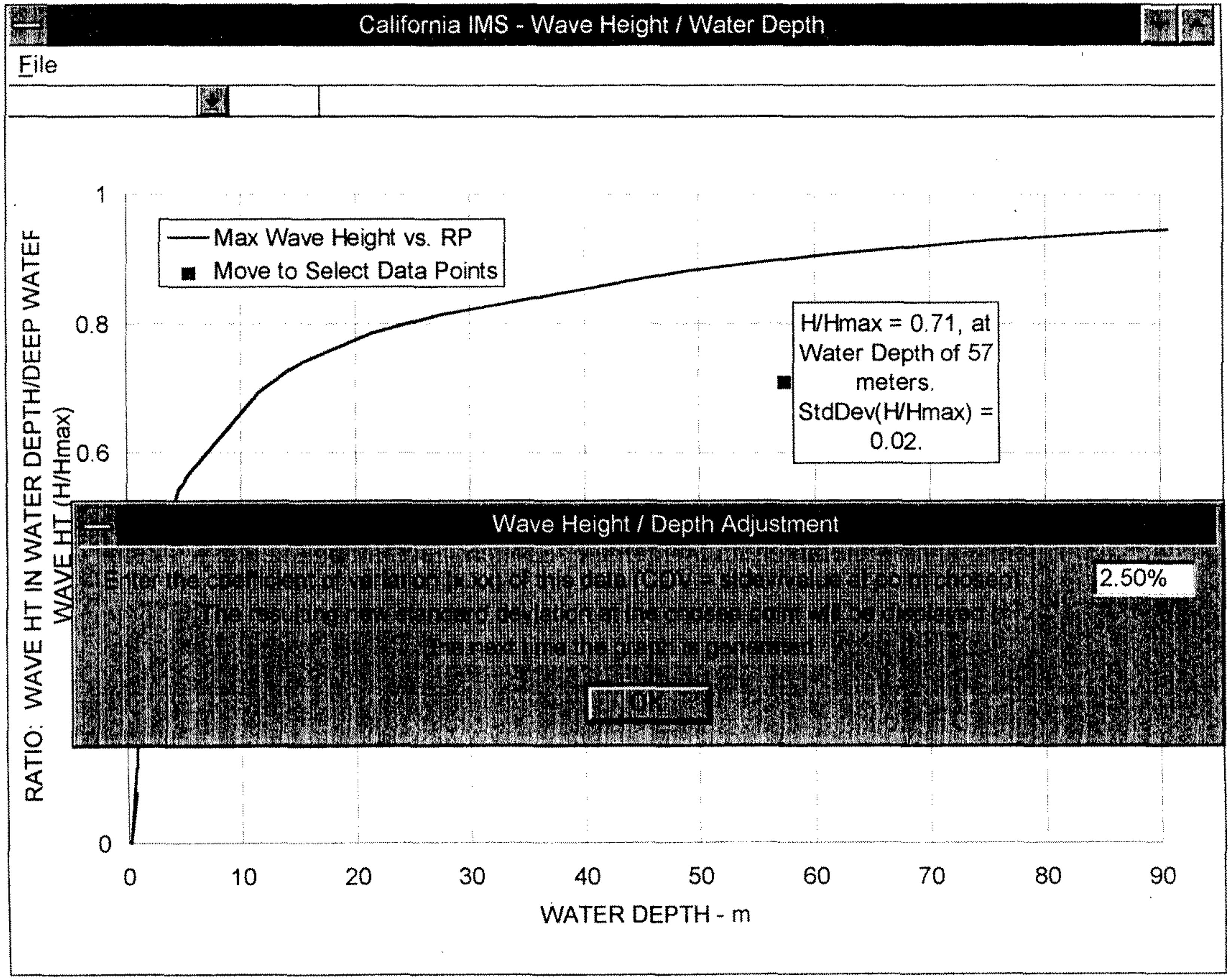
5
4
3
2
1
0
LEVEL 1 CONSEQUENCE MEASURE
Very High
High
Medium
Low
Very Low
UNFIT FOR PURPOSE
Line of Acceptability
Acceptable
Line of Marginal Acceptability
FIT FOR PURPOSE
Very Low
Low
Medium
High
Very High
0
0.5
1
1.5
2
2.5
3
LEVEL 1 RSR

