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Installation Restoration Research Program

Summary of a Workshop on Ecological Risk Assessment and Military-Related Compounds: Current Research Needs

by Todd S. Bridges, WES
Janet E. Whaley, U.S. Army Center for Health Promotion and Preventive Medicine

Prepared for Headquarters, U.S. Army Corps of Engineers

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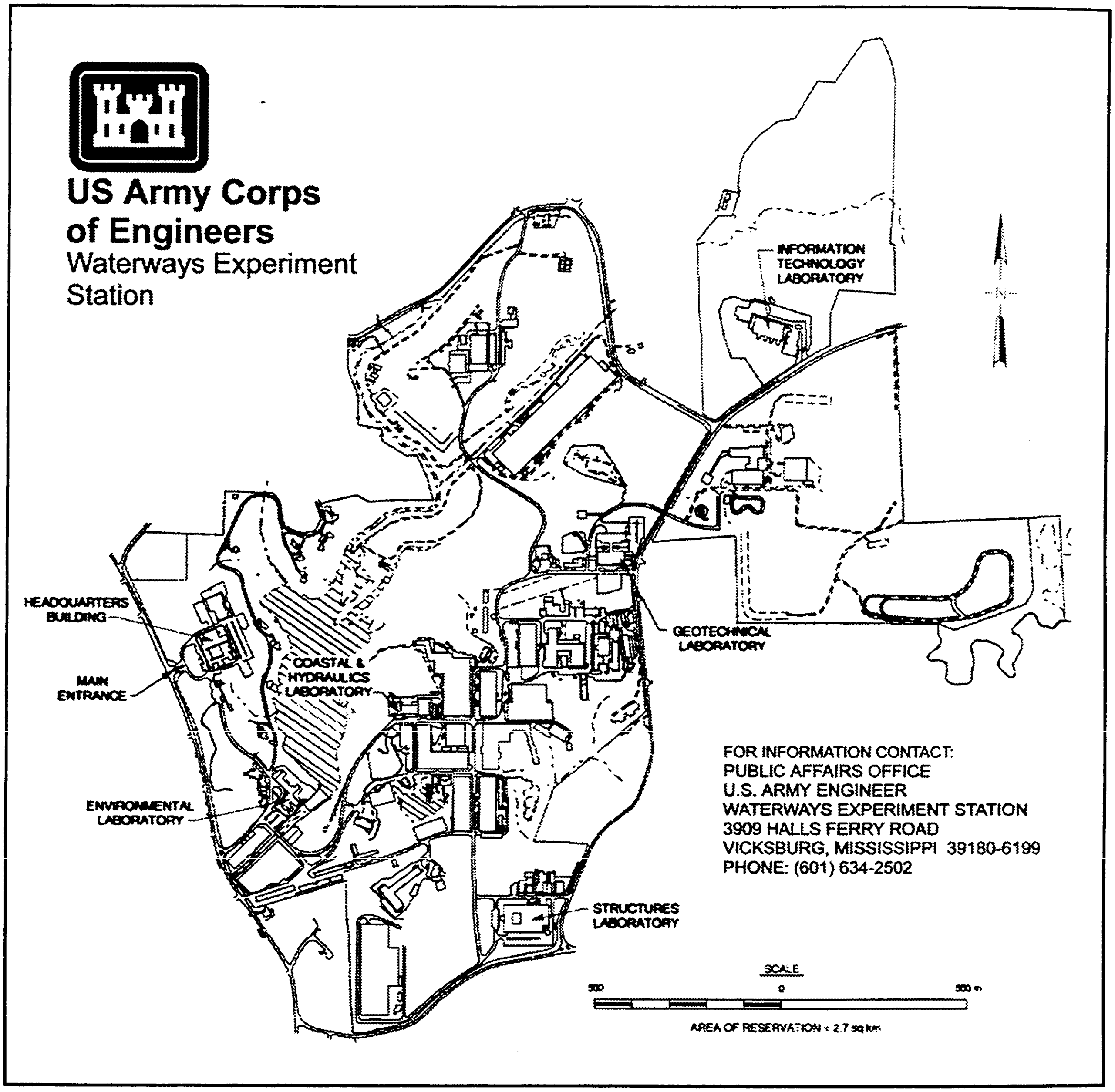

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Contents

Preface

The workshop summarized herein was entitled "Ecological Risk Assessment and Military Related Compounds: Current Research Needs." The workshop was held in Denver, CO, 31 July-2 August 1996. This effort was sponsored by the Department of Army Installation Restoration Research Program (IRRP). Dr. Clem Meyer was the IRRP Coordinator at the Directorate of Research and Development, Headquarters, U.S. Army Corps of Engineers. Dr. M. John Cullinane, U.S. Army Engineer Waterways Experiment Station (WES), was the IRRP Program Manager. This workshop summary report was prepared by compiling the abstracts of papers presented at the workshop and written summaries submitted by the chairmen of four separate discussion groups formed during the workshop.

This summary report was prepared by Dr. Todd S. Bridges, Fate and Effects Branch (FEB), Environmental Processes and Effects Division (EPED), Environmental Laboratory (EL), WES, and Dr. Janet E. Whaley, Health Effects Research Program, U.S. Army Center for Health Promotion and Preventive Medicine. The organizers of this workshop wish to acknowledge and thank each of the workshop participants for their valuable contributions. Special thanks are expressed to Ms. Freda Gibson, WES, for logistical support provided during this project.

The work described here was performed under the general supervision of Dr. Bobby L. Folsom, Jr., Chief, FEB. The Chief of EPED was Mr. Donald L. Robey, and the Director of EL was Dr. John Harrison.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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1 Introduction

More than 21,000 contaminated sites have been identified on Department of Defense (DoD) installations. The scope of this environmental problem is obvious whether one considers the nature and extent of contamination or the amount of resources required to evaluate and/or clean up such a large number of sites. Under most circumstances, decisions regarding the need for and the scope of any cleanup action will be driven by environmental risk assessment. As required by Federal regulation, such assessments must address the potential risk to human health and the environment posed by the contaminants present at any particular site. Over the last 20 years, methods for performing human health risk assessments have developed, matured, and been incorporated into well-established Federal guidance used within various Federal programs and agencies, e.g., Comprehensive Environmental Response, Compensation and Liability Act or Superfund. Greater public concern in recent years has been focused on more general environmental problems resulting from the presence of contaminants in the environment, e.g., the influence of chlorinated hydrocarbons on threatened and endangered bird species. However, the issues involved in making a determination about the broader ecological consequences of contaminant exposure are more complex than those related to human health risk. This fact is most simply illustrated by considering that human heath risk assessments need only focus on the risk to one receptor, humans; whereas, an ecological risk assessment must potentially consider the risk to hundreds of interacting species located at any particular site. This disparity in the complexity involved in human and ecological assessments of risk is further emphasized by the fact that for ecological risk assessments, the number and kinds of receptors (i.e., species) vary considerably from site to site.

One of the consequences of the fact that ecological risk assessments are more complex is that such assessments often require the risk assessor to make many assumptions. In simple terms, this is due to the fact that necessary data are often not available. This may not seem particularly problematic until one considers how "safety factors" are used to overcome data gaps. When data must be extrapolated (e.g., toxicity data extrapolated between different species) to bridge such gaps, the data are typically "adjusted." This adjustment is applied, for example, by reducing the contaminant concentration expected to produce toxicity by a factor of 10, in order to ensure that the value will be protective, given that the true value is not known. A typical ecological risk assessment may include many such adjusted values that collectively drive the level of protection to higher and higher limits.

From the standpoint of ensuring environmental protection, this approach may not seem so bad. However, the costs of such an approach are real. Balancing uncertainty by applying safety factors results in excessively low cleanup levels, and as a consequence, greater cleanup costs. The price paid for ignorance is difficult to determine. Calculating the additional costs associated with cleaning up sites to excessively low levels presumes one has the data needed to calculate more appropriate cleanup levels; research will be required to generate these missing data.

The Fate and Effects Program was formed to fill data gaps and develop tools to facilitate the timely completion of environmental risk assessments at DoD sites and to ensure the establishment of ecologically reasonable/relevant cleanup goals. To this end the Fate and Effects Program sponsored a workshop entitled "Ecological Risk Assessment and Military Related Compounds: Current Research Needs" in Denver, CO, 31 July-2 August 1996. The workshop was attended by over 100 people from the Army, Navy, and Air Force, the Department of Energy, State and Federal regulatory agencies, the private sector, and academia (Appendix A contains a list of attendees). The purpose of the workshop was to provide a forum to discuss needed improvements in the way ecological risk assessments are being conducted on DoD facilities and to determine how future research activities should be directed to fill data gaps and develop needed assessment tools. Forty-two papers related to the subject of the workshop were presented during the meeting (see Appendix B for the meeting agenda). Abstracts for these papers are included in Appendix C. In order to facilitate discussion among workshop participants, four discussion groups were formed to address specific issues relevant to conducting ecological risk assessments on DoD facilities. Discussion summaries prepared by the workgroup chairmen are provided below.

2 Workgroup Summary Reports

Addressing Data Gaps and Uncertainty in Ecological Risk Assessments[1]

Introduction

Risk managers, who are responsible for choosing the most feasible remediation alternative, must understand what uncertainties and professional judgments are included in an ecological risk assessment. Ecological risk assessments are made despite the existence of numerous data gaps and the need for "professional judgments" related to defining both exposure and resulting effects. Ecological risk assessment commonly involves the use of food ingestion models and food web models that require the use of default values. These values are often used during assessments of exposure when there are species-specific data gaps. Such values are selected to be conservative, i.e., they err on the side of protection; the maximum reported or predicted exposure rate for a particular contaminant is typically chosen. Arbitrary uncertainty/safety factors are often selected to extrapolate toxicity information across taxonomic groups and study durations. The uncertainty surrounding final risk estimates is often assumed to be equal even though the uncertainty associated with each of the values used to calculate an overall risk varies substantially. Convention has encouraged the use of these approaches to bridge data gaps while at the same time risk managers and the public rely increasingly on the resulting estimates of risk. The false confidence created in managers and the public in technically uncertain estimates of risk will result in debates over ultimately insignificant differences.

More specific information would help to reduce uncertainty. However, considering the complexity of many natural communities, the intrinsic variability among habitats, the number of compounds and species for which there are no

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[1] Chairmen: Mark S. Johnson, Health Effects Research Program, and Matthew J. McAtee, Environmental Health Risk Assessment and Risk Communication Program, U.S. Army Center for Health Promotion and Preventive Medicine, Aberdeen Proving Ground, MD.

relevant data, the laboratory constraints in the determination of ecologically relevant criteria, and the complex mixture of xenobiotics characteristic of many hazardous waste sites and chemical exposures suggest that these gaps will never be fully explained. Therefore, a more comprehensive and consistent effort to handle these uncertainties is needed, and is the genesis of this workshop session.

Problems identified

The uncertainties described arise from the complexity of quantifying the exposure and effects of xenobiotics for systems composed of many interacting species. Given that not all species for a site can be modeled, a selection process occurs where key species are chosen. Subsequently, their exposure and the effects from the exposure for each of the compounds of concern are investigated. Information gaps arise from both ends of this spectrum. Variation in exposures including daily ingestion rates, home ranges, and seasonal use of habitat are often lacking within and among species. The information used for the determination of effect is absent for many species and for many compounds. The information that does exist may not be particularly relevant if the laboratory end point is not practical at the population level, i.e., if the end point has an unknown effect on growth, reproduction, or mortality, directly or indirectly.

Currently, there is no guidance or uniformity regarding how uncertainty is described or addressed in the risk assessment process. Often included where defaults are used is a brief justification supporting the selection of the default and its probable effect. In addition, a summary of the uncertainties are described at the end of the assessment. However, rarely are there accurate, specific descriptions of the predicted direction and magnitude in which the defaults affect the risk estimate. This results in a general overview of these complex uncertainties that leave the reader (and risk manager) confused and less confident about the risk estimate.

Based on these concerns, three keystone questions were deliberated and developed. Three groups were formed with each being assigned one question. Each group participated in and presented their collective views. These problems/questions can be summarized as follows:

a. Since improvements are needed in the evaluation and communication of uncertainty in risk assessment, how should they be handled?

b. What are the potential, feasible ways of reducing uncertainty?

c. How should toxicological data gaps be addressed?

Possible solutions and recommendations

In order to develop recommendations to the three problems/questions defined in the first half of the session, the three groups developed recommendations concerning the questions they considered. These recommendations are summarized below.

Group 1 — How should uncertainties be handled in risk assessment?

This group suggested approaching uncertainty in an iterative fashion, as the recent ecological risk assessment guidance documents have suggested. The discussion group specifically defined several formal steps that can be followed in order to provide for proper technical consensus and risk communication to stakeholders. Three formal steps are recommended. These steps include tasks that are to be performed during the Data Quality Objectives process, at the Risk Characterization phase, and as a part of the Remedial Selection process.

Step 1. Explicitly address expected uncertainties in the development of Data Quality Objectives (DQOs). The sources of uncertainty and variation should be identified and ranked. Uncertainties should be ranked, at least qualitatively, by both degree and ease of reduction. Most importantly, acceptable levels of uncertainty within each process or evaluation must be defined.

