RISK ANALYSIS
For Water Resources Investments
NEWSLETTER

Spring 1998
Issue No. 3

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U.S. Army Corps of Engineers
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Risk Analysis Program Developments

News from the Program Manager

Risk Analysis research is expanding in the Corps' civil works arena. The ongoing R&D program, Risk Analysis for Water Resources Investments, is being joined in FY99 by a new program entitled Risk Analysis for Dam Safety. Reed Mosher (CEWES-SS) will be the manager of this new program. A new R&D area was created for these programs, Risk Analysis for Civil Works. Don Dressler (CECW-ED) and Bob Daniel (CECW-PD) are the area coordinators.

The Risk Analysis for Water Resources Investments program is scheduled to fund R&D in two new focus areas, Environmental Restoration and Deep Draft Navigation. Both of these areas present thorny problems with many uncertainties that need to be quantified within a unified analysis framework. Experience with past R&D successes has shown that coordinated, cross-lab efforts on a single problem can successfully produce risk analysis products that are accepted and used by the field. This approach will be used again with both of these focus areas.

While R&D is just beginning in these areas, work in Flood Damage Analysis and Major Rehabilitation is winding down. Several products from this R&D are described later in the newsletter. However, one should note that just because the focus of future R&D is shifting, it is not to be implied that all risk analysis work in these areas is complete. Nonetheless, it can safely be stated that the basic frameworks and tools have been developed and provided to the field. Most new R&D will be in specific technical areas to develop more advanced tools for quantifying uncertainties.

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GIWW Navigation Cost Evaluation Model

A Site Specific Simulation Model

IWR in cooperation with Galveston District has developed a computer model to evaluate the potential improvements of the Gulf Intracoastal Waterway (GIWW). It is designed to evaluate the economic effect of improvements in individual reaches of the waterway on system-wide transit times, and associated aggregate travel costs. While the model has been developed specifically for the requirements of the High Island to Brazos River GIWW Section 216 study, it has many general features to enhance its applicability to other sections as well as providing a prototype for a more general model. The model will be used in future 216 studies on the GIWW and should be usable for other similar

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HEC-FDA Computer Program

A Risk-based Flood Damage Analysis Tool from the Corps' Hydrologic Engineering Center in Davis, CA

Version 1.0 of the Hydrologic Engineering Center Flood Damage Analysis (HEC-FDA) computer program and accompanying user's manual was distributed to Corps offices and the general public in February 1998. HEC-FDA is designed to assist analysts in formulating and evaluating flood damage reduction projects using risk-based analysis procedures. The analytical procedures and output of the program are consistent with present Corps of Engineers' policy and technical requirements for performing flood damage reduction studies using risk-based analysis as described in ER 1105-2-101.

