Institute for Water Resources

RISK ANALYSIS FOR WATER RESOURCES INVESTMENTS

NEWSLETTER

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A MESSAGE FROM THE PROGRAM MANAGER

The objective of the Risk Analysis for Water Resources Investments research program is to develop improved techniques for decision making in the planning, engineering, operation and management of the Corps water resources infrastructure. The need for risk-based analysis extends across all of the functional areas within the Corps and across all project outputs. The impetus of this newsletter is to provide a forum on risk analysis applications in Corps planning procedures, opening a dialogue between researchers at Corps labs such as IWR, HEC, and WES and Corps engineers, planners, and other professionals at the Division and District offices who apply risk analysis techniques. The ultimate goal of this endeavor is to enhance the overall level of understanding of risk analysis in the Corps: what it is, what it does, how to do it, and what does its results tell the analyst.

To those not familiar with statistical analysis, risk analysis may seem like an enigma, a black box using indiscernible procedures to produce uninterpretable results. Without practice or use, statistical procedures are hard to grasp, easy to forget, and difficult to apply. Nevertheless, the purpose of risk analysis is not to increase confusion and costs, but to increase our understanding of how our projects will perform measured from both engineering and economic perspectives. Risk analysis increases the information we have about our data and thus, our results, without generating new data. We know that in reality the benefits, costs, and thus the benefit-cost ratio are not going to be exactly what we state in the project decision document. Similarly, the reliability of engineered structures is not always as designed due to construction tolerances and deterioration from age, the environment, usage, and other factors. Risk analysis helps us predict how close reality will be to the results we derived in the planning and design process.

This first newsletter will review the research program in terms of its structure, advances in the state of the practice in risk analysis due to the program, and advances in Corps methodology and procedures fostered by the program.

David A. Moser

A BRIEF HISTORY OF THE RISK ANALYSIS PROGRAM DEVELOPMENT

The impetus for research in risk analysis originated in the office of William R. Gianelli, then Assistant Secretary of the Army. In a letter dated 28 September 1983, he requested, "a substantial program of research which addresses the issue of dam safety assurance for existing structures as it relates to the criteria used in spillway design. In a memorandum later dated that year, 22 December 1983, between HEC and IWR concerning risk analysis for spillway design, the concept of incorporating risk analysis into Corps planning practices is stated as follows, "risk-based analysis is the conflict of the ethical values of the engineering profession with rapid changes in public policy."

In FY 1985, the Dam Safety Research Program was initiated. This program, as it's title suggests, focused upon aspects of risk of failure involving dams and spillways that had been constructed by the Corps. In the early 1980s, The National Weather Service changed the manner in which it calculated the probable maximum precipitation, which forced the Corps to recalculate the probable maximum flood for various projects. The safety of the design of projects constructed under the previous method of calculation then came in question. Risk analysis research was performed to produce analytical tools which would aid in deciding whether some dams and spillways needed to be retrofitted.

In FY 1987, the program expanded to involve aspects of Corps planning procedures and policy, being named the Risk Analysis for Water Resources Planing research program. The program under this title focused upon incorporating risk analysis into broad civil works planning issues. In FY 1992, the program was expanded as the Risk Analysis for Water Resources Investments Program. In this form the program expanded to allow for the inclusion of research into:

(a) specific areas of planning
(b) operations-related risk-cost analyses
(c) engineering needs
(d) program management.

From FY92 to FY94, the Risk Analysis for Water Resources Investments research program has concentrated on three key project areas of the Corps civil works program: flood damage reduction, major rehabilitation, and maintenance dredging.

RESEARCH CONDUCTED FROM FY92-FY94

Flood Damage Reduction.

In flood damage reduction project formulation and evaluation, research results have been used to describe risk-based analysis and identify the sources of engineering and economic risks and uncertainties. More practically, the research has developed procedures for implementing risk-based analysis codified in EC 1105-2-205. Four key areas have been subject for quantifying risks and uncertainties. In hydrologic engineering, methodologies for quantifying the uncertainty in discharge have been advanced. In hydraulic engineering, methods for quantifying the uncertainty in stage for a rating curve have been developed. Geotechnical engineering has advanced the understanding of levee physical performance to quantify the uncertainty of levee stability under load. Economics research has developed methods and analyzed underlying data to quantify the uncertainties in damage for the stage-damage relationship. Finally, methods have been developed for combining this uncertain information to derive the distribution of benefits. Most of these efforts have been advanced in close cooperation and support of ongoing District flood damage reduction studies. There has been almost continual dissemination of the research advances through PROSPECT training, individual District training, special project training, and individual project consultation. Working closely with Districts has assured that the research addresses pressing needs for risk analysis such as stage-frequency uncertainties and uncertainties due to debris flow. These project oriented results have been incorporated in research documentation and training.