Step 2. Re-evaluate uncertainties at the risk characterization phase. This step should not simply restate the uncertainties described in the Problem Formulation and DQO phases, but should re-evaluate the uncertainties at the end of the process to describe if the DQOs were accomplished. If any variation in data quality or site characteristics has changed the expected degree of, and probable acceptance of, uncertainty, then the effect of such variation should be evaluated and communicated to risk managers. Also, if uncertainties are to be addressed further, uncertainties should be reranked in the risk characterization phase, if warranted.

Step 3. Describe the confidence and uncertainty in estimates for varying risk scenarios. Specifically, quantitatively describe the differences in uncertainty levels for the range of remedy options the risk managers are to select. This can include uncertainty analysis or comparative risk analysis techniques. A weight-of-evidence approach applying a qualitative score to each alternative would be one such example.

Group 2 — What are feasible ways of reducing uncertainty?

It is important to group uncertainties under their appropriate risk assessment phase (e.g., exposure assessment or sampling and analysis phase). This group suggests that the three most feasible ways to reduce risk assessment uncertainty are to improve end point selection, sampling schemes, and toxicological benchmarks.

a. End Point Selection. The primary problem the group identified here is that the connections between the assessment end points and the measures of effect (i.e., measurement end points) are vague and often unclear. Again, an iterative approach in the selection of end points is recommended, where additional tiers would use different and more specific measures of effect.

b. Sampling Schemes. The group suggested that the statistical power of typical methods of sampling and analysis are insufficient to adequately distinguish between variation and uncertainty. The group suggested that the sampling and analysis phase of a risk assessment should follow iterative steps, similar to suggestions for the previous evaluation phases. It becomes crucial to establish a scheme designed to contain an acceptable level of statistical power and analytical prediction. Including probability estimates (e.g., Monte Carlo Analysis), range of potential effects, and weight of evidence approaches would be advisable.

c. Toxicological Benchmarks. The ecotoxicity information used in risk assessments contain knowledge gaps and are often applied inconsistently. The suggested solution to this problem is to develop an inclusive and accessible ecotoxicological database. The database would standardize the values and selection processes for appropriate studies and uses. The Ecotox Data Base developed by the U.S. Environmental Protection Agency (USEPA) is an excellent model, though refinement and accessibility is needed.

Group 3 — How should toxicological data gaps be addressed?

The group recommended that knowledge gaps regarding toxicity should be addressed along two main lines of investigation. Where data gaps exist, data development needs to be attempted if the efforts are not overly time-consuming and/or cost prohibitive.

a. There is a need to improve the toxicity extrapolations across classes of chemicals. For example, quantitative structural activity relationships (QSARs) are applicable to narrowing the knowledge gaps in this area, where appropriate.

b. Reliable estimates of variability are needed for intertaxonomic differences of toxic effect, type of end points (i.e., relevance to population dynamics), and for chronic exposure extrapolation. A peer-reviewed selection of compound-specific uncertainty factors would greatly aid in the risk assessment/characterization process; however, these would have to be agreed to by assessors and regulators alike.

The group suggested considering information from site-specific characterization of risk to fill in the data gaps that exist in the toxicological literature. Indices of biodiversity (including community structure), density estimates, characterization of wildlife health, and analyses of reproductive performance aid in addressing such "holistic" uncertainties as combined effect of multisubstance exposure as well as specifically addressing mechanistic toxicology in specific circumstances. Often these assays can be compared with literature results or compared with a reference site, assuming that other biological and abiotic effects (resulting from other than xenobiotic exposure) are similar.

Summary

The results from this workshop session describe suggestions for reducing uncertainty in ecological risk assessment. It was the consensus of this group that uncertainty could be reduced through thoughtful end point selection, sampling schemes, and the development of an accessible toxicological database. Toxicological data gaps may be improved through the use of QSARs and a characterization of the variability in taxonomic, study duration, and end points of the laboratory data for each group of compounds and animal models. Site-specific qualitative and quantitative assays could be performed and used to address population-relevant criteria for selected measurement end points. An analysis of the uncertainty and expected variation in a risk assessment should be identified and ranked from the start (i.e., at the DQO stage), re-evaluated at the risk characterization phase, and described using a weight-of-evidence approach. These estimates could be further characterized through a probabilistic model (e.g., Monte Carlo Analyses) or a presentation of the range of possibilities.

Bridging the Gap Between Science and Politics[1]

Introduction

The interface between the risk assessor, the risk manager, and interested parties needs to occur at the beginning of a risk assessment and during risk characterization. In addition, discussions should occur during the other phases of the risk assessment to ensure appropriate focus, communication, and coordination.

Topic areas

In this breakout discussion five topics were addressed. They were as follows:

a. Coordinating with risk managers/policy makers.

b. What information assessors should supply to risk managers to aid decision making.

c. Guidance and standardization needs in ecological risk assessment.

d. What are we trying to protect?

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[1] Chairmen: Randall S. Wentsel, U.S. Army Edgewood Research, Development and Engineering Center, Aberdeen Proving Ground, MD, and David Charters, U.S. Environmental Protection Agency, Emergency Response Team, Edison, NJ.

e. Uses of bioavailability and environmental chemistry in ecological risk assessments.

Problems and recommendations

Group 1 — Coordinating with risk managers/policy makers.

a. Risk managers believe that human health risk assessments are more quantitative and certain than ecological risk assessments. This is certainly not true.

b. Without proper coordination between risk assessors and risk managers, risk assessments may be "undirected." Agreement must be reached among regulators, risk managers, and interested parties regarding the scope of the assessment (e.g., when will the assessment be considered complete?). Without this agreement delays and increased costs will result.

c. Regulators and risk managers should be more permanently "fixed" to a particular project or site. The movement and transfer of regulators and risk managers make agreements difficult to enforce.

d. Communication is critical to the DQO process. Agreement must be reached on what the data quality objectives are.

e. Risk managers must be central figures in defining assessment goals. These goals must be agreed to by risk managers, interested parties, and risk assessors.

f. Receptors must be defined before agreement can be reached on a sampling program to provide data for the identified receptors.

g. Consideration must be given to land use in planning an ecological risk assessment, as this can dictate the direction the risk assessment takes.

Group 2 — What information assessors should supply to risk managers to aid decision making.

a. Communicate the importance of coordination for the purpose of consensus building.

b. Communicate the iterative nature of the risk assessment process and the relationship between uncertainty and cost.

c. Educate on the topic of "what is it that we are trying to protect?" Assist in identifying what the ecologically important parameters/attributes of a site are.

Group 3 — Guidance and standardization needs in ecological risk assessment.

a. General ecological risk assessment methods are needed.

b. Specific guidance (versus generic) is needed for some aspects of the risk assessment process. This need would include appropriate exposure models, effects models (bioaccumulation or direct toxicity), and risk characterization methods.

c. Superfund signoffs should be standardized. Increased standardization will reduce waste and delay.

d. The ecological risk assessment process for the tri-services should be standardized. This process should include peer review.

e. A home page on the internet should be developed to facilitate consistency among tri-service organizations.

Group 4 — What are we trying to protect?

To a certain degree this is a site-specific issue. However, the following attributes must be considered: key habitats, niches, species, and ecosystem function.

Group 5 — Uses of bioavailability and environmental chemistry in ecological risk assessment.

a. Initial default is to assume that all chemicals are 100-percent bioavailable. Often this is not true. Environmental chemistry must be used to a greater extent.

b. Bioavailability, bioaccumulation, and trophic transfer models commonly used during the performance of ecological risk assessments need to be validated with field and/or laboratory data.

c. Methods need to be developed to better define contaminant bioavailability in environmental media. Problems to be addressed should include extraction techniques for metals, changes in polycyclic aromatic hydrocarbon availability in soils over time, and soil to plant transfer of contaminants.

d. Environmental chemistry principles (e.g. physical chemistry of contaminants) should be considered before tissue sampling studies are performed. Predictive models should be used to identify bioaccumulative contaminants.

Summary

Participants were able to provide a good deal of guidance on areas to improve risk manager and risk assessor interactions. The critical need for standardization of ecological risk assessment methods was stressed by the group. Discussions on what site attributes should be protected and environmental chemistry issues produced interesting points where further research or guidance is needed.

Screening for Contaminants of Ecological Concern[1]

Introduction

Currently, there is no single standardized method for screening contaminants of concern in the ecological risk assessment (ERA) process. As a consequence, results vary and the process is often overly time-consuming and costly. Furthermore, the lack of a standardized approach is often disconcerting to all those involved in the process. The purpose of this workgroup was to call upon the expertise of the participants to help identify the impedances to the process of screening for the contaminants of ecological concern (COEC), and to make recommendations for resolving these issues. The final objective of this exercise is to convey this information to ERA administrators and managers through publication in these proceedings.

Problems identified

This effort was an interactive collaboration among practitioners and experts in the ERA arena. Participants included those from the Tri-Services (Army, Navy, and Air Force), USEPA, State and Federal Regulatory Agencies, universities, and private industry. The workgroup identified five areas of primary concern within the COEC screening processes. Participants volunteered to address the individual subject areas. They then went on to identify specific concerns within the area, and to make recommendations for resolving these problems.

Within the general subject of "screening for contaminants of ecological concern" (COECs), the five subject areas identified for further discussion were as follows:

a. What are the objectives of a COEC screening process?

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[1] Chairmen: Ronald T. Checkai, U.S. Army Edgewood Research, Development and Engineering Center, Research and Technology Dirctorate, Environmental Technology, Aberdeen Proving Ground, MD, and Janet E. Whaley, Health Effects Research Program, U.S. Army Center for Health Promotion and Preventive Medicine, Aberdeen Proving Ground, MD.

b. How to select an analyte list.

c. How to select a reference/background site.

d. What benchmarks should be used in the COEC screening process?

e. How to consider fate/transport and bioavailability in the COEC screening process.

Possible solutions and recommendations

Group 1 — What are the objectives of the COEC screening process?

Participants considering this question identified three problems and offered multiple recommendations for each.

a. The first problem identified is that the USEPA Framework Paradigm for ERA does not adequately address habitat or the "The Big Picture." The participants recommended that a "weight-of-evidence approach" be used more frequently. Such an approach may justify "No Further Action" at the level of ecological communities.

b. The next problem is that the aesthetic values associated with ecosystems are difficult to quantitatively define, especially in an economic sense. Yet these aesthetic values are often deemed most worthy of preservation. The participants recommended solutions that included the following: (a) accept the qualitative weight-of-evidence approach, (b) obtain deed and zoning restrictions to constrain property usage in order to preserve ecosystems, and (c) do not default to the residential land use scenario, but consider actual planned land use.

c. Lack of early involvement by community members and regulators in the ERA process was also a major concern. Participants recommended that (a) stakeholders' goals be addressed during the COEC screening process, and (b) involved parties should build a consensus document upfront at the DQO development stage.

Group 2 — How to select an analyte list.

The participants in this subject area identified four topics of concern, and provided several conditional recommendations to resolve the issues.

a. One concern was how to address the problems associated with COEC detection limits. Recommendations made by participants for resolving these issues included the following: (a) specify the COEC detection limits in the work plan and within the DQO process, (b) promote early interaction between risk assessors and chemists (it was noted that all too frequently this interaction does not occur until problems arise), and

(c) when COEC detection limits were above screening values, the COEC should be retained for further evaluation in the ERA process.

b. Another concern was how to address the process of obtaining an adequate site history to identify the COEC. Recommendations concerning this issue included (a) performing an extensive records search, (b) interviews with personnel that have had "first-hand experience" with the activities and waste disposal practices at the installation under investigation, (c) considering all existing data regarding the potential for the presence of COEC, (d) identifying data gaps within both the chemical and physical information available on the COEC, and (e) using the bottom-up approach to identify the COEC. The empirical definition of the bottom-up approach is as follows: after reviewing the site history and existing data, all chemicals that could conceivably be present onsite must be considered for inclusion as COEC; in order to remove any from the COEC list, specific rationales must be provided in context and reported within the ERA.

c. If the site history is deemed to be insufficiently complete following in-depth investigation, the recommendation was to take the conservative approach regarding preparation of the COEC list (i.e., invoke the bottom-up approach).

d. Soliciting input into the COEC screening process from all involved or interested parties was identified as an important issue. Two important actions were recommended to resolve both communication and perception problems: (a) early and continuous involvement of environmental regulators throughout the ERA process, and (b) early and continuous input from citizens' groups.

Group 3 — How to select a reference/background site.