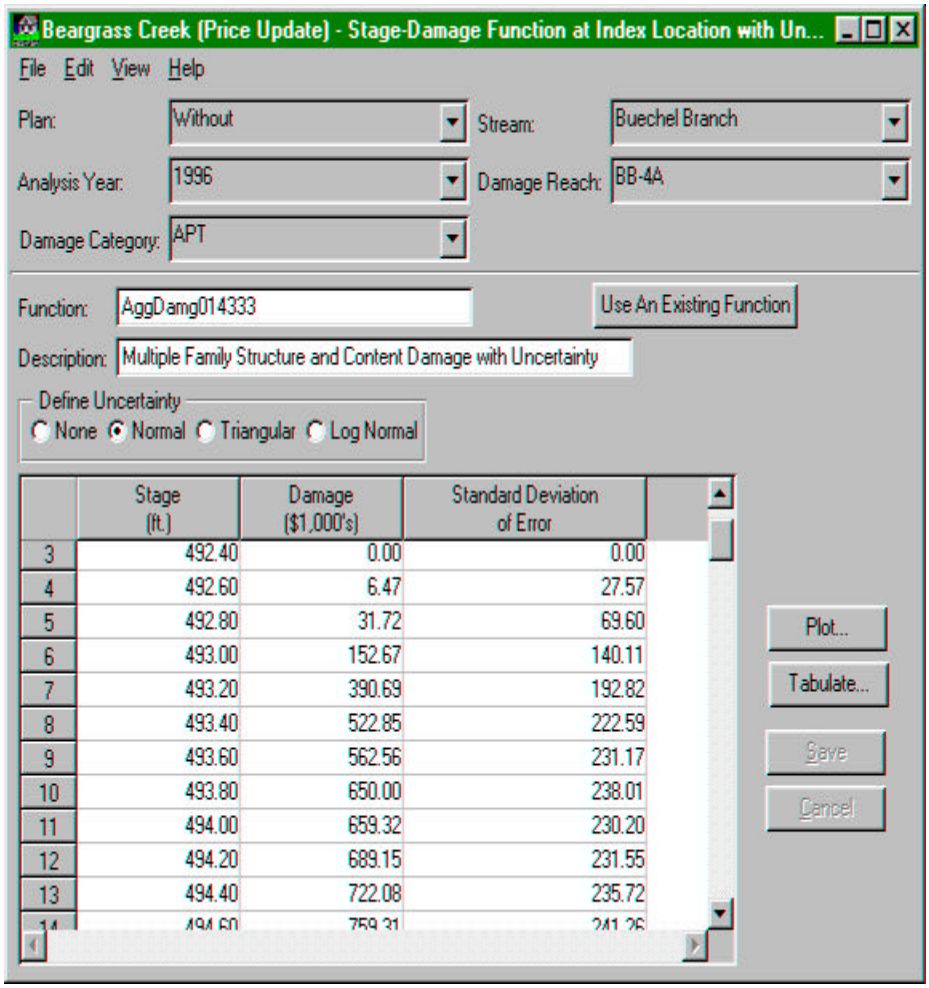
Risk-based analysis methods are applied to provide decision makers with better project performance technical information and insights so that ultimately better plans are selected for implementation. The procedures define the uncertainty of the exceedance probability, stage, and damage functions. Monte Carlo simulation is then applied for the full range of possible outcomes by iteratively developing and then integrating the damage-exceedance probability functions. The result is the expected annual damage and corresponding variance. Levees are evaluated considering the uncertainty associated with geotechnical failure and wave overtopping. Project performance analyses use the uncertainty of the exceedance probability and stage functions to generate risk reduction information. The annual exceedance probability and long-term risk of exceedance of project capacity stage are estimated. Also, the conditional probability of safely passing a specific event is computed.

HEC-FDA functions on the Windows 95 and NT operating systems. Software configuration requirements and installation directions are included in the user documentation. The program replaces the old Flood Damage Analysis package (EAD, SID, DAMCAL, etc.), the LOTUS@RISK spreadsheet risk-based analysis applications, and the Provisional Version 1.0 release of HEC-FDA of January 1997. The program, user's manual, and notification of periodic updates will be made available via HEC's internet home page address at

http://www.hec.usace.army.mil.

In addition to the HEC-FDA program and documentation, the above listed HEC home page on the Web contains a wealth of other information. At the site there is an organizational chart, personnel contact information, a list of publications including a number which have the ability to be directly downloaded, and a list of training courses.

The picture below is an example of the visual layout of the windows-based HEC-FDA program. This particular screen displays a risk-based stage-damage function for an apartment building at a specific location relative to the flood hazard under the without project plan condition. Clearly, the program facilitates the required tasks of risk and uncertainty analysis by bringing together the hydrologic and economic data associated with specific plans in a ready to use manner.



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studies at other locations through changes in the data.

The GIWW model is a discrete event Monte Carlo model that simulates movement of tows along a waterway network. The model exhibits stochastic generation of behavior in terms of generation of trips, transit time on each segment of the waterway, and choice of routes taken by traffic. The statistical parameters used in generating this data are input by the model user.