Major Rehabilitation.

The focus of research on major rehabilitation has been on both developing procedures to conduct risk-based life-cycle benefit-cost analysis and the quantification of the uncertainty in engineering performance of existing structures and equipment. A spreadsheet-based analysis model was initially developed to combine engineering risks with economic costs over a life-cycle to calculate life-cycle costs and cost reductions from major rehabilitation alternatives. A prototype object-oriented program running under Windows was then developed to overcome the limitations of the spreadsheet model. Both these models were used in field applications to enhance their usefulness, demonstrate shortcomings, and advance their development. For non-hydropower major rehabilitation, methods for developing probabilistic measures of engineering performance of structural components have been developed. A special effort has been extended to describe these reliabilities over time through the use of hazard functions and degradation functions. Methods for quantifying the reliability of navigation structural components such as miter gates and guide walls have been developed. The result of this research has been disseminated through special workshops on structural and hydropower major rehabilitation. These have also been used to distribute the computer software and spreadsheet templates useful for major rehab. In addition, reports, manuals, and ETL's have

been developed and published providing procedures and guidance.

Dredging.

Research on risk analysis applications to maintenance dredging has been conducted in both real time management aids and dredging planning and budgeting. These two areas have common uncertainty issues of channel reliability, dredging performance, and cost. This has allowed joint investigations into these areas that benefit both analyses. In the real time area a risk-based decision support system (DSS) has been developed to assist dredging managers in dredge management. The intention is to provide the manager with risk information related to alternative decisions on when to call dredges and how long to keep dredging. By incorporating uncertainties in sedimentation, dredge performance, and dredge availability, the manager will more fully have the implications of his decision. This approach can assist the manager in dredge deployment and routing to maximize channel reliability within a budget constraint. The maintenance planning and budgeting research has concentrated on the longer time frame decision process. Probabilistic information on sediment, dredging performance, and dredging costs is used to derive a channel reliability-cost tradeoff. This is then compared to a channel reliability-benefit tradeoff relationship to disclose the risk-based reliability that maximizes net benefits. The associated reliability can then be related to the appropriate distributions of dredging costs to develop a probabilistic based annual budget for dredging. This information can also be used to allocate budget reductions to minimize benefit losses. Both models have been developed and tested in cooperation with the field. Advances have been incorporated in PROSPECT training as well as demonstrations for field and dredging industry meetings.

Risk Management.

Management extends across all the areas of risk analysis. Work in this area has provided an organizing structure to each of the three major thrusts of the research. In addition, research in this area has pursued how the Corps and other organizations make decisions involving risks. One of the major problems of risk management is the communication of risk information to both educate and change behavior. Recommendations have been made for improving the acceptance of risk-based methods and information both within the Corps as well was by non-Federal partners.

RISK ANALYSIS FOR WATER RESOURCES INVESTMENTS FY95-

The first additional new directions in risk analysis research were initiated in FY95. These new directions will plot the course of the research program for the next five years. New work to develop procedures for incorporating risk and uncertainty for shore protection and inland navigation were initiated. In both instances, the research is proceeding in cooperation with Districts with ongoing studies. In addition to the new thrusts, ongoing work unit efforts related to structural reliability and performance degradation applicable to major rehabilitation will continue. Software tools to combining uncertainties for major rehabilitation analysis will be refined and extended. Efforts in flood control will refine the tools for quantifying uncertainty in damages and combining uncertainties to derive the uncertainty in project benefits.

Shore Protection. The team effort includes work by the Coastal Engineering Research Center (CERC) at WES, IWR, and the Wilmington District. CERC is using its existing data bases and procedures to provide uncertainties on storm parameters and erosion. IWR is quantifying uncertainties in storm losses based in part on models developed for flood damage analysis. The Wilmington District is developing models to combine this information within a life-cycle framework. It is anticipated that a prototype model will be developed by the middle of FY95 with refinements to be made based on additional research. The approach developed will be available to all Districts with shore protection projects. The capability of the model will be included in existing prospect courses. In addition, workshops for coastal districts will be conducted to introduce the risk-based methodology.