Five related problems with selecting reference sites were individually addressed by this group.

a. The ecology of the reference site was deemed to be a matter of critical importance for the COEC screening process. The recommendation of the group was that investigators ensure that the habitat fauna of the reference site is similar to that of the site under investigation.

b. The geology/hydrology of the reference site must also have comparable characteristics with that of the site under investigation. The group recommended that water quality characteristics be taken into consideration and, in this regard, the reference sampling for COEC should be done upgradient of the site under investigation. These considerations apply to both surface and groundwater. For solid media, the geologic/hydrologic characteristics are applied to soils/sediments. The recommendation of the group was that investigators ensure that the same principal soil types are identified and sampled in the reference site, as those found onsite.

c. The proximity of the reference site to the investigation site was an issue of concern. The group agreed that the COEC reference site should be within reasonable proximity of the investigation site. However, the group recommended that the reference site must be outside known COEC screening impact areas.

d. The group recognized that there are other confounding factors in selecting reference sites for the COEC screening process. They recommended that meteorology and climate must be taken into consideration. Also, the presence of complex soils and fill materials on sites must be addressed. Here the recommendation was to call upon the expertise of soil scientists to resolve these issues.

e. In order to establish COEC background levels at a reference site, several recommendations were made regarding the issue of sample design and methodology. The group recommended the following: (a) take a phased/tiered approach to the design of the sampling plan (i.e., the design should be integrated across tiers rather than be subject to a "disjointed" action plan, as the investigation progresses through the tiers), (b) the null hypothesis should be statistically tested, (c) the sample size should be adequate for the analytical determinations specified in the DQO process, and (d) both organic and inorganic COEC must be considered for establishing background reference concentrations.

Group 4 — What benchmarks should be used in the COEC screening process?

The participants in this group recognized the following three issues:

a. Too little toxicity data exist in the literature to establish benchmarks for most compounds. The group attributed this problem to the lack of research funds for establishing benchmark values. They recommended that (a) more research be funded, especially in the area of terrestrial benchmark values (e.g., avian, amphibians and reptiles, soil fauna), (b) existing data should be extrapolated using QSARS, and (c) appropriate surrogate species should be selected, with a focus on site-specific receptors.

b. This group was concerned that the "most conservative species" values are selected during the COEC screening process in an effort to be protective of the environment. They endorsed the selection of site-related surrogates in order to make the COEC screening process relevant and applicable. Overly conservative approaches can negatively influence both risk estimation and risk management decisions.

c. A major concern identified in this discussion group was that the COEC screening process sometimes occurs prior to the selection of assessment end points during the ERA process. The group emphasized that assessment end points should be established before the process of COEC screening begins.

Group 5 — How to consider fate, transport, and bioavailability of contaminants in the COEC screening process.

a. During this discussion, the group determined that many definitions and interpretations of the COEC screening process currently exist. In order to avoid misunderstanding and dissention among the parties with interests in the COEC screening process, it was recommended that consensus be built among all involved parties. This consensus building must be initiated at the onset of the ERA process.

b. The group further recognized that fate, transport, and bioavailability (FTB) issues are sometimes ambiguous at the screening level. However, FTB issues are important enough to the COEC screening process that they should be considered at the screening level. They further recommended that FTB of COEC degradation products also be considered.

c. This group agreed that the identification of potential pathways is a problem area. In considering the FTB of COEC, they recommended that a tiered approach be developed where abiotic/abiotic, abiotic/biotic, and biotic/biotic pathways all be considered.

d. This group addressed the problem of establishing the single best measurement for interpreting the FTB of organic compounds in the environment. Drawing upon their personal knowledge and expertise and following much deliberation, they concluded that the octanol-water partition coefficient (Kow) be used. They further recommended that other values should be considered, including Koc (i.e., the Kow corrected for the soil/sediment organic carbon concentration), Kd (i.e., soil-water partition coefficients), and others.

Summary

Two themes reoccurred throughout the course of individual group discussions. These were as follows: (a) early involvement of community members, regulators, and all stakeholders in the ERA and COEC screening process is critical to success, and (b) the COEC screening process should be approached in a tiered manner, making use of the DQO process. The consensus of this workgroup was that these themes are imperative for effective and efficient implementation of the COEC screening and ERA process.

Planning, Designing, and Coordinating Ecological Risk Assessments[1]

Question 1: How can the DQO process be used to ensure completion of an ERA that adequately answers the appropriate questions?

Responses:

a. The DQO process is the definitive tool in planning, designing, and coordinating an ERA. You cannot do an ERA without going through this process.

b. The DQO process is an essential and critically important planning tool in the ERA decision process. The ERA team must know about and use the DQO process (see U.S. Army Corps of Engineers guidance). Education and communication are key. Success stories should be communicated along with stories that highlight problems.

c. The DQO process defines what the assessment questions are and what data are needed to answer those questions and make decisions. Management plays a key role in supporting the process and ensuring that it is used in completion of ERAs.

d. Toward the goal of ensuring implementation of the DQO process, policy directives should be developed. Critical management people should receive training on the DQO process, in order to promote the DQO process.

e. The DQO process results in ERAs that are as follows:

(1) Cost efficient and effective.

(2) Consistent in their results.

(3) Less arbitrary and capricious in process and outcome.

(4) Legally defensible.

(5) Successful.

(6) Products for which people are accountable.

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[1] Chairmen: Stanley O. Hewins, U.S. Air Force Center for Environmental Excellence, Brooks AFB, TX; David W. Charters, U.S. Environmental Protection Agency, Emergency Response Team, Edison, NJ; and Cheryl Davis, U.S. Army Corps of Engineers HTRW Center of Expertise, Omaha, NE.

Question 2: What are the goals of an ecological risk assessment, and who (corporately) determines what they are?

Responses: This question is much more difficult to answer. Goals are loosely defined in the regulatory world and are specifically defined by the risk assessment/risk management team. Concerns of the group included the following:

a. How is the site different since we got there?

b. What methodology should one use to select the goals. Most responders were reluctant to comment or implied that they did not really know.

c. Issues discussed relative to the subject of goals included the need for the following:

(1) Developing cleanup numbers.

(2) Developing testable hypotheses.

(3) Selecting a range of values for end point measurement is preferable to use of a single point estimate.

Question 3: Partnering—Fact or Fiction: Does partnering really work, and can it facilitate a properly planned, designed, and coordinated ecological risk assessment?

Responses:

a. The goal is to create trust among groups.

(1) Acknowledgment that there is more than one way to do things should be encouraged.

(2) Partners need to be committed—not come and go during the process.

b. There was a major concern that management personnel seem to be the only ones involved in the partnering effort. Technical personnel as well as stakeholders need to be involved at all levels. This makes sense since one tends to listen to and consider the opinions of those one knows.

c. A key step in the partnering process is to assemble the assessor, manager, and regulator at the initial work plan meeting.

d. One mechanism for formalizing "partnering" would be through the development of a formalized tri-agency agreement.

Question 4: Is the DoD's/Department of Energy (DoE)'s "corporate structure" appropriate to optimize the ecological risk assessment process? To what extent have the various agencies developed a formal peer review process to perform "sanity checks" on ecological risk assessments?

Responses:

a. Can a "centralized group" manage the large number of sites present in the DoD or DoE?

(1) DoD/DoE can do a much better job within the current structure if the focus is on dramatic improvement in communication techniques (e.g., this workshop, formalized lessons learned, success stories). There is a definite need for the establishment of a source of "centralized expertise."

(2) More effort should be made in the area of capturing the "stupid" as well as the "smart" stuff each agency/organization does in order that information can be shared?

(3) There is some evidence of movement in the direction of cooperation among the services, e.g., the Tri-Service Eco Risk Group and the subsequent Procedural Guidance is a start.

b. With the exception of the Air Force, there is no formalized peer review program for risk assessments established within DoD. To a certain degree, peer review is being performed, but not through a formalized program. A potential problem associated with the development of a formalized peer review program is that regulators may take exception to "second guessing" after they have given their blessing to a particular project.

Other questions requiring attention were suggested by the group including the following:

a. Applicable or Relevant Appropriate Requirements (ARARs): Does the sum of regulatory compliance necessarily mean that you are adequately managing the site?

b. What do you do with imperfect data?

c. What guidance documents are available for ERA?

d. For the ecological risk assessor, what happens "before" you begin Step 1 in the DQO process? Answer: Visit the site!!

3 Conclusions

Based on discussions held at this workshop, it is clear that two major issues must be addressed with regard to policy and research: (a) the need for communication and (b) the importance of uncertainty.

The need for communication is evident at a number of levels. As much as practical, the Tri-Services within DoD should continue to coordinate their efforts to ensure adequate environmental protection at DoD facilities and should work to standardize risk assessment guidance for performing assessments at military installations. Such coordination will work to conserve both our natural and fiscal resources. The need for communication is also evident at the level of individual projects, e.g., between DoD personnel and regulators and risk assessors and risk managers. Organized forums such as this workshop can help to ensure such necessary communication in the future.

Developing the means to reduce the level of uncertainty associated with characterizing ecological risk and of providing adequate descriptions of uncertainty are critical research needs. In more specific terms, research should be directed in the following areas:

a. *Toxicity data for military relevant contaminants and species.* All too often, the appropriate toxicity data for terrestrial and aquatic species needed to produce an adequate characterization of risk are not available. This is particularly true for many terrestrial species including amphibians, reptiles, and birds. Research efforts should be directed at filling in such critical data gaps.

b. *Trophic transfer.* Many of the contaminants of concern on military installations can be transferred and concentrated in food chains. Technically sound approaches must be developed to quantitatively address the potential risk of exposure and effects resulting from this specific pathway.

c. Screening tools. Screening contaminants of concern at a particular site can be a very time-consuming and expensive process. Software tools should be developed to aid in the process of screening contaminants of concern during the performance of ecological risk assessments.

e. Descriptive tools. Quantitative techniques and software tools should be developed to characterize ecological risk and describe the associated uncertainties. Because fiscal resources are limited, management decisions must be justified in quantitative terms.

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Appendix B
Workshop Agenda

Wednesday, July 31

Plenary

8:00 a.m. Welcome Remarks and Introductions (Janet Whaley and Todd Bridges)

8:20 a.m. *Tri-Service Activities in Ecological Risk Assessment.* Randall Wentsel, U.S. Army Edgewood Research, Development, and Engineering Center

8:40 a.m. *Overview of Corps Ecological Risk Assessment Program.* Kathleen Forgét, U.S. Army Corps of Engineers Hazardous, Toxic and Radioactive Waste Center of Expertise

9:00 a.m. *Overview of Air Force Ecological Risk Assessment Program.* Stan Hewins, U.S. Air Force Center for Environmental Excellence

9:20 a.m. *Characterizing Ecological Risk: Recent Developments.* Simeon Hahn, U.S. Naval Facilities Engineering Command-Northern Division

9:40 a.m. **Break**

Session A (Chair- Janet Whaley, USACHPPM)

10:00 a.m. *Chemical Metabolism as a Determinant of the Appropriateness of Test Species.* John C. Lipscomb, U.S. Air Force Armstrong Laboratory; and Carol M. Garrett and Patricia D. Confer, Geo-Centers, Inc.

10:20 a.m. *Comprehensive Assessment of Background Soil Geochemistry.* Carol L. Bieniulis, Foster Wheeler Environmental Corporation

10:40 a.m. *Analyses for Military Unique/Relevant Compounds to Meet Risk Assessment Needs.* Ann B. Strong, Karen F. Myers, and Richard A. Karn, U.S. Army Corps of Engineers Waterways Experiment Station

11:00 a.m. *Risk Assessment at Army Firing Ranges: Understanding Military-Unique Ecological Risk.* Matthew McAtee and Lawrence Tannebaum, U.S. Army Center for Health Promotion and Preventive Medicine

11:20 a.m. *Analysis of Explosives in Plant Tissues: Modifications to Method 8330 for Soil.* Steven L. Larson, Ann B. Strong, Karen Myers, Sally Yost, Lynn Escalon, and Don Parker, U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS

11:40 a.m. *Computer Simulation and Experimental Investigation of the Sorption Energetics on Clay Soils.* S. L. Larson, J. W. Adams, and C. A. Weiss, Jr., U.S. Army Corps of Engineers Waterways Experiment Station

Session B (Chair- Todd Bridges, USAE-WES)

10:00 a.m. *Exposure Assessment Models for Military Unique Compounds.* Mark S. Dortch and Patrick N. Deliman, U.S. Army Corps of Engineers Waterways Experiment Station

10:20 a.m. *Comparison of Deterministic and Monte Carlo Analyses for Evaluating Risks to Ecological Receptors with Contaminant Uptake Models.* J. W. Hayse and I. Hlohowskyj, Argonne National Laboratory

10:40 a.m. *Development of Ecological Risk Assessment Tools at the Oak Ridge Laboratory.* Daniel S. Jones and Bradley E. Sample, Oak Ridge National Laboratory

11:00 a.m. *Methodology for Integrating Ecological Risk Assessments with Geographical Information Systems Approaches to Support Risk Management Decision Making.* John G. Wegrzyn, Susan C. Kennedy, and Douglas N. Cox, Harding Lawson Associates

11:20 a.m. *Demonstrating the Integration of an Ecological Risk Assessment with GIS at a DOD Facility.* Lori A. Torikai, Khalil H. Nasser, and John Wegrzyn, Harding Lawson Associates

11:40 a.m. *Ecotoxicological Implications of Irrigating Field and Garden Crops with Groundwater-Levels of RDX and TNT.* Ronald T. Checkai, U.S. Army Edgewood Research, Development and Engineering Center; and Mike Simini, Geo-Centers, Inc.