The model consists of the following integrated components:

a) A Microsoft Access 97 database that stores the waterway system representation, statistics on tow transit times, routes through the system, and model output;

b) A C++ "simulation kernal" that performs the detailed simulation calculations, reading data from the database and storing the output results back in the database and in separate detailed output data files;

c) A user interface, written in Visual BASIC, that allows for data input and editing, graphical display of the system, running of the kernel, and output reporting.

The three components work together to satisfy the goal of providing an integrated system for the user.

The model includes capabilities to simulate congestion and transit rules in the waterway. At present, the model does not simulate locks but the addition of this feature is being explored.

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Risk Analysis Applications to Project Cost Estimation

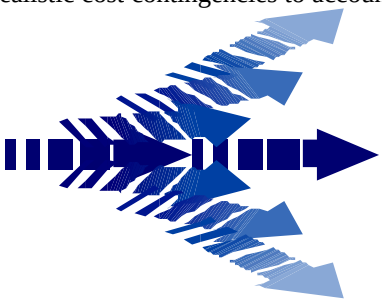
The Uncertainty of NED and Financial Cost Estimates.

Historically benefit estimation has been viewed as the largest source of uncertainty in the Corp's Benefit Cost Analysis framework. While project costs have been typically assumed as something known or readily calculable, i.e., a matter of summing up the costs of the parts of the project and thus a function of the project scope. Thus, since the mid 1980s, the research, development, and employment of risk analysis techniques has focused on providing additional information on the estimation of project benefits rather than costs. Although this progression in the state of analysis is clearly an advancement in terms of the quantity and quality of valuable information provided for making project decisions, the balance of information is notably skewed.

In project planning, there is one thing that can be known with certainty; the realized project costs will not exactly equal estimated project costs. Once this concept is grounded in the minds of analysts, questions arise concerning the evolution of costs through the process of planning and construction. Why do cost estimates vary at different stages? What are the sources of cost variance? Does cost variance realistically mean cost appreciation? If project cost estimates are expected to change through the course of project planning and construction, how can the decision maker be sure the correct choice is being made in the present? These are the fundamental issues that this new risk research effort intends to clarify.

Corps project costs come in two forms: NED and financial. NED costs, or the economic opportunity costs of the project, are estimated using a variety of techniques depending on the specific nature of those costs. The techniques are themselves a process of evolution stemming from research to improve the measurement of costs. Most of the time, these costs are never realized.

On the other hand, financial costs are those direct expenditures incurred in constructing the project. These costs are realized. Traditionally financial cost estimates have been developed based on experience, construction cost history, recent comparable bid unit costs, and professional judgement. Implicit in this traditional method was the addition of realistic cost contingencies to account



for possible unforeseen changes in costs due to site conditions, resource market conditions, and numerous other factors.

The objective of this research is to develop a method to analytically incorporate the uncertainty in project cost components and to provide procedural guidance for estimating the distribution of possible project costs, both financial and NED. In other words to provide a scientific based process for what is currently called "cost contingencies."

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Uncertainty in Ecosystem Restoration Outputs

An Application of Risk-based Techniques to Environmental Investment Decisions

Under the Corps Evaluation of Environmental Investments Research Program (EEIRP), managed by the Institute for Water Resources and the Waterways Experiment Station, researchers undertook a variety of investigations related to the planning challenges posed by environmental restoration projects. Planning methodologies were developed to address what became known as the "site" and "portfolio" questions:

1) From a range of alternatives, how can the Corps determine whether the recommended action is the most desirable in terms of environmental objectives? And,

2) How should the Corps allocate limited resources among many "most desirable" environmental investment decisions?