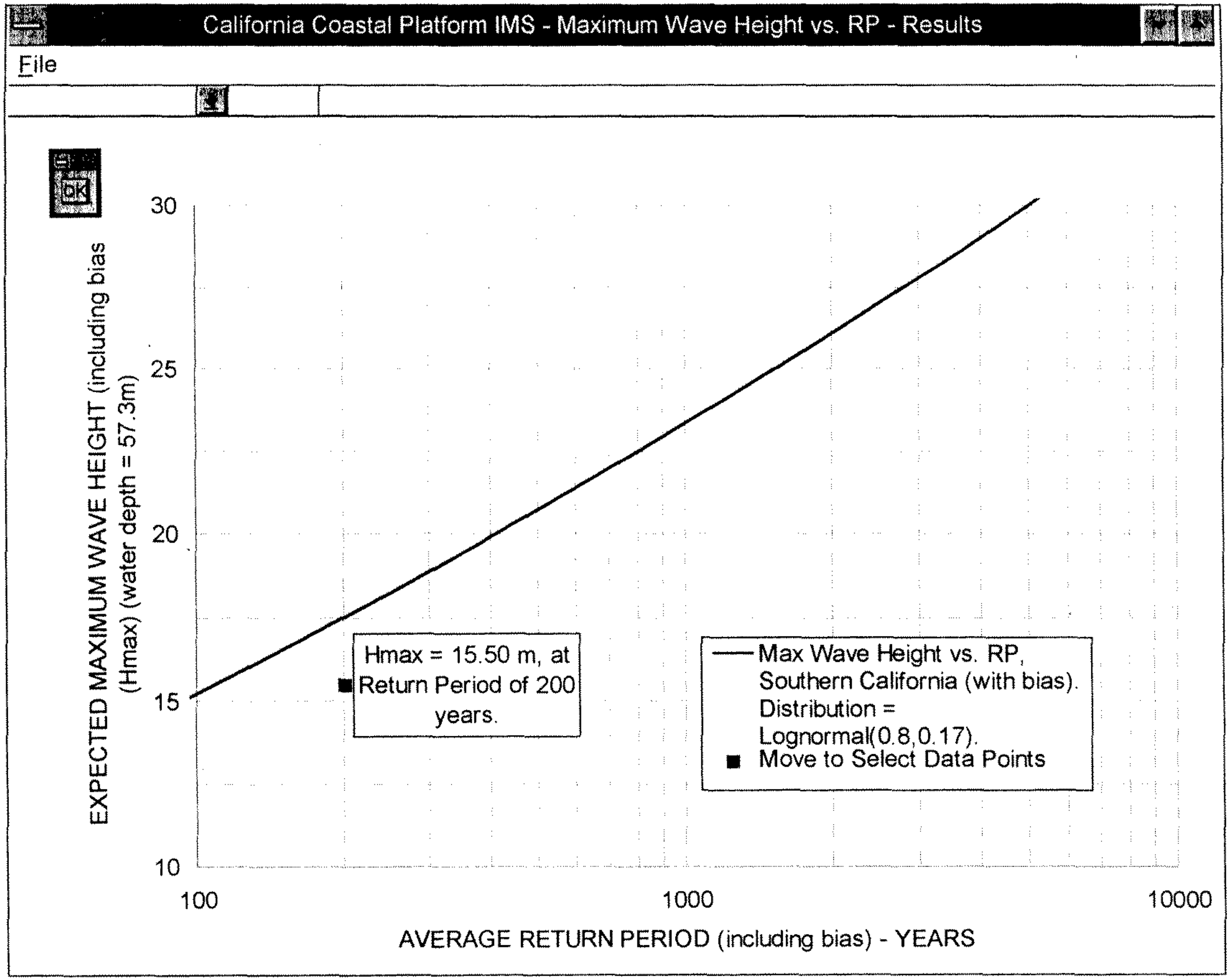

California Coastal Platform IMS - Santa Barbara Offshore Oil Platforms
Select "OK" box to exit; pull down this menu for options . . .
OK
IRENE
HIDALGO
HARVEST
HERMOSA
HERMAN
HELEN
HERITAGE
HARMONY
HONDO
HOLLY
HILDA
HAZEL
C
B
A
D
HENRY
HABITAT
HEIDI
HOPE
HOGAN
GRACE
GAIL
Not for navigational purposes
Not to Scale
PERMDATA.XLS
Template
34.3819444
-119.71249
ACME
N/A
56
188
7
985000
804374
1/1/1948
3/3/1949
PLATFORM
SB CHANN
5.5
3.5
PRODUCIN
Restore



California IMS - Wave Height vs. Return Period
File
Wave Height vs. Return Period
OK
EXPECTED MAXIMUM WAVE HEIGHT (Hmax) - Meters
(water depth = 91 meters)
35
30
25
20
15
10
5
0
100
1000
10000
AVERAGE RETURN PERIOD - YEARS
Max Wave Height vs. RP, Southern California
Move to Select Data Points
Hmax = 11.43, at Return Period of 200 years.


California IMS - Wave Height Bias
File
Probability Distribution
Select One, and Input Criteria
Normal
Mean:
0.08
StdDev:
0.4
0.1010
0.45
Poisson
Lambda:
0.01
Weibull
Alpha:
0.64
Beta:
0.029
0.4
0.2
0
PROBABILITY
Probability vs. Maximum Wave Height Bias
0
0.5
1
1.5
2
2.5
3
MAXIMUM WAVE HEIGHT BIAS - Measured/Predicted


California IMS - Wave Height / Water Depth
File
Max Wave Height vs. RP
Move to Select Data Points
H/Hmax = 0.71, at Water Depth of 57 meters. StdDev(H/Hmax) = 0.02.
RATIO: WAVE HT IN WATER DEPTH/DEEP WATEF WAVE HT (H/Hmax)
1
0.8
0.6
0
0
10
20
30
40
50
60
70
80
90
WATER DEPTH - m
Wave Height / Depth Adjustment
2.50%
OK


California Coastal Platform IMS - Maximum Wave Height vs. RP - Results
File
OK
EXPECTED MAXIMUM WAVE HEIGHT (including bias (Hmax) (water depth = 57.3m)
30
25
20
15
10
100
1000
10000
AVERAGE RETURN PERIOD (including bias) - YEARS
Hmax = 15.50 m, at Return Period of 200 years.
Max Wave Height vs. RP, Southern California (with bias). Distribution = Lognormal(0.8,0.17).
Move to Select Data Points

List of Figures