12:00 p.m. **Lunch**

1:30 p.m. **Breakout Discussion Sessions**

A - Bridging the Gap Between Science and Politics (Chairs- Randall Wentsel, USAERDEC, and David Charters, USEPA)

B - Screening for Contaminants of Concern (Chairs- Ronald Checkai, USAERDEC, and Janet Whaley, USACHPPM)

3:00-3:30 p.m. **Break**

5:00 p.m. **Conclusion Day 1**

Thursday, August 1

Session A (Chair- David Moore, USAE-WES)

8:20 a.m. *Addressing Data Gaps in Ecological Risk Assessment.* Mark S. Johnson and Laura S. Franke, U.S. Army Center for Health Promotion and Preventive Medicine

8:40 a.m. *Solution Techniques Used in Ecological Risk Assessments at Southern California Navy and Marine Corps Bases.* Christopher J. Leadon, U.S. Naval Facilities Engineering Command South West Division

9:00 a.m. *Use of an Inhibition Concentration Approach in the Extrapolation of Sublethal Toxicity Results.* Robin D. Zimmer, IT Corporation; David Brancato and Kathy McClanahan, U.S. Army Corps of Engineers-Nashville District; and Gregory Sylwestor, IT Corporation

9:20 a.m. *Using Habitat Evaluations to Plan and Focus Terrestrial Risk Assessments.* Letitia Savage, Baker Environmental

9:40 a.m. *Refinements to an Ecological Risk Assessment: Multiple Lines of Evidence and Risk Uncertainties.* Norman Richardson, Nancy Roka, Jeffrey Pickett, and John McKinnon, ABB Environmental Services; and Keith Williams and Jackie Howard, U.S. Army Center for Health Promotion and Preventive Medicine

10:00 a.m. **Break** (Chair- Jody Cline, USAMRD-WPAFB)

10:20 a.m. *Ecological Risk Management.* R. Merril Coomes, Harding Lawson Associates

10:40 a.m. *A Tiered Approach to Screening Ecological Risks at Ecologically Relevant Scales at a Complex Superfund Site.* Frank Vertucci, ENSR Environmental Toxicology and Risk Assessment; and Mark C. Lewis, SM Stoller Corp.

11:00 a.m. *How Can the Data Quality Objectives Process Be Used During the Design and Conduct of Ecological Risk Assessments*? Frank Vertucci, ENSR Environmental Toxicology and Risk Assessment; Gordon Bilyard, Pacific Northwest National Laboratory; and John Bascietto and Heino Beckert, U.S. Department of Energy

11:20 a.m. *Bioassay Methods for Risk Assessment of Chemical Contamination and Site Remediation at Naval Weapons Station, Concord.* C. R. Lee, J. W. Simmers, and D. L. Brandon, U.S. Army Corps of Engineers Waterways Experiment Station

11:40 a.m. *Evaluating the Toxicity of a Contaminated Sediment: The Scientific and Regulatory Challenge.* T. S. Bridges and D. W. Moore, U.S. Army Corps of Engineers Waterways Experiment Station

Session B (Chair- Patricia Hovatter, ORNL)

8:20 a.m. *Methodology for Development of Ecological Criteria and Screening Benchmarks for Nitroaromatic Munitions Compounds.* Sylvia S. Talmage, Dennis M. Opresko, and Patricia S. Hovatter, Oak Ridge National Laboratory

8:40 a.m. *Ecological Risk Assessment and Development of Site-Specific Remedial Goal Options for Explosives and Metals to Protect Ecological Receptors at an Ammunition Plant.* Barney W. Cornaby, Thomas P. Burns, Charles T. Hadden, Stephen V. Mitz, Connie D. Samson, and Alfred N. Wickline, Science Applications International Corporation

9:00 a.m. *Uses Versus Misuses: A "How To" for Selecting Ecological Cleanup Levels.* Thomas M. Biksey and Jodi A. Golden, Baker Environmental, Inc.

9:20 a.m. *Detailed Soil Survey in Ecological Risk Assessment: Locating Background Soil Samples.* Ronald T. Checkai, U.S. Army Edgewood Research, Development and Engineering Center

9:40 a.m. *Radiological Benchmarks for Ecological Risk Assessment.* Kathryn A. Higley, Dept. of Nuclear Engineering, Oregon State University

10:00 a.m. **Break** (Chair- Barbara Larcom, USAF-Armstrong Labs)

10:20 a.m. *Assessment and Management of Explosives Toxicity and Risk to Avians: A Case Study at Joliet Army Ammunition Plant, Illinois.* Matthew McAtee and Lawrence Tannenbaum, U.S. Army Center for Health Promotion and Preventive Medicine

10:40 a.m. *Toxicological Evaluation of 2,4,6-Trinitrotoluene in Cotton Rats (Sigmodon hispidus) for Ecological Risk Assessment.* A. M. S. Chandra and C. W. Qualls, Jr., Oklahoma State University; and Gunda Reddy, U.S. Army Center for Health Promotion and Preventive Medicine

11:00 a.m. *An Ecological Risk Assessment for the American Kestrel at Rocky Mountain Arsenal—Use of Site-Specific Data.* F. M. Applehans, Foster Wheeler Environmental Corporation; R. R. Roy and M. Sorsby, U.S. Fish and Wildlife Service; and L. DiNorcia, Geo-Centers, Inc.

11:20 a.m. *Ecological Risk Assessment of Protected Species at a Military Installation.* M. L. Jones, S. T. Faulk, C. Lukin, and M. J. Kochel, Foster Wheeler Environmental Corporation

11:40 a.m. *Methods for Ecological Risk Assessment for Military Smokes and Obscurants and Endangered Species.* Keturah Reinbold, U.S. Army Construction Engineering Research Laboratories

12:00 p.m. **Lunch**

1:30 p.m. **Breakout Discussion Sessions**

A - Planning, Designing, and Coordinating Ecological Risk Assessments (Chairs - Stan Hewins, USAF-AFCEE; Cheryl Davis, USACE-HTRW; and Connie Merting, NAVFAC-South Div.)

B - Dealing with Uncertainty and Extrapolation (Chairs - Mark Johnson and Matt McAtee, USACHPPM)

3:00-3:30 p.m. **Break**

5:00 p.m. **Conclusion Day 2**

Friday, August 2

Session A (Chair - Cheryl Davis, USACE-HTRW)

8:30 a.m. *An Evaluation of Composting for Soils Contaminated with TNT.* Michael Honeycutt, U.S. Army Corps of Engineers Waterways Experiment Station

8:50 a.m. *Ecological Risk Assessment Issues at DOE Facilities.* Elizabeth Kelly, Los Alamos National Laboratory; and William Roy-Harrison, U.S. Department of Energy

9:10 a.m. *Problem Solving Aspects of Evaluating Ecological Risks of Military Related Compounds at the Fort Devens Military Reservation and the Sudbury Training Annex, MA.* A. Rawa, S. Peterson, R. Kim, C. Mach, and H. Pirela, Ecology and Environment, Inc.

Session B (Chair - John Paul, USA-APG)

8:30 a.m. *Importance of Attitudes and Perceptions Toward Environmental Contamination and Clean-Up Activities in Risk Assessments.* C. R. Lee, U.S. Army Corps of Engineers Waterways Experiment Station

8:50 a.m. *Environmental Management of Artillery Impact Areas in Future Use.* John W. Simmers and Richard A. Price, U.S. Army Corps of Engineers Waterways Experiment Station

9:10 a.m. *Evaluation of White Phosphorus Contamination in Wetlands of the Fort McCoy Artillery Impact Area.* Richard A. Price and John W. Simmers, U.S. Army Corps of Engineers Waterways Experiment Station

9:30 a.m. **Break**

Plenary

10:00 a.m. *Overview of U.S. Environmental Protection Agency Superfund Ecological Risk Assessment Program.* Dave Charters, U.S. Environmental Protection Agency Environmental Response Team

10:20 a.m. **Breakout Session Chair Reports**

11:45 a.m. **Wrap-up (Todd Bridges)**

12:00 p.m. **Workshop Concludes**

Appendix C
Abstracts

An Ecological Risk Assessment for the American Kestrel at Rocky Mountain Arsenal--Use of Site-Specific Data. **F. M. Applehans,[1] R. R. Roy,[2] and M. Sorsby,[2] and L. DiNorcia[3]; [1]Foster Wheeler Environmental Corporation, Lakewood, CO, [2]U.S. Fish and Wildlife Service, [3]Geo-Centers, Inc., Rockville, MD**

Literature values have frequently served as the source for species-specific input parameters when modeling potential ecological risks at Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) sites because of the scarcity of site-specific biota data. Models based primarily on literature values serve as a good starting point or screening process on which to estimate risk and base remediation decisions; however, the results of these modeling efforts may not be reflective of site conditions and may overestimate or underestimate potential risks. Site-specific variations in feeding habits, habitat usage, prey availability, and contaminant bioavailability all contribute to the uncertainty of models using only literature data. Therefore, site-specific data are preferred to literature data when performing ecological risk assessments. This presentation will focus on the collection of site-specific data and its use to calculate potential risk for the American kestrel at the Rocky Mountain Arsenal. The sensitivity of the model to variations in selected input parameters will be explored for the American kestrel by showing the effect of using literature data and site-specific data on areas modeled as having potential risk. The use of site-specific data in ecological risk modeling is critical in providing useful information for risk management decisions at CERCLA sites.

Comprehensive Assessment of Background Soil Geochemistry. **Carol L. Bieniulis; Foster Wheeler Environmental Corporation, Lakewood, CO**

During ecological risk assessments, it is important to properly characterize background geochemistry because natural levels of some metals in soils may result in risk calculations that exceed regulatory guidelines for clean closure. Objective methods can be developed to estimate accurate background concentrations of metals that are scientifically defensible. These estimated background values can then be used for comparing to site-specific data in order to identify contaminant releases and select chemicals of concern for the risk assessment.

Acquiring adequate background data, calculating background values, and using comparative statistics are powerful tools available to the risk assessor to meet the objectives of site investigations. However, the utilization and assessment of background data must be addressed during the planning stage of any project. Planning a background study should take into account the use and disposal practices of suspected site contaminants, the geographic extent of site activities, and the number of background data necessary to adequately assess a facility. If data are adequate and sufficient in size, comparative statistics can be used to evaluate individual samples or the site as a whole. Next, a subjective review of the site-specific military use of metals is necessary to identify which chemicals are a real concern. This general approach has been followed with success in meeting risk assessment requirements for sites in Colorado, New Mexico, Wyoming, and Utah.

***Use Versus Misuse: A "How To" for Selecting Ecological Cleanup Levels*. Thomas M. Biksey and Jodi A. Golden; Baker Environmental, Inc., Coraopolis, PA**

Ecological risks, not human health risks, typically drive remediation at military sites. The misuse of ecological cleanup levels may result in unnecessary remediation because some generic levels may be overly conservative to account for natural ecological variability and the lack of applicable ecological effects data, especially for military contaminants. A decision-making process is proposed as a guide in selecting the appropriate ecological cleanup levels. Starting with the results of the baseline risk assessment, the contaminants are identified that pose a significant risk; then generic, conservative benchmarks are selected as the cleanup levels. At this point, the decision-making process requires input on the potential for habitat destruction and the cost-benefit analysis of the remedial action. If habitat destruction or remediation cost warrant, site-specific cleanup levels are developed. First, the baseline end points are revised as necessary, and site-specific cleanup levels are developed using the appropriate tools (trophic models, biomarkers, bioassays, biosurveys). A "bright line" based on land use, critical habitat, biotransfer potential, and sensitive species is used in the development of the levels. Based on these site-specific cleanup levels, the decision-making process again requires input for the potential for habitat destruction and the cost-benefit analysis of the remedial action. Consequently, an iterative process may be used to compile additional site-specific information to reduce uncertainty and refine the cleanup levels, recognizing that additional monitoring and/or intrinsic remediation may be the best alternative to physical remediation. Details of the process will be complemented by specific examples from Navy sites in Virginia and North Carolina.

***Evaluating the Toxicity of a Contaminated Sediment: The Scientific and Regulatory Challenge*.** **T. S. Bridges and D. W. Moore; U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS**

Predicting the toxicity of a contaminated sediment is complicated by the physical and chemical processes occurring within the sediment matrix that control the bioavailability of contaminants. Some predictive methods have been proposed (e.g., EPA Sediment Quality Criteria, NOAA ERLs and ERMs); however, the utility of these approaches is limited. The use of these methods as screening tools is also questionable given their inability to provide conservative estimates of risk. The most commonly used approach for assessing the potential toxicity of sediments involves short-term bioassays which use lethality as an end point. Chronic sediment bioassays are being developed and used to evaluate effects of longer term exposures to relatively low contaminant levels. Interpreting such tests represents a formidable challenge considering the subtle nature of the effects being measured. Sublethal end points (e.g., growth and reproduction) will respond not only to the presence of contaminants, but to a number of other environmental factors (e.g., grain size distribution, concentration of suspended sediment) that produce so-called nontreatment effects. In addition, evaluating the ecological relevance of small changes in growth and reproduction is problematic. To meet this specific scientific and regulatory challenge, we have developed population models for the test organisms we use in chronic sublethal bioassays (e.g., *Neanthes arenaceodentata, Daphnia magna*). Matrix population models were constructed for these organisms to evaluate the importance to population dynamics of relatively small treatment induced changes in survival, growth, and reproduction. Population models can provide the needed ecological foundation for interpreting chronic bioassay results by linking effects observed on individuals during a bioassay to potential effects on populations in nature.