One of the EEIRP research areas sought to incorporate risk and uncertainty-based analyses into the evaluation of ecosystem restoration studies. Three reports that dealt with different aspects of this topic were published:

- *An Introduction to Risk and Uncertainty in the Evaluation of Environmental Investments*

  IWR Report 96-R-8,

- *Incorporating Risk and Uncertainty into Environmental Evaluation: An Annotated Bibliography*

  IWR Report 96-R-9, and

- *Risk and Uncertainty Analysis Procedures for the Evaluation of Environmental Outputs*

  IWR Report 97-R-7

Each of these reports are available at the IWR web site: http://www.wrc-ndc.usace.army.mil/iwr/index.htm

Although ecosystem restoration projects are replete with uncertainties, both large and small, one of the major sources of uncertainty and the primary focus of the completed research is uncertainty in the estimation of environmental outputs. To estimate existing and future environmental outputs, many Corps studies rely on habitat evaluation models like the Habitat Evaluation Procedures (HEP) developed by the U.S. Fish & Wildlife Service. HEP analysis involves the estimation of the number of habitat units that exist at a site given certain environmental conditions. Habitat units are the simple product of a number of acres of habitat and a habitat suitability index (HSI), where the HSI indicates the relative suitability of those acres for a particular wildlife species. The HSI is based on the mathematical manipulation of a set of habitat variables that are specifically selected for judging the environmental quality relative to the sustainability of the specie(s) of focus.

A case study involving alternatives to restore aquatic habitat for a recreational fishery was used to illustrate the role that habitat variable measurements play in the uncertainty in estimating environmental project outputs, i.e., habitat units. As a result of the lessons learned during the course of the case study and prior experience with risk analysis, a flexible eight-step set of procedures was developed. The major steps include the following:

1) select the analytical framework for estimating environmental outputs;
2) identify the types and sources of uncertainty in the analysis;
3) identify the potential key variables in the analysis;
4) design the risk analysis;
5) carefully collect data;
6) identify major uncertainties once data are available;
7) do the risk-based analysis; and
8) communicate the results of the risk analysis.

To assist in conducting these procedures, the planner's "risk analysis toolbox" should include a number habitat evaluation models and techniques. Although HEP analysis was used in the case study, the procedures presented are general enough to allow use with other kinds of models used to measure ecosystem resources. The value of using interval rather than point estimates, for example, is that they can be used to support sensitivity analysis and Monte Carlo simulations. These are two of the most commonly used techniques in this form of risk analysis.

The *ex post facto* application of the procedures to the case study clearly indicates the feasibility of conducting a risk-based analysis of ecosystem restoration project outputs. Once habitat suitability index models have been converted to a spreadsheet format, Monte Carlo process software can be used to turn a simple HSI model into a Monte Carlo simulation model. Not only can the simulation yield a range of outputs, it can also provide an estimate of the likelihood of any one level of output occurring. This could prove to be an invaluable tool where there are significant output threshold values for projects under investigation.

Although the EEIRP research focused on identifying and quantifying the uncertainty in environmental outputs, much risk and uncertainty-related research remains to be done in the area of ecosystem restoration.

Specifically, future research has been proposed in the Risk Analysis for Water Resources Investments Research Program in the following areas:

- uncertainty in the habitat evaluation models per se (models which are used to estimate existing and future ecosystem outputs);
- uncertainty in the costs associated with management measures and techniques used to produce ecosystem outputs;
- uncertainty in both the cost and output components of cost effectiveness and incremental cost analyses (Corps guidance requires such analyses for ecosystem restoration studies); and
- uncertainty in the hydrologic functioning of ecosystem restoration projects; and uncertainty in project performance.

Within each of these areas, sources and types of uncertainties will be identified, potential risk-based tools to address the uncertainties will be proposed and tested, and methods to quantify the "high priority" uncertainties will be identified and evaluated. It is expected that different tools and techniques will be proposed for restoration studies and projects of varying scales, costs, purposes, and degree of stakeholder agreement. An evaluation framework will be developed to tie the separate research, techniques, and procedures together, as well as to incorporate risk-based information into the decision criteria for environmental restoration project decision-making. The goal is to develop guidelines that help Corps district planners recognize, address, and quantify the uncertainties inherent in these ecosystem restoration studies, and to communicate that information to decision-makers. This three-year research effort is proposed to begin in FY 1999.

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Risk-Based Analysis For Deep Draft Navigation

The Inherent Uncertainty of Forecasting the Future.