Inland Navigation. Applying risk-based procedures for inland navigation has been recommended. Ongoing District studies are proceeding to develop the basic methodology. Research efforts are being concentrated on verifying the methodology and quantifying key economic uncertainties. The research will use completed and ongoing work from the major rehabilitation research to quantify structural reliabilities and degradations for navigation structures.

Deep Draft Navigation. This area is scheduled to be initiated in FY96. Again a cooperative effort will be used to both assure that the research is immediately useful and to provide a reality check on the proposed procedures. The maintenance dredging research completed will be incorporated in the channel reliability quantification. Additional uncertainties will include tonnage forecasts, vessel fleet forecast, and vessel operating costs. An additional aspect will be vessel safety.

Other. The proposed out-year program is scheduled to extend the risk-based methods with particular emphasis on key variables that were not considered initially. For instance, work on developing methods to quantify uncertainties in rate savings for navigation analysis is proposed. Additional structure types will be subjects of reliability analysis and methods. More broadly applicable research is proposed to quantify NED and financial cost uncertainties and the elicitation and use of expert opinion in risk analysis. Major rehabilitation is proposed to be revisited to identify and classify the key variable types for various rehabilitation projects.

Emerging Issues. The emerging issue most important to risk analysis by the

Corps is the likely national risk assessment legislation before Congress. The passage of this legislation such as H.R. 9, Title III, "The Risk Assessment and Communication Act of 1995," will introduce risk analysis to the Corps regulatory program. In addition, regulations dealing with dredge material management and disposal will be subject to risk assessments and benefit-cost analyses. Finally, Superfund site cleanup might require risk analysis that will consider the extent and nature of the cleanup. This would impact the Corps involvement in Superfund. Completed research will prove valuable in meeting the requirements of this law. In addition, the implementation of the law will demonstrate the wisdom of establishing the program in 1991. Finally, the program may require some refocusing of work depending on the legal requirements for risk analysis that impact Corps programs.

PROGRAM DIRECTION

The Risk Analysis for Water Resources research program has provided valuable contributions to Corps civil works planning, engineering, and operations activities since its inception. Methods developed under the program have been adopted into the everyday activities of the field offices. The results of the program have been disseminated through PROSPECT training, workshops, seminars, conferences, and technical reports. The singular feature of the program of cross disciplinary team work and cooperation has led to rapid, coordinated development of methodologies and tools vital to the Corps program. Tools and technical reports have been adapted and extended to address emerging project specific analysis problems and issues. The continuation of the program under its current, focused structure will assure that agency risk related issues will be addressed in a comprehensive, efficient manner.

PROSPECT TRAINING PROGRAM RISK COURSES

RISK ANALYSIS-WRP&M
Course Number: 349
Session Number: 96-01
Location: Washington, DC
Date: 8 APR 96 to 12 APR 96

RISK-BASED ANALYSIS
Course Number: 209
Session Number: 96-02
Location: Davis, CA
Date: 16 SEP 96 to 20 SEP 96

PRODUCTS AND PUBLICATIONS

REPORTS

IWR:

Contract Report 74-9: A Framework for Uncertainty Management in Water Resources Planning, October 1974

Contract Report 89-P-1: Uncertainty Analysis for Urban Flood Damage Reduction Benefits, January 1989

Socioeconomic Considerations in Dam Safety Risk Analysis, August 1987, IWR Report 87-R-7.

Guidelines For Risk And Uncertainty Analysis in Water Resources Planning, Volume I: Principles with Technical Appendices, March 1992, IWR Report 92-R-1.

Guidelines For Risk And Uncertainty Analysis in Water Resources Planning, Volume II: Examples, March 1992, IWR Report 92-R-2.

Multiobjective Risk Partitioning: An Application To Dam Safety Risk Analysis, April 1988, IWR-88-R-4.

Risk and Uncertainty Analysis Perspectives in Planning, an unpublished paper for IWR by Dr. David Moser, 1989.

Guidebook for Risk Perception and Communication in Water Resources Planning, Part I - Underpinnings and Planning Applications, October 1993, IWR-93-R-13

Guidebook for Risk Perception and Communication in Water Resources Planning, Part II - An Annotated Bibliography, October 1993, IWR-93-14

Development of Prototype Software for Risk-Based Benefit-Cost Analysis of Major Rehabilitation Proposals: Phases I and II, September 1994, IWR-94-R-5

Reliability Assessment of Geotechnical Structures, 4 April 1995, Draft Engineering and Design ETL

WES:

Contract Report ITL-95-2: Event Combination Analysis for Design and Rehabilitation of US Army Corps of Engineers Navigation Structures, September 1993.