Toxicological Evaluation of 2,4,6-Trinitrotoluene (TNT) in Cotton Rats (Sigmodon hispidus) for Ecological Risk Assessment. **A. M. S. Chandra,[1] C. W. Qualls, Jr.[1] and Gunda Reddy[2]; [1]Dept. of Veterinary Pathology, Oklahoma State University, Stillwater, OK, [2]U.S. Army Center for Health Promotion and Preventive Medicine, Aberdeen Proving Ground, MD**

The contamination of soil and water with munition chemicals and their degradation products has been reported at certain munition production waste disposal sites and at certain Army installations. The effects of TNT on wild cotton rats were evaluated to identify target organ toxicity that could be used to develop biomarkers for exposure assessment for ecological and health risk assessments. The oral LD50 values for TNT in corn oil were found to be 607 and 767 mg/kg in male and female rats, respectively. The effects of single (male) and multiple oral doses of TNT in corn oil at doses of 0, 75.9, 151.8, and 303.5 for males and 0, 96, 192, and 384 mg/kg for females for 7 days were studied. Hematological, pathological, and biochemical effects were studied 5 hr after a single dose and 24 hr after multiple doses. Five hours after a single dose, there was a significant increase in methemoglobin, but there was no change in hepatic cytochrome P450 dependent enzymes and cytosolic glutathione S-transferases (GST) in males. Cotton rats of both sexes treated for 7 days had hemolytic anemia with reduced erythrocytes, hemoglobin, and hematocrit in high dose groups. Methemoglobin levels were elevated in male rats at mid and high dose. Histopathological analysis of spleen revealed mild to marked congestion and hematopoiesis in all treated rats. At high dose, pathological changes in liver (hepatocellular swelling and increased pigmented Kupffer cells) and testis (exfoliated spermatozoa, dilated seminiferous tubules) were observed. Hepatic drug metabolizing enzymes analysis revealed that microsomal O-dealkylase of methoxy, ethoxy, and pentoxy resorufin activities were not affected, but cytosolic GST activities were elevated significantly in male and female rats after 7 days. These results suggest that hepatic GST and hemolytic anemia may be biomarkers of cotton rats of terrestrial contamination with TNT or other nitroaromatic explosive compounds.

Detailed Soil Survey in Ecological Risk Assessment: Locating Background Soil Samples. **Ronald T. Checkai; U.S. Army Edgewood Research Development and Engineering Center, Aberdeen Proving Ground, MD**

In terrestrial ecosystems, soils are the repositories for chemically persistent pollutants in the environment. By their nature most soils tend to sorb many such pollutants, reducing acute toxicity. But ultimately through buffer action, soils also become the media source for a reduced rate of entry of such pollutants into the food chain, and ultimately the focus for possible ecological risk assessment (ERA) and remediation efforts. Detailed soil surveys have been prepared for most counties throughout the United States by soil scientists. Unfortunately, soil surveys as field resources for ERA have frequently been overlooked, although detailed soil surveys contain a wealth of information useful to ERA in support of Superfund sites, Base Realignment and Closure, and Installation Restoration. Detailed soil surveys locate, identify, and define soil types/phases/associations on aerial photographic maps by mapping symbols, and in textual descriptions of soil properties and profiles. Detailed soil surveys are invaluable tools for locating and identifying soil types with similar properties, as are needed for background/comparison samples to those in polluted areas. Furthermore, modern soil surveys include additional information on soil physiography, relief, drainage, and geology; weather/climate; and land uses and resources. Use of detailed soil surveys in ERA helps locate appropriate background/comparison soil samples, thus reducing uncertainty in ERA and soil-remediation decision making.

Ecotoxicological Implications of Irrigating Field and Garden Crops with Groundwater Levels of RDX and TNT. **Ronald T. Checkai[1] and Michael Simini[2]; [1]U.S. Army Edgewood Research, Development and Engineering Center Aberdeen Proving Ground, MD, and [2]Geo-Centers, Inc., Aberdeen Proving Ground, MD**

This project is the first to investigate and characterize plant uptake of RDX and TNT from groundwater levels of contamination. These studies establish baseline data for uptake of RDX and TNT from irrigation waters containing groundwater levels of RDX and TNT for both crop and garden plant species grown to maturity. Plants were irrigated in an environment-controlled greenhouse to water holding capacity in soil from the NPL Superfund site Cornhusker Army Ammunition Plant (CHAAP). Nominal (actual) irrigation treatments of 2 (1.8), 20 (18), and 100 (90.2) ppb RDX; 2 (1.9), 100 (92.8), and 800 (742.4) ppb TNT; 100 (90.2) ppb RDX +800 (742.4) ppb TNT; or ASTM Type I water. Potential for uptake of RDX and TNT by each species was maximized. Soil loading of RDX and TNT in response to evapotranspirative demand was tomato > alfalfa = corn = soybean > bush bean > lettuce > radish. Uptake of RDX into lettuce leaves, corn stover, and alfalfa shoots was positively correlated with treatment level. RDX was not significantly ($p = 0.05$) taken up into tomato fruit, bush bean seeds and pods, radish roots, and soybean seeds. TNT was not significantly taken up into the tissues of any of the crops. Yield and biomass of tomato fruit, bush bean fruit, corn stover, and soybean seeds were significantly ($p = 0.05$) less when irrigated with the RDX+TNT treatment compared to controls. Lettuce leaf, radish root, and alfalfa shoot yield and biomass were unaffected by treatment level. Mean RDX levels in plant tissues reached highest levels for those tissues that included leaves. For TNT there appears to be nil hazard at these levels. There is no indication that either RDX or TNT at CHAAP groundwater levels are actively bioaccumulating in plants. Plant tissues that are consumed by humans did not exceed the highly conservative human health risk limit of 190-ppb RDX, previously established for the CHAAP site in conjunction with USEPA, for human food safety.

Ecological Risk Management. **R. Merril Coomes; Risk Management Programs, Harding Lawson Associates, Denver, CO**

This presentation recommends a strategic ecological risk management approach that follows agency guidance, but does not rely on an ecotoxicological or hazard index (HI) approach to make risk management decisions. Effective environmental risk management requires understanding the limitations and potential misapplication of an ecotoxicological (HI) risk assessment process. For example, an HI risk assessment approach that uses benchmark concentrations as decision criteria often identifies potentially unacceptable risk for very small increases in chemical concentrations in environmental media. The ecotoxicological approach focuses narrowly on chemical-specific, toxicologically oriented assessments of single issues in the ecosystem. Ecotoxicologists and ecologists seldom communicate the important issues during the performance of a single risk assessment to ensure that a functioning ecology is considered. EPA's experience shows that even when chemical-specific criteria are met, an ecosystem may continue to be unhealthy, and even if a habitat is optimal (cleanup criteria are met), wildlife populations may not exist. Unfortunately, regulatory agency decision makers often inappropriately equate a numerically high HI with ecological assessment end points and risk. In addition, risk managers do not generally evaluate the potential ecological effects of proposed remedial actions. These remedial action effects need to be considered during the planning phase of data collection for the risk assessment. In order to evaluate assessment end points, expressions of the valued ecological resources to be protected, one needs to use an ecological approach to risk assessment. The presentation will discuss alternative strategies to perform ecological risk assessments that are not limited to the current chemical paradigm.

Ecological Risk Assessment and Development of Site-Specific Remedial Goal Options (RGOs) for Explosives and Metals to Protect Ecological Receptors at an Ammunition Plant. **Barney W. Cornaby,[1] Thomas P. Burns,[1] Charles T. Hadden,[1] Stephen V. Mitz,[1] Connie D. Samson,[2] and Alfred N. Wickline[2]; Science Applications International Corporation (SAIC), Engineering and Environmental Compliance Group (EECG), [1]Oak Ridge, TN, and [2]McLean, VA**

The Alabama Army Ammunition Plant (ALAAP) near Childersburg, AL, was built in 1941 on approximately 13,200 acres of land. Operated during World War II, ALAAP produced nitrocellulose, single-base smokeless powder, tetryl, trinitrotoluene, and dinitrotoluene and used many metals too, such as lead. ALAAP was maintained in standby status until the early 1970s. The Army wants to certify remaining Area B (approximately 2,200 acres)—a mix of pine and hardwood forests, old fields, abandoned buildings, and water bodies where many wildlife species live—free of contamination, but the extent and magnitude of these and other contaminants must be understood and managed properly. Therefore, soils, sediment, surface water, groundwater, and biota are being investigated to determine the level of contamination that exists.

The ecological risk assessment relied on all the state-of-the-practice tools: assessment end points, measurement end points, and decision criteria; exposure factors for various receptors and habitats; site-specific bioassays; quotient method and weight-of-evidence. Ecological dose-responses for TNT, DNT, tetryl, and breakdown products and selected metals were identified in the appropriate literature and organized for ecological receptors found at ALAAP, e.g., plants, fish, crayfish, herons, rabbits, hawks. Also, site-specific bioassays of seeds, earthworms, *Hyalella*, and *Ceriodaphnia* were conducted. Emphasis is on lowest-observed-adverse-effect-levels for each receptor and each chemical. Contaminants of concern were as follows: in soil, nine metals (especially aluminum and lead) and 2,4-DNT; in sediment, seven metals (especially arsenic and lead); and in water, four metals (especially manganese).

RGOs are being developed for these ecological receptors. Contaminant body burdens were measured in fish, crayfish, and cottontail rabbits. These measurements provide more realistic data for exposure models of human and nonhuman ingestion and for, of course, RGOs. RGOs were calculated as concentrations in each medium below which adverse effects are absent or minimal to ecological receptors. These RGOs are being systematically compared to soil, sediment, and surface water concentrations measured at many locations at ALAAP. Possible risk and effects were inferred where the RGOs were exceeded. Follow-up bioassays are being completed in the summer of 1996.

This technical paper champions the use of data quality objectives, quotient method, and weight-of-evidence in conjunction with site-specific body burden and bioassays. RGO development builds on these tools and promises to make this part of the work more credible in the feasibility study.

Exposure Assessment Models for Military-Unique Compounds.
Mark S. Dortch and Patrick N. Deliman, USAE Waterways Experiment Station, Vicksburg, MS

Several models have been developed to provide exposure assessments to determine the effect of various chemical concentrations on human health. Transport and transformation of military-unique compounds

(MUCs) occur within soil, sediment, groundwater, surface water, and air. Exposure assessment through these various media is required to effectively screen the potential risks associated with MUCs. Potential multimedia exposure assessment models include the Multimedia Environmental Pollutant Assessment System (MEPAS), Multiple Media (MULTIMED), Residual Radioactivity (RESRAD), and Multimedia Soils (MMSOILS). The Department of Energy developed and supports the MEPAS and RESRAD codes, while the Environmental Protection Agency supports the MULTIMED and MMSOIL codes. A review of these multimedia models indicates that MEPAS has the broadest capabilities. An overview of MEPAS will be presented along with an example application to a military site. This presentation should help foster discussions on linking exposure assessment to effects for ecological risk assessment.

***Characterizing Ecological Risk: Recent Developments*. Simeon Hahn; U.S. Naval Facilities Engineering Command-Northern Division, Lester, PA**

The Center for Naval Analysis, at the request of the Assistant Secretary of the Navy, Installations and Environment, conducted a study of the utility of ecological risk assessments in the CERCLA program. The majority of the principal findings related to the degree of risk characterizations and how the results are used in the remedial process. Northern Division, Naval Facilities Engineering Command, in cooperation with EPA Region I and Natural Resource Trustees, is collaborating on an effort to improve risk characterization using a recently developed weight of evidence approach. The approach is being used to finalize an ecological risk assessment for the Portsmouth Naval Shipyard. The approach integrates measurement end point attributes such as data quality, strength of association to the assessment end point, and study design, with outcomes (i.e., response and magnitude of measurement end point) and uncertainty to characterize risk to assessment end points. This should allow stakeholders (risk managers) to further understand the ecological risk assessment process and improve their ability to make risk-based remedial decisions.

***Comparison of Deterministic and Monte Carlo Analyses for Evaluating Risks to Ecological Receptors with Contaminant Uptake Models*. J. W. Hayse and I. Hlohowskyj, Environmental Assessment Division, Argonne National Laboratory, Argonne, IL**

Ecological risk assessments often include contaminant uptake modeling using single-point estimates of input parameters to provide point estimates of risk for wildlife receptors. In this deterministic approach, uncertainty and variability are typically addressed only in a qualitative manner. Human health risk assessments, which employ deterministic methods to estimate risk, are beginning to employ Monte Carlo analyses to show the combined effects of uncertainty and variability in the model input parameters on the calculated risk. In this presentation, we compare and contrast deterministic and Monte Carlo-derived risk estimates for wildlife at a former ordnance disposal site. The deterministic approach predicted daily contaminant doses to wildlife using single point estimates for media contaminant concentrations and ecological exposure factors. Risk estimates obtained using the deterministic approach predicted contaminant doses exceeding acceptable dose levels for over half of the modeled receptors. For the Monte Carlo analyses, statistical distributions were assigned to the input parameters that most greatly affected the deterministic model outcome, and Monte Carlo analyses were performed by varying the values of these parameters. The Monte Carlo results identified only a low probability of exceeding acceptable dose levels for most of the contaminants and receptors. Differences in the risks predicted that using the deterministic and Monte Carlo approaches could result in selection of different remediation goals and actions, with different associated costs, for the same area of contamination.