The Navigation Analysis Division of the Institute for Water Resources is now completing two work efforts studying the application of risk-based analysis for deep-draft navigation benefits. A draft report entitled, *Risk-Based Analysis for Deep Draft Navigation: Benefit and Cost Overview*, has been published and reviewed by district personnel. A second research project, *Risk-Based Analysis for Deep Draft Navigation: Commodity and Fleet Forecasting*, is nearing completion.

The intent of the first research effort is not only to provide a perspective into the analytical problems of measuring of the benefits and costs in deep draft navigation but also proposes a framework for conducting risk-based analyses of deep draft navigation improvements. Uncertainty in the calculation of both benefits and costs is addressed. The draft report includes the results of a literature search and survey of projects by Corps District. The results of the surveys, among other things, include the key variables and the status of risk-based deep draft navigation analysis in the districts. The final report will incorporate the comments from the districts and be sent to headquarters for review before being published and distributed.

The second research effort, the development of risk-based commodity and fleet forecasting, is nearing completion. The types of risk and uncertainty inherent in commodity and fleet forecasts and potential methods for accounting for the uncertainty have been identified and evaluated. This analysis was documented in an interim report. Risk-based methods for developing commodity and fleet forecasts are currently being applied to a case study and documented in another interim report. When the case study is completed, a final report will be published that incorporates the evaluation and the case study. This work is scheduled to be completed this fiscal year.

These two research efforts are the first pieces in the development of an overall decision model for deep-draft navigation that will incorporate economic, engineering, environmental, and operational uncertainties. The decision model will integrate the uncertainty of benefit realization related to fleet and commodity forecasts and vessel operating costs, as well as the uncertainty of costs related to planned dredging and disposal activities**.** Work on the overall decision model is subject to funding availability, but is expected to begin next fiscal year.

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Engineering Reliability Assessment

Progress in Risk-based Engineering Measurement

The Waterways Experiment Station (WES) has completed a number of work units in the Risk Analysis for Water Resources Investments Program. These work units developed reliability estimating methods and procedures in the context of examples and case studies. This form of "how-to" guidance has been shown to be useful to USACE Districts. The reliability focus area and POCs for these completed work units are:

- Timber and steel pile foundations included deep-seated stability, loss of support, and system reliability (Drs. Reed Mosher or Mary Ann Leggett).
- Gravity structures both with and without anchors including geotechnical strength parameters (Dr. Mary Ann Leggett)
- Quantifying the stage-discharge relationship for flood control (Dr. Ron Copeland)
- Coastal structures (Dr. Norm Scheffner)
- Stability of levees (Dr. Ron Meade)

An Engineering Technical Letter (ETL) or Engineering Circular (EC) has been published for each of these focus areas.

Computer procedures have been developed to in applying this guidance to reliability procedures. Reliability assessment procedures are being added to Computer-Aided Structural Engineering (CASE) programs. Reliability versions of CSLIDE and CPGA, RCSLIDE and RCPGA respectively, are currently available. All the current versions of these programs function in a Windows operating system environment with a windows user interface, enhanced graphical input/output, and each utilize advanced reliability calculation procedures.

The work unit to develop time-dependent reliability analysis procedures will be completed by September 1999. This work unit evaluates a structure's degradation with regard to time by considering the component's initial strength, degradation characteristics of construction materials, rate of occurrence of loads, and magnitude of stress variations. Time-dependent models have been developed to formulate a hazard function. This hazard function can then be incorporated into the economic risk model developed by IWR under a separate work unit. Guidance on time-dependent reliability procedures is currently available.

Subject to program direction and budgetary restrictions, in Sept 1998, WES will begin work units on 3 new areas:

1. Quantification of risk and uncertainity in environmental restoration models (POC: Dick Kasual)
2. Quantification of uncertainity in key engineering variables for deep draft channels (POC: Dr. Zeki Demirbilek)
3. Expert elicitation (POC: Dr. Mary Ann Leggett)

These work units along with IWR and HEC companion work units will expand the focus areas covered by the Risk Analysis R&D program.