Contract Report ITL-95-3: Engineering Reliability and Risk Analysis for Water Resources Investments: Role of Structural Degradation in Time-Dependent Reliability Analysis, September 1995.

Contract Report: Reliability Assessment of Miter Gates, November 1991.

Contract Report: Engineering Reliability of Navigation Structures, January 1992.

Contract Report: Engineering Reliability of Navigation Structures: Supplement No. 1, March 1992.

Contract Report: Reliability Analysis of Mississippi River Lock Number 25 Miter Gates, March 1992.

Contract Report: Reliability Analysis for Deep-Seated Stability of Pile Foundations: Initial Report, October 1992.

Contract Report: Time-Variant Reliability of Rock Anchors for Navigation Structures, December 1993.

Contract Report: Reliability of Hydropower Equipment, April 1994.

Contract Report: Turbine Reliability, August 1994.

Evaluation of Current Data Collection Startegies for Reliability Analysis of Civil Works Structures, December 1995, Technical Report ITL-95-X.

Loading Cycles for the Fatigue Reliability Analysis of Miter Gates, December 1995, Technical Report ITL-95-X.

FORTHCOMING REPORTS

IWR:

Comparing Benefit Estimation Techniques: Residential Flood Hazard Reduction Benefits in Roanoke Virginia, December 1994, Draft Report.

Development of Methodology for Assessing the Economic Cost of Lost Energy and Capacity Due to Unreliable Hydropower Unit Performance, May 1995, Final Draft Report.

Applied Risk Communication Within The Corps Of Engineers, July 1995, Draft Report.

Review And Assessment Of Risk Management Strategies, January 1994, Draft Report.

Evaluation of Risk Analysis As An Alternative to Standards-Based Design By the U.S. Army Corps of Engineers, July 1995, Draft Report.

Risk Analysis for Dam Safety Evaluation: Hydrologic Risk, Final Draft Report.

WES:

Unsaturated Flow Model to Predict Critical Saturation of Concrete Surfaces in Lock Chambers, Technical Report ITL-96-X.

Reliability Analysis of a Reinforced Concrete Drainage Structure, Technical Report ITL-96-XC.

Physical Data Collection for Lock Wall Deterioration, Technical Report ITL-96-X.

Reliability Assessment Model for Concrete Overstressing, Technical Report ITL-96-X.

One-Dimensional Finite Element Thermal Model for Vertical Concrete Surfaces, Technical Report ITL-96-X.

Reliability Assessment of Pile-Founded Navigation Structures, Technical Report ITL-96-X.

GUIDANCE

HEC:

ETL 1110-2-XXXX, "Risk-based Analysis for Flood Damage Reduction Studies," Draft 1 October 1994.

EM 110-2-XXX, "Risk-based Analysis for Flood Damage Reduction Studies," Draft September 1994.

ETL 1110-2-XXX, "Uncertainty Estimates for Non-analytical Frequency Curves," November 1993.

EM 1110-2-1419, "Hydrologic Engineering Requirements for Flood Damage Reduction Studies"

ETL 1110-2-XXXX, "Performance, Function, and Workability of Levee Closure and Interior Facilities Considering Risk and Uncertainty," Draft September 1995.

WES:

ETL 1110-2-532, "Reliability Assessment of Navigation Structures," May 1992.

ETL 1110-2-321, "Reliability Assessment of Navigation Structures, Stability of Existing Gravity Structures," December 1993.

ETL 1110-2-354, "Reliability Assessment of Pile Founded Navigation Structures," September 1995.

ETL 1110-2-547, "Introduction to Probability and Reliability Methods for Use in Geotechnical Engineering," September 1995.

SOFTWARE

HEC:

LIMIT Program for Non-analytical Frequency Curves.

Risk Spreadsheet (Lotus 1-2-3 and @RISK).

NexGen HEC-Flood Damage Analysis Program (Beta version), scheduled release date 1 February 1996.

WES:

RCSLIDE: Reliability and Stability Assessment of Concrete Structures (Beta Version), scheduled for December 1995.

IWR:

Hydropower REPAIR V1.0: Hydropower Risk-based Economic Program for the Analysis of Investments in Rehabilitation, Nov 1995.

ORDERING INFORMATION

To order IWR publications, please contact Ms. Arlene Nurthen at:

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INFO ON THE INTERNET

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, information is provided about current risk analysis projects as well as other research being performed at IWR. Currently we are working to include a full copy of this newsletter in electronic form at this site.

NEWSLETTER COMMUNICATION

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

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