***Radiological Benchmarks for Ecological Risk Assessments*. Kathryn A. Higley; Department of Nuclear Engineering, Oregon State University, Corvallis OR**

As part of the ecological risk assessment process at the U.S. Department of Energy's Rocky Flats Environmental Technology Site, potential chemicals of concern (PCOCs) were identified. Because of the nature of work conducted at the site, radionuclides were included in the list of PCOCs. "Benchmark" concentrations (amounts of radionuclides in environmental media that do not pose harm to biota) were needed as part of the ecological risk assessment screening process.

Radionuclides present hazards through two routes of concern: external and internal exposure. However, a single metric can be used to assess potential impact: absorbed dose (a measure of energy deposition in tissue). Radionuclide benchmarks were established based on limiting the dose to the sensitive species to the equivalent of 100 mrem/day. An iterative approach was taken in constructing the benchmarks: the dose limit was selected, limiting tissue concentrations were generated, and environmental concentrations for the radionuclides of concern were back-calculated. Environmental concentrations of radioactive PCOCs were derived using commonly accepted radiological modeling techniques and tools.

Radioactive materials typically represent a small fraction of the contaminants of concern in military remediation activities. However, the technical approach used to develop screening-level benchmarks for radionuclides in ecological risk assessments has relevance to other military-unique/related compounds. This presentation will cover the approach used to develop the screening methodology for radionuclides, discuss the strengths and weaknesses in applying these benchmarks in the field, and provide media-specific benchmarks developed for two military relevant contaminants: ^{239}Pu and ^{238}U.

Addressing Data Gaps in Ecological Risk Assessment. **Mark S. Johnson and Laura S. Franke; U.S. Army Center for Health Promotion and Preventive Medicine, Health Effects Research Program, Aberdeen Proving Ground, MD**

Due to limited species-specific toxicological information and to our lack of understanding regarding chemical-induced population dynamics, a modeled approach to assessing ecological risk addresses only a subset of the potential effects. We present qualitative and quantitative site-specific methods which, when used in conjunction with a modeled approach, assist in addressing these gaps and aid in describing potential populational effects at hazardous waste sites.

Development of Ecological Risk Assessment Tools at the Oak Ridge National Laboratory. **Daniel S. Jones and Bradley E. Sample; Oak Ridge National Laboratory, Oak Ridge, TN**

Significant environmental contamination has resulted from more than 50 years of operations on the Oak Ridge Reservation (ORR). Beginning in 1989, ecological risk assessments (ERAs) have been performed for at least 10 sites on the ORR. Problems and solutions identified in the process of performing these ERAs are outlined below.

Problem: While the EPA's ERA framework outlines the general principles underlying an ERA, specific guidance is lacking.
Solution: Guidance for conducting ERAs was developed to guarantee the consistency and quality of ERAs on the ORR. This guidance defines components of an ERA, provides generic conceptual models, identifies data needs and responsibilities, summarizes potential end points, and presents approaches for characterizing risks. A weight-of-evidence approach to evaluate risks to clearly defined end points at the most appropriate spatial scale is emphasized.
Problem: Standardized toxicity values for ecological end points are needed to conduct an ERA.

Solution: Chemical-specific toxicological benchmarks were developed for aquatic and sediment biota, plants, soil/litter invertebrates, and wildlife. Chemicals include many metals, PCBs, pesticides, VOCs, other organics, and recently, explosives. A PC-based database has been developed to facilitate the use of these benchmarks. These benchmarks have been distributed to all DOE sites, have been made available on the Internet, and have been adopted in part by the EPA. In addition, detailed, contaminant-specific ecotoxicological profiles that include exposure and effects distributions are being developed.

Additional problems and solutions that we are working on, such as evaluation of habitat and population-level effects, site-specific remedial goals, and soil-biota contaminant transfer factors will be summarized.

***Ecological Risk Assessment of Protected Species at a Military Installation*. M. L. Jones,[1] S. T. Faulk,[1] C. Lukin,[2] and M. J. Kochel[2]; Foster Wheeler Environmental Corp., [1]Denver, CO, [2]Bellevue, WA**

A quantitative ecological risk assessment was performed to determine potential adverse effects posed by chemical contamination for two State-protected mammal species (Skull Valley pocket gopher and spotted bat) known to occur or potentially occur within the confines of the U.S. Army Dugway Proving Ground, Utah. Surface soil and prey items were analyzed for metals, (cadmium, lead, and mercury). Receptor-specific biological parameters and the use of a geographic information system allowed the risk assessment to be tailored to the very different natural histories of the two mammals. A grid of interpolated soil concentrations was created for the entire base using measured soil concentrations and knowledge of site history. Spatially averaged soil exposure concentrations were calculated using receptor home range areas. Doses were stochastically computed using the probability density functions of soil exposure concentration data, biomagnification factors, and measured prey concentration data. An extensive literature search provided the ecotoxicological benchmark values for the contaminants, and hazard quotients were computed. The use of receptor-specific information and a geographic information system for spatial analysis of contaminant concentrations and animal exposure allowed a more precise estimate of risk for these two State-protected mammal species.

***Ecological Risk Assessment Issues at DOE Facilities*. Elizabeth Kelly[1] and William Roy-Harrison[2]; [1]Los Alamos National Laboratory, Los Alamos, NM, [2]Department of Energy, Germantown, MD**

With the increased interest in potential ecological risks or impacts associated with past, current, and future Department of Energy (DOE) activities, DOE sponsored this study to (a) evaluate the effectiveness of the current compliance-driven environmental protection and assessment efforts relative to ecological concerns, (b) explore the need for an integrated, big-picture approach for assessing ecological risks or impacts, and (c) identify the requirements for such an approach, if deemed necessary.

Evaluations of the effectiveness and efficiency of compliance-driven activities at DOE facilities with respect to protection and assessment of impacts to ecological resources were based on an extensive review of environmental protection regulations and in-depth interviews with individuals at DOE facilities responsible for implementing these regulations.

Interviews were also conducted with industry environmental managers from several nationwide firms. The goal of these interviews was to learn about industry issues and approaches to provide a basis for comparison with those of DOE and to glean from industry useful information for DOE environmental managers.

This paper presents the results of the document review and interviews and a discussion of the study conclusions based on these results. A major conclusion of the study is that high-level guidance is needed to direct the development of a big-picture, integrated approach for ecological impact assessments at DOE facilities. This paper also discusses the requirements for such an approach, and describes lessons learned at a DOE facility that implemented these requirements in an attempt to streamline data collection activities.

Computer Simulation and Experimental Investigation of the Sorption Energetics on Clay Soils. **S. L. Larson,[1] J. W. Adams,[1] and C. A. Weiss, Jr.[2]; [1]Environmental Laboratory, [2]Structures Laboratory, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS**

A primary goal of the U.S. military cleanup effort is to develop technologies that can expedite the remediation of explosive contaminants in soils. Nitroaromatic explosives are known to be extremely resistant to degradation in soils, with as much as 20 to 50 percent of radio-labeled explosives not accounted for in controlled degradation studies. [1,2] This high loss rate suggests that absorption of explosives onto clay substrates renders them unavailable to conventional extraction methods. Thus, there is a need to investigate the reaction chemistry of energetics in soil. The approach used to study the nature of explosive contaminant/clay material associated complexes employs a variety of disciplines: geological soil characterization techniques, analytical chemical techniques, and theoretical chemical investigations.

Sorption/desorption experiments have been performed to determine the behavior of explosives and explosive by-products on purified clay soils. X-ray diffraction studies of measuring the interlaminar distance expandable clays show and expansion as contaminants are bound to the clay.

In addition, we performed computational simulations of explosive-clay interactions to gain insight into the absorption process. Hydrophilic clay lamellar structures posses high ion exchange site density where chemical and physical activity may occur. Strong adsorption of organic explosive molecules onto clays should decrease the mobility of the explosives effect remediation treatment processes.

We investigated the sorption behavior of the explosives TNT and RDX and their proposed breakdown chemicals to some common clay minerals. The clays used include expandable smectitic and nonexpandable kaolinitic clays. Experimental data were integrated into molecular dynamics computer experiments.

[1]Carpenter, D. F., McCormick, N. G., Cornell, J. H., and Kaplan, A. M. (1978). "Microbial transformation of ^{14}C-labeled 2,4,6-trinitrotoluene in an activated-sludge system," *Applied Environmental Microbiology* 35(5), 949-954.

[2]Pennington, J. (1990). "Proceedings of the sixth Corps chemists meeting, 16-17 May 1989," Miscellaneous Paper EL-90-14, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Analysis of Explosives in Plant Tissues: Modifications to Method 8330 for Soil. **Steven L. Larson, Ann B. Strong, Karen Myers, Sally Yost, Lynn Escalon, Don Parker; Environmental Chemistry Branch, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS**

A great deal of interest has been generated recently in the determination of explosives and explosives by-products in exotic matrices including composts, bioslurries, and plants. The methods traditionally utilized for the analysis of organic and inorganic contaminants in these types of environmental samples are not adequate due to the unique properties of the energetic material being studied. The contaminants of interest are thermally labile and span a relatively broad range of molecular properties.

Knowledge of the concentration of the contaminants and the molecular state of their degradation products is helpful in assessing the environmental risks associated with the contaminants as well as the design of remediation technologies. Examples of remediation technologies that necessitate the analysis of other than standard matrices for explosives include composting, aerobic and anaerobic microbial degradation, and plant-assisted degradation. The toxicity and mobility of explosives in the food chain is also of interest, and analytical techniques for studying explosives in plant and animal tissues that provide valid information regarding trace levels in theses matrices are also required.

The presentation will address three important points in connection with the problem. The extraction of the contaminants from the matrix requires a different set of extraction techniques from those utilized for standard water and soil extractions. These exotic matrices contain much higher organic content than soil or water and, as a result, are prone to interference from biological molecules. Most matrices require some type of sample cleanup step, and a number of methods will be discussed.

Solution Techniques Used in Ecological Risk Assessments at Southern California Navy and Marine Corps Bases. **Christopher J. Leadon, Southwest Division, Naval Facilities Engineering Command, San Diego, CA**

Solution techniques for assessing ecological risks from hazardous materials contamination are described in this paper using examples from Installation Restoration (IR) Program sites at Navy and Marine Corps bases in southern California. Specific examples of setting up scoping, screening, baseline, and presumptive remedy eco-risk assessments are shown for IR sites in terrestrial and brackish-water ecosystems. The example IR sites are located at the Defense Fuel Support Point, San Pedro, Salton Sea Test Base, Marine Corps Air Station, El Toro, Marine Corps Base, Camp Pendleton, and Long Beach Naval Complex. The solution techniques include mathematical and statistical analyses of site data and comparisons of these results to the values of similar parameters in the scientific literature. Methods of surveying the components of terrestrial and brackish-water ecosystems are described for planning scoping eco-risk assessments. Federal and State applicable or relevant and appropriate requirements, such as the Federal Endangered Species Act, that affect the estimation of eco-risks are briefly described. Data quality objectives are presented as a statistical basis for estimating the minimum number of samples needed for screening and baseline eco-risk assessments at IR sites. Statistical techniques are described for analyzing site data and literature values to estimate baseline eco-risks. A multivariate analysis is described that was used to delineate zones of ecological risks in the harbor sediments of West Basin at the Long Beach Naval Complex.

Importance of Attitudes and Perceptions Toward Environmental Contamination and Cleanup Activities in Risk Assessments. **C. R. Lee; U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS**

The attitudes and perceptions of individuals involved in decision making must be factored into risk assessment. This is especially true with base closures, where previous military installation properties will be turned over to the public. The risk assessment and the question of how clean is clean must be addressed. Individuals involved in the decision making could include the public, environmental watchdog groups, regulatory agencies, and politicians. Issues such as the level of contamination that can be tolerated or the level of risk that can be tolerated will need to be addressed. Methods of evaluating the attitudes and perceptions need to be identified and developed.