Based upon district needs, another Risk and Reliability Analysis Workshop for Major Rehabilitation Reports is scheduled to be taught this summer. Previously held workshops were attended by approximately 400 District and Division personnel. This workshop will focus on the addition of hazard functions in the Major Rehabilitation procedures. For additional information or to reserve team space in this current workshop, please call 601-634-2724.

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At this point, the research is in its preliminary stages. A review of past research on this subject is currently being performed. The academic literature is being screened for any potential method and/or findings that can be applied to Corps practices. Simultaneously, the Corps' methods and tools for cost estimating are being reviewed in order to provide an idea of the current state of cost estimating procedures. A product of this latter work will be the identification of the potential areas or practices that harbor or produce uncertainty in project cost estimates. Another direction of the research is an inquiry into the availability of cost data for the different types of projects, i.e., what level of detail of cost data is available for the different types of projects at different stages of the planning process?

The general idea is to approach this research topic from these three angles simultaneously: to provide a sound theoretical basis, to adjust and merge such a theoretical approach with

Corps economic evaluation planning practices, and to utilize historic data in order to provide specific estimates of the uncertainty in Corps cost estimates.

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Demonstration Risk Analysis for Dam Safety

An Exercise in Application

A demonstration application of using an existing risk analysis approach for evaluating dam safety and safety improvements is underway. The approach being applied is similar to that used by the Bureau of Reclamation, B.C. Hydro, and in Australia. It follows the classic risk analysis framework of relating consequences to initiating events which, in this case, are either hydrologic, seismic, or static loads. This problem lies in quantifying the likelihoods of the events and levels of consequences since many of these values can be highly uncertain.

The Los Angeles District accepted the challenge by offering Alamo Dam as a test example for applying the approach. A team from the district, assisted by RAC Engineers and Economists, lead by David Bowles of Utah State University, will provide the data for the demonstration. The goal of the exercise is to help the Corps learn more about what is involved in conducting a risk analysis for dam safety. Of special interest is the state of the science for quantifying the probabilities and outcomes necessary to calculate overall risks and to measure risk reduction.

The results of the demonstration will be used to guide the initial efforts in the new R&D program, Risk Analysis for Dam Safety.

A total of three team meetings will be held to complete the analysis. The first was June 15-17 in Phoenix, AZ and included a site visit. The second team meeting will be at the Los Angeles District office. This meeting will review the results of analyses conducted by the district and provide estimates of the probabilities of loading events and system responses. The final team meeting will review the results and provide an assessment of the process. For further information contact:

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Information on the Net

The Institute for Water Resources (IWR) World Wide Web (WWW) home page address is as follows:

http:/www.wrc-ndc.usace.army.mil/iwr/index.htm

At this location reports, newsletters, working papers, and other types of IWR research products may be downloaded in a format identical to the original hardcopy publication. Such products on the IWR home page cover a wide spectrum of research topics as there are products representing work from each of IWR's divisions:

- Research and Technical Analysis Division,
- Navigation Division,
- Policy and Special Studies Division, and
- Program Analysis Division.

Some of the products are also the result of inter-divisional cooperation. The myriad of topics include: wetland mitigation banking reports, alternative dispute resolution case studies, national drought study reports, navigation news, environmental evaluation investment program reports, and information and reports of the risk program.

Newsletter Communication

To comment on the newsletter. Suggest topics, or to submit an article, please contact Mr. David Hill at:

CEWRC-IWR-R

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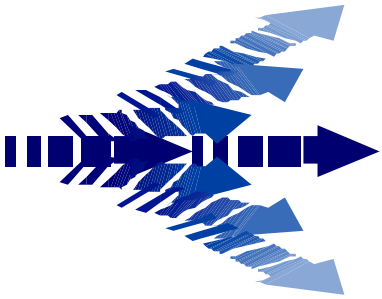

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Articles and/or Case studies describing or summarizing the process of applying developed risk and uncertainty principles and guidance to a project in planning or construction are welcomed.