Bioassay Methods for Risk Assessment of Chemical Contamination and Site Remediation at Naval Weapons Station, Concord. **C. R. Lee, J. W. Simmers, and D. L. Brandon; U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS**

The nature and extent of heavy metal contamination was assessed using plant, earthworm, and clam bioassays in conjunction with soil sample analyses. The site consisted of terrestrial uplands, transition zones, and wetlands in both freshwater and brackishwater environments contaminated with lead, cadmium, copper, zinc, arsenic, and selenium as a result of uncontrolled discharges of chemical wastes. Test data from the bioassays were used in conjunction with soil data to determine the specific areas of contamination and the need for remedial action. Laboratory plant bioassays showed bioaccumulation of zinc and cadmium in certain locations. Laboratory earthworm bioassays showed bioaccumulation of lead, cadmium, arsenic, and selenium in specific locations. Clam bioassays conducted in the field showed bioaccumulation of zinc, cadmium, lead, and arsenic at specific locations in a stream and drainage ditches along contaminant migration pathways. Bioassay results indicated potential migration of hazardous chemicals from soil into foodwebs associated with these environments. Field-collected small mammals confirmed bioassay test results and showed bioaccumulation of lead and cadmium in those locations indicated by laboratory bioassay test results. Because of the presence of endangered species, remedial action consisted of active excavation of contamination in certain areas and passive monitoring of contamination left in other areas. Plant, earthworm, and clam bioaccumulation tests will be an integral part of the monitoring plan before, during, and after excavation of contaminated soil. Bioassays gave a good indication of the nature and extent of chemical migration into foodwebs associated with the site and were the basis for the risk assessment, the Record of Decision and a litigation settlement for a 17 million dollar cleanup action.

Chemical Metabolism as a Determinant of the Appropriateness of Test Species. **John C. Lipscomb,[1] Carol M. Garrett,[2] and Patricia D. Confer[2]; [1]U.S. Air Force, Armstrong Laboratory, Toxicology Division, Wright-Patterson AFB, OH, and [2]Geo-Centers, Inc., WPAFB, OH**

The appropriateness of a test species is a fundamental, but often overlooked, step in experimental design. Biochemical and physiological variables among species determine which can serve as surrogates for others. Once a chemical is absorbed, metabolism is the primary variable in determining its disposition and toxicity. Metabolism can increase or decrease toxicity. Differences in chemical metabolism among species often determine the manifestation of chemical injury. Chlorinated solvents such as trichloroethylene (TRI) are generally metabolized to more toxic compounds. TRI exists in many groundwater supplies and is extensively metabolized (to chloral hydrate and further compounds) in the mammal. TRI's metabolism in several species was examined because of the high degree to which TRI is found in environmental sites for which DoD has some responsibility, the U.S. Environmental Protection Agency's ongoing reclassification of the carcinogenic potential of TRI, the current reevaluation of chloral hydrate by the U.S. Federal Drug Administration, and the vast database implicating metabolism as a determinant of TRI's toxicity. Based on the historical role of the rodent in determining human health risks, the growing popularity of the medaka as a test species, and other reasons, TRI metabolism was evaluated in the Japanese medaka minnow, the B6C3F1 mouse, the Fischer 344 rat, and the human. Because of the dependence of TRI metabolism on cytochrome P-450 2E1 in the mammal and due to the apparent lack of this particular enzyme in fish, it was hypothesized that medaka would not form toxic metabolites of TRI. Studies in this laboratory have demonstrated otherwise. This paper underscores the need for an evaluation of the mechanism of toxicity and demonstration of that mechanism in the species of interest prior to extensive investigation. (Funded by SERDP and USABRDL).

Risk Assessment at Army Firing Ranges: Understanding Military-Unique Ecological Risk. **Matthew McAtee and Lawrence Tannenbaum; U.S. Army Center for Health Promotion and Preventive Medicine, Aberdeen Proving Ground, MD**

The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) has been tasked to produce ecological risk assessments for Army firing ranges at five installations. Designing for these assessments is most challenging, given the enormity of the sites (upwards of 1 million acres) and the fact that the number of environmental samples to be collected will fall far short of the ideal. The novelty in carrying out these risk assessments is that all of the exposures that ecological receptors receive are "military unique," a term somewhat abused by those who reserve it for describing chemical compounds. The risk assessments to be conducted for the five installations allow for an examination of the actual military-unique context in which our ecotoxicological skills need to be applied. Both USACHPPM's approach to assessing ecological risk as well as our perspective toward applied research directions will be presented for a firing range in excess of 800,000 acres.

Assessment and Management of Explosives Toxicity and Risk to Avians: A Case Study at Joliet Army Ammunition Plant, Illinois. **Matthew McAtee and Lawrence Tannenbaum; U.S. Army Center for Health Promotion and Preventive Medicine, Aberdeen Proving Ground, MD**

The use of toxicological data from laboratory and other studies is crucial for the evaluation of biological risks within ecological landscapes. This type of data does not exist in sufficient quantities, if at all, for explosive compounds and avian species. This situation makes it very difficult and often impossible to quantify risks to avians using traditional techniques without incorporating excessively large amounts of uncertainty. For example, risk assessors have used toxicological data from other classes of organisms (e.g., mammals) to estimate avian toxicity at contaminated sites on military lands, without regard to physiological differences. At the Joliet Army Ammunition Plant, this level of uncertainty was not accepted and a different approach was used. We will present how risks were assessed for the Upland Sandpiper (a State-endangered species), in light of these uncertainties, to address risk management objectives and direct future monitoring and research.

Evaluation of White Phosphorus Contamination in Wetlands of the Fort McCoy Artillery Impact Area. **Richard A. Price and John W. Simmers; U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS**

White phosphorus (WP) was identified as the causative agent of waterfowl mortality in the artillery impact area of Fort Richardson, in the estuarine wetlands of Eagle River Flats (Cook Inlet), Alaska. As a result, the Assistant Secretary of the Army (Installations, Logistics, and Environment) temporarily suspended the firing of WP munitions into wetland areas on 10 Sep 91 and tasked the U.S. Army Environmental Center (USACE) to conduct a survey to determine the extent of the problem. A total of 22 installation impact areas were investigated. Fort McCoy is an active training facility with extensive range usage. As a result, much of the La Crosse River and its tributaries are extensively impacted with 1- to 5-m-diam craters, most of which are full of water. The more recent craters contained only bare wetland soil, and the older craters contained a vigorous growth of wetland plants. The impact area is littered with armored vehicles and civilian vehicles used as targets. Practice and/or unexploded rounds and TOW (tethered ordnance weapon) missile parts were frequently seen. Whitetail deer and some waterfowl were observed in the impact area. WP was detected in the sediments of Fort McCoy wetlands peripheral to the La Crosse River on 14 Oct 1992. Twelve of the forty-five sediment samples contained WP, with concentrations from 0.0007 to 58.0 mg/kg. As this installation does contain active ranges where several kinds of WP-containing munitions have been used in training, and the ranges have resulted in extensive cratering of wetland areas, the risk to waterfowl from WP storage in the Fort McCoy wetlands should be subject to further review.

Problem-Solving Aspects of Evaluating Ecological Risks of Military-Related Compounds at the Fort Devens Military Reservation and the Sudbury Training Annex, Massachusetts. **A. Rawa, S. Peterson, R. Kim, C. Mach, and H. Pirela; Ecology and Environmental, Inc., Arlington, VA**

As part of an Army/USEPA interagency agreement and an accelerated remedial investigation/feasibility study schedule for Base Realignment and Closure sites, Ecology and Environment (E & E) conducted ecological risk assessments (ERAs) for 11 sites at Fort Devens Military Reservation and the Sudbury Training Annex between 1990 and 1995. Fort Devens, the main facility, is a 9,600-acre facility in east-central Massachusetts, located near the Nashua River, and adjacent to the Oxbow National Wildlife Refuge. The Sudbury Annex is situated approximately 40 miles south of the main facility. ERA sites included landfills, artillery and grenade firing ranges, EOD open-burning and detonation areas, storage yards, and abandoned military R&D facilities in various kinds of ecosystems (upland forest and grassland, wetlands, streams, and ponds). Military-related contaminants included explosives, fuels, pesticides, and metals in groundwater, surface water, sediment, and soil. ERAs were conducted under close local, State, and Federal scrutiny and required a sustained community relations and agency negotiation effort. Scientific and regulatory issues encountered in conducting the ERAs included three main categories: (a) addressing community relations concerns, (b) obtaining credible data, and (c) selecting appropriate background/ reference areas. These issues will be discussed in relationship to the 11 ERA sites and to the military base in general. E & E's approach will be discussed and illustrated in a case study involving the use of fish tissue data to evaluate military-related bioaccumulative contaminants.

Methods for Ecological Risk Assessment for Military Smokes and Obscurants and Endangered Species**. Keturah Reinbold; U.S. Army Construction Engineering Research Laboratories**

The military releases smokes and obscurants in the field during training exercises for preparation of troops for combat. The requirement to comply with the Endangered Species Act may conflict with the need to meet military training requirements. In order to provide the information needed to balance these potentially conflicting goals, USACERL is developing and testing methods for ecological risk assessment to realistically evaluate effects of smokes and obscurants on endangered species, their habitat, and their food resources. Direct effects on endangered species must be extrapolated from surrogate species. The proposed methods are consistent with the U.S. EPA Ecological Risk Assessment Framework and address exposure, fate, and effects. Currently, USACERL is assessing risks of fog oil obscurant to the red-cockaded woodpecker (RCW), an endangered species in the southeastern United States. Fog oil obscurant training is restricted, in some cases severely, where RCW is present.

The assessment includes evaluation of the physical and chemical characteristics, dispersion, deposition, and environmental fate and effects of fog oil. End point selection is based on ecological relevance and life history of RCW. Assessment issues and research and development needs will be discussed.

Refinements to an Ecological Risk Assessment: Multiple Lines of Evidence and Risk Uncertainties. **Norman Richardson,[1] Nancy Roka,[1] Jeffrey Pickett,[1] John McKinnon,[1] Keith Williams,[2] Jackie Howard,[2] and James McKenna[3]; [1]ABB-Environmental Services, [2]U.S. Army Center for Health Promotion and Preventive Medicine, [3]U.S. Army Corps of Engineers.**

A baseline Ecological Risk Assessment, which was conducted for an inactive army ammunition plant in 1992, concluded that wildlife receptors that were exposed to certain inorganic and explosives-related contaminants in surface soil could experience adverse population-level effects. In several cases, the magnitude of the risk estimates were extremely high, suggesting that the projected effects were quite likely. The Feasibility Study determined that the ecologically derived preliminary remediation goals (PRGs) would likely drive cleanup at the facility and that remedial costs could be dramatically high. PRGs were based on the original assessment for which site-specific data regarding the nature and magnitude of the actual wildlife exposures were not available and large uncertainties were associated with the derived risk estimates.

We report the results of a reexamination of potential ecological risks at the facility including several studies designed to reduce overall risk uncertainties. Studies such as small mammal prey tissue analysis and small mammal/bird receptor surveys have been conducted to verify contaminant uptake and receptor occurrence assumptions. The potential adverse effects associated with contaminant exposure were also reevaluated and ecological exposures and effects quantitatively described using probability distributions rather than point estimates. Simulation modeling results will be presented that suggests that the original risks estimates, which were based on several conservative assumptions, are unlikely. This weight-of-evidence approach will be used to support responsible, and cost-effective, remedial decision making at the facility.

Using Habitat Evaluations to Plan and Focus Terrestrial Risk Assessment. **Letitia Savage; Baker Environmental, Inc., Coraopolis, PA**

Methodology for ecological risk assessment of terrestrial systems is often less well defined than methodology for risk assessment of aquatic systems. Because the methodology is less well defined, terrestrial risk assessments must be carefully focused. One tool for focusing terrestrial risk assessment and involving terrestrial ecologists early in the process is the habitat evaluation. Habitat evaluations provide basic information on habitats potentially at risk; identify potential receptors for the risk assessment; identify terrestrial habitats of real concern versus those already affected by industry or development; allow risk assessors to adequately address endangered species, wetlands, and sensitive environments; and provide information to assist risk assessors in designing toxicity tests and field studies.

This paper will focus on the habitat evaluation process and describe how it can be used to focus risk assessment for terrestrial systems. Three case studies will be utilized to illustrate the process in action and its application to terrestrial risk assessment. These case studies involve evaluations of multiple habitats including wetlands, sensitive environments, and habitats of endangered species on three military facilities: Marine Corps Base, Camp Lejeune, Jacksonville, North Carolina; Naval Weapons Station, Yorktown, Virginia (an NPL site on Chesapeake Bay); and Naval Base Norfolk, Virginia.

Environmental Management of Artillery Impact Areas in Future Use.
John W. Simmers and Richard A. Price; U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS

Installation managers throughout the Army are aware of the necessity of protecting threatened plant and animal species without compromising the Army mission. Within many installations, unique native American ecosystems exist that are dependent on isolation from anthropomorphic activities for survival. Often the most isolated portions of installations are those areas contaminated in some manner. The contaminants may range from chemical spills to unexploded ordnance (UXO). Artillery impact areas have extensive buffer zones where access is restricted due to UXO. In these buffer zones the ideal conditions of periodic burning and lack of human activities have resulted in the survival of native American ecosystems of near presettlement quality and species richness. While the periodic disturbance of some incoming ordnance, creating explosive and/or contaminant discharges, can be accommodated by a conservative ecosystem, cleanup activities cannot. Disruption by excavation, vehicles, and personnel will permit the establishment of more aggressive Eurasian weeds, and even extensive restoration efforts are unlikely to recover more than 30 percent of the previous ecosystem quality. In general, once a group of uniquely associated species, or ecosystem, has been disrupted, it cannot be restored. In a time of downsizing, base closures and realignments, concerns about UXO, and contaminant cleanup are increasing. The establishment of a protocol to relate the value of the ecosystem that would be destroyed to the value the cleanup would have on the future land use of the site needs to be considered.

***Analyses for Military-Unique/Relevant Compounds to Meet Risk Assessment Needs*. Ann B. Strong, Karen F. Myers, and Richard A. Karn; U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS**

Military installations have become contaminated throughout the years with defense-related compounds such as explosives, propellants, and smokes in addition to the more traditional solvents, fuels, and metals. In order to determine if these contaminants present a problem to the environment or to human health, a risk assessment must be made. Many factors must be considered when making an ecological assessment; but ultimately, the basis for decision will be the concentration of the contaminant in the media of concern and its availability to the environs.

Analytical chemical methods needed to make these assessments are initially developed to identify and quantify contaminants in air, water, soil, or sediment, and investigators then try to adapt them to other matrices of interest. Frequently these methods fail to consider the complexation or degradation that can occur naturally in the environment, sometimes yielding contaminants more toxic or harmful than the parent compound. The environmental pathway of these compounds may result in uptake by plants and/or animals for which there is no readily available analytical technique. Remediation technologies used in various cleanup investigations may introduce analytical interferences requiring innovative methods of analysis. We have found that researchers of cleanup technologies often request determination of analytes that will never be present due to the process that they have used or the origin of the contamination. Adapting analytical methods that have been developed for one purpose may not provide the data needed to resolve questions raised for another. For these reasons, it is important that the researcher, the environmental investigator, the remediator, and the risk assessor work together with the chemist to provide a true appraisal of the environment.

This presentation will focus on analytical chemical methods needed to make ecological assessments of explosives and their degradation products, propellants, smokes (white phosphorus) together with solvents, fuels, and metals in both traditional and nontraditional matrices. Limitations of methodologies will be discussed together with the quality assurance needed to confirm that data meet the investigators requirements.

***Methodology for Development of Ecological Criteria and Screening Benchmarks for Nitroaromatic Munitions Compounds*.** **Sylvia S. Talmage, Dennis M. Opresko, Patricia S. Hovatter; Health Sciences Research Division, Oak Ridge National Laboratory, Oak Ridge, TN**

Nitroaromatic compounds are released into the environment during manufacturing and load, assemble, and pack operations at Army Ammunition Plants (AAPs). The important fate processes affecting persistence and transformation of these compounds in the environment are photolysis and biodegradation. Adsorption to soil and sediment are low to moderate, allowing transport to surface and groundwater. Available data on the aquatic and terrestrial toxicity of eight nitroaromatic munitions compounds and/or their degradation products, 2,4,6-trinitrotoluene, 1,3,5-trinitrobenzene, 1,3-dinitrobenzene, 3,5-dinitroaniline, 2-amino-4,6-dinitrotoluene, RDX, HMX, and tetryl were used to calculate criteria or screening benchmarks that can be used to establish cleanup levels for remediation at AAP sites. For compounds with sufficient aquatic toxicity data, Tier 1 or Tier 2 Water Quality Criteria and Sediment Quality Criteria for the protection of aquatic organisms were derived. For terrestrial mammals, plants, and soil microflora and fauna, toxicological benchmarks were also derived. Toxicological benchmarks for mammalian species were derived in the same manner that Reference Doses for the protection of human health are derived from mammalian laboratory toxicity studies. Screening benchmarks for plants and soil organisms were based on lowest-observed-effect values. These criteria and benchmarks represent concentrations in the environment that are presumed to be nonhazardous to the biota and can be used in ecological risk assessments as a first-tier screening assessment for selecting chemicals of ecological concern or as evidence to support or refute the presence of ecological effects in a second-tier baseline assessment.

***Demonstrating the Integration of an Ecological Risk Assessment with GIS at a DOD Facility*.** **Lori A. Torikai, Khalil H. Nasser, and John G. Wegrzyn; Harding Lawson Associates, Denver, CO**

The presentation demonstrates using a GIS in a hypothetical ecological risk assessment with topographical features of a Department of Defense Superfund site. Detailed topographic maps and other spatial data were used as the basis for developing the GIS demonstration baseline map in ArcView. This baseline map represents man-made and natural attributes that potentially could interact to cause ecological risk at the site. Hypothetical chemical concentration data attributable to abiotic matrices that were stored as Access databases and ecological risk parameters derived through Excel spreadsheets were imported as layers of information into the ArcView. Results and conclusions of ecological risk evaluations are combined with the topographic parameters as layers within ArcView. Risk attributes can be assessed and graphically portrayed to evaluate their spatial relationships with important habitats and other natural resource considerations by querying the GIS database. Advantages and utility of portraying hypothetical ecological risk concepts and approaches through GIS for a DOD facility is demonstrated in detail.

How Can the Data Quality Objectives Process Be Used During the Design and Conduct of Ecological Risk Assessment? **Frank A. Vertucci,[1] Gordon Bilyard,[2] John Bascietto,[3] and Heino Beckert[3]; [1]ENSR Environmental Toxicology and Risk Assessment, [2]Pacific Northwest National Laboratory, [3]U.S. Department of Energy**

Unfocused, poorly designed, and poorly planned ecological risk assessments (ERAs) contribute little support to risk management decisions. For example, the remedial investigations that ecological risk assessments often support are sometimes driven by data requirements for site characterization, rather than the information needs of risk managers. Yet decisions about whether or not to remediate and to what extent remediation is needed are risk based. The Data Quality Objectives (DQO) Process, developed by the U.S. Environmental Protection Agency, is designed to help focus data collection efforts in support of management decisions. To improve the quality and utility of ERAs, DOE's Office of Environmental Policy and Assistance has held two workshops exploring the utility of the DQO process in designing and conducting ecological risk assessments. The objective of this paper is to stimulate discussion of the DQO process and its applicability to ERAs, building on the lessons learned at the DOE workshops.

Contaminated DOE and DoD sites pose many similar technical challenges that may be addressed by applying the DQO process to the response actions. Some difficult issues that may be facilitated by the application of all or part of the DQO process include the following: (a) creation of a focused framework for constructive communication between risk assessors and risk managers, (b) design of ERAs to support risk management decisions, (c) use of historical data, identification of critical data gaps, and design of data collection efforts to fill them, (d) design of ERAs based on ecological units and provision of appropriate information for discreet operable units, (e) designation of ERAs to address more than one regulatory need or application, (f) insertion of DQO process requirements into contracts as a means of keeping the scope of the contracted ERAs in line with the needs of the regulatory decision makers and site risk managers.

The above list is not inclusive but is provided to stimulate further discussion on the use of the DQO process in ecological risk assessment.

A Tiered Approach to Screening Ecological Risks at Ecologically Relevant Scales at a Complex Superfund Site. **Frank A. Vertucci[1] and Mark C. Lewis[2]; [1]ENSR Environmental Toxicology and Risk Assessment, [2]S. M. Stoller Corporation**

Large complex Superfund sites are often divided into discrete operable units (OU) to facilitate the remedial investigation feasibility study process. Interagency facility cleanup agreements, enforcement schedules, budgets, and site management are often organized by operable units. Subsequently, risk assessments are often done on an OU by OU basis. Yet ecological systems, and the communities, populations, and individual organisms they support, have spatial boundaries unrelated to delineation of OUs. To be technically defensible, ecological risk assessments should be evaluated at ecologically relevant scales that often are not congruent with OU boundaries. A tiered screening ecological risk assessment process was implemented at the U.S. Department of Energy Rocky Flats Environmental Technology Site, which resolved this conflict. This paper will describe the process and its applicability to other complex sites.

The risk assessment approach at Rocky Flats was developed with the cooperation of the regulatory agencies and included development of site-wide technical memoranda which included the site conceptual model and a description of the process for objectively and efficiently identifying ecological chemicals of concern (ECOCs) from over 120 potential chemical contaminants identified during RCRA/CERCLA remedial investigations. Data were collected from several abiotic and biotic media in eight operable units and two watersheds. An efficient method for identifying ECOCs was needed so that the risk characterization phase of the ecological risk assessment could focus on the most important chemical stressors and risk could be evaluated at ecologically relevant scales for the receptors identified in the site-wide conceptual model.

The ECOC screening methodology was based on a phased approach with analyses conducted in tiers. Initial screens were conducted using conservative estimates of exposure and toxicity designed to minimize the chance of underestimating risk. Each successive tier provides a less conservative estimate of risk but requires a higher level of effort to complete. Exposure estimates were compared to various ecotoxicological benchmarks to estimate risk and were calculated for cumulative intake from several environmental media, and simultaneously for several aquatic and terrestrial species. Results were organized by 16 ecologically relevant source areas at the site so that analysis could be useful in prioritizing areas for remediation or further investigation based on estimated risk. Results were used to rank chemical and source areas according to their contribution to cumulative toxic risk for each receptor group. Results were presented to environmental regulators, and a consensus on ECOCs was reached. Ecological risk from ECOCs was then evaluated in the risk characterization phase of the risk assessment. Results were interpretable on an OU basis or aggregated at a watershed or site-wide scale.

Tri-Service Activities in Ecological Risk Assessment. **R. Wentsel,[1] S. Hahn,[2] S. Hewins,[3] R. Porter[3]; [1]U.S. Army, Aberdeen Proving Ground, MD, [2]U.S. Navy, Northern Division, Lester, PA, [3]U.S. Air Force, Brooks AFB, TX**

This paper will present information on Tri-Service (U.S. Army, Navy and Air Force) coordination of ecological risk assessment programs. A Tri-Service Working Group on ecological risk assessment was established in 1995. The working group has collaborated on methodologies, procedures, and regulatory guidance. Information will also be presented on a Tri-Service procedural guideline for ecological risk assessment.

Methodology for Integrating Ecological Risk Assessments with Geographical Information System (GIS) Approaches to Support Risk Management Decision Making. **John G. Wegrzyn, Susan C. Kennedy, and Douglas N. Cox; Harding Lawson Associates, Denver, CO**

An efficient approach for evaluating and prioritizing ecological risks at large sites such as Department of Defense (DoD) facilities was developed to evaluate ecological risks present at a U.S. Army post in Alaska. This approach integrates ecological risk assessment (ERA) techniques consistent with USEPA guidance with geographical information system (GIS) approaches to better visualize the receptors and locations at risk, and to provide support for prioritized risk management decision making. A U.S. Army post serves as the geographical backdrop for this hypothetical presentation. A variety of compounds, including mercury, arsenic, DDT, dieldrin, polychlorinated biphenyls, and petroleum hydrocarbons, have been detected at different source areas across the site. Many of the source areas potentially drain to a large river system that traverses the post. Selected indicator species for this hypothetical presentation include small mammals, benthic macroinvertebrates, salmonids, predator species, and raptors. Ecological toxicity data, specific receptor attributes, and hazard estimators were developed using linked Access databases and Excel spreadsheets. In this, the first of two sequential presentations, we describe the methodology used to integrate the results of the individual ERAs with a GIS format. The advantages of portraying ecological risk assessments through GIS are discussed in our second presentation.

Use of an Inhibition Concentration Approach in the Extrapolation of Sublethal Toxicity Results. **Robin D. Zimmer,[1] David Brancato,[2] Kathy McClanahan,[2] and Gregory Sylwester[1]; [1]IT Corporation, Knoxville, TN, [2]USACE HTRW Design Branch, Nashville District**

Careful evaluation and selection of assessment end points at military sites are of paramount importance in successfully quantifying potential hazards or risks to ecological systems. Once the selection is made, however, one cannot dismiss the equally critical task of evaluating and selecting measurement end points. Measurement end points, either field or laboratory based, provide the assessor with quantifiable evidence to predict effects of a hazard on the chosen population, community, or ecosystem level assessment end point(s). Toxicity testing has become a commonly used means to measure laboratory responses to defined or unknown military-related contaminants of concern. Although laboratory-derived toxicity data should not be the sole means to predict potential effects in the field, they are extremely useful when properly applied. This paper presents an argument for use of the inhibition concentration (IC) estimate as a supplement or replacement to the standard No Observable Adverse Effect Concentration (NOAEC) approach when evaluating sublethal toxicity data and especially when extrapolating results from common laboratory species to site-related species. An IC estimate is an interpolative means to calculate the percent reduction in response (growth, reproduction, etc.) or organisms within test treatments relative to control responses. While NOAEC computations provide a single point of reference, an IC computation provides confidence intervals and therefore a more powerful measurement end point, resulting in better predictive powers when extrapolating between species.

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A workshop entitled "Ecological Risk Assessment and Military Related Compounds: Current Research Needs" was held in Denver, CO, 31 July-2 August 1996. The purpose of the workshop was to provide a forum to discuss needed improvements in the way ecological risk assessments are being conducted on Department of Defense facilities and to determine how future research activities should be directed to fill data gaps and develop needed assessment tools. The workshop was attended by over 100 people from the Army, Navy, and Air Force; the Department of Energy; State and Federal regulatory agencies; the private sector; and academia. Forty-two papers related to the subject of the workshop were presented during the meeting. Discussions at the workshop regarding science and policy, selecting contaminants of concern, designing ecological risk assessments, and the issue of uncertainty are summarized in this report. Specific recommendations are made regarding directions for future research.

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