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May 31, 2005

Mr. Michael A. Parker, Director
Chemical Materials Agency
5183 Blackhawk Road
Edgewood Area
Aberdeen Proving Ground, MD 21010-5424

Re: Review and Assessment of the Bechtel National, Inc.–Parsons Infrastructure and Technology Group, Inc., Joint Venture Proposal for the Design and Operation of the Blue Grass Chemical Agent Destruction Pilot Plant at Richmond, Kentucky

Dear Mr. Parker:

As requested by the Department of Defense (DOD) and the Program Manager, Assembled Chemical Weapons Alternatives (PMACWA), the National Research Council (NRC) of the National Academies established a committee—the Committee to Review and Assess the Proposals for Design and Operation of Designated Chemical Agent Destruction Pilot Plants, called the CAPP Committee—to review and assess (1) the design proposal submitted by Bechtel National, Inc., for the design and operation of the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) in Pueblo, Colorado, and (2) the Bechtel National, Inc.–Parsons Infrastructure and Technology Group, Inc., Joint Venture[1] proposal for the design and operation of the Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP) in Richmond, Kentucky (see Attachment A for the statement of task).

The CAPP Committee's first letter report,[2] issued February 14, 2005, addressed the Pueblo Chemical Agent Destruction Pilot Plant. This second letter report addresses only the Blue Grass Chemical Agent Destruction Pilot Plant.

This study was initiated on April 18, 2005, and was to be completed within 45 days. In view of the short study schedule and the nature of the task, this report does not refer extensively to or rely on detailed evidence from published sources to support the CAPP Committee's assessment. Rather, this assessment reflects primarily the consensus views and judgments of the committee members, based on their substantial project and program management experience (see Attachment B). This committee was constituted by the NRC to guarantee a breadth of

[1] The Bechtel National, Inc.–Parsons Infrastructure and Technology Group, Inc., Joint Venture is hereafter referred to as the BPBGT—the Bechtel Parsons Blue Grass Team.

[2] Review and Assessment of the Bechtel National, Inc., Proposal for the Design and Operation of the Chemical Agent Destruction Pilot Plant at Pueblo, Colorado, February 14, 2005.

perspectives by including as members senior executives, engineers, and researchers with extensive and diverse experience in industry, government, and academia.

The Army prepared a request for proposal (RFP) for the BGCAPP that called for disassembly of the Blue Grass chemical munitions, neutralization of the energetics and agent by hydrolysis, and treatment of the hydrolysate streams using supercritical water oxidation to be completed by 2012, the date specified by the modified Chemical Weapons Convention treaty. The Blue Grass stockpile is detailed in Table 1-1.

The CAPP Committee used the BPBGT proposal as the basis for its deliberations.[3] The committee reviewed the BPBGT proposal to determine what systems might be altered and/or eliminated in order to reduce cost and/or schedule.[4] The results of this review (although not explicitly detailed owing to the brief nature of the report) provide an assessment of the proposal, its major costs, and how alternative concepts might potentially reduce both cost and schedule**.** In addition the committee was briefed on the BPBGT proposal[5] and was also made aware of BPBGT redesign efforts[6] intended to identify alternative design configurations that would reduce life-cycle costs.[7]

As with the Pueblo effort, Mitretek Systems is also conducting an independent assessment of BGCAPP at the request of the DOD with the aim of reducing the cost and schedule for the plant. The CAPP Committee received an informational briefing[8] outlining Mitretek Systems' findings and recommendations.

In the near future, a new NRC report that is being prepared by a different committee to address a separate charge will provide an in-depth assessment of the main unit operations and their adequacy to dispose of the Blue Grass stockpile.[9]

STUDY SCOPE AND METHODOLOGY

Figure 1-1 depicts the major components of the BGCAPP design as proposed by BPBGT.

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[3] BPBGT (Bechtel Parsons Blue Grass Team). Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP) Initial Design. Rev. 0, July. Aberdeen Proving Ground, Md.: Program Manager for Assembled Chemical Weapons Alternatives, July 2004. NOTE: The BPBGT proposal is source selection information and qualifies under Subsection 15(b)(3) of the Federal Advisory Committee Act, 5 U.S.C. App., as amended by the Federal Advisory Committee Act Amendments of 1997, P.L. 105-153, December 17, 1997, 111 Stat. 2689. The National Research Council has determined that to release this information to the public would disclose information described in 5 U.S.C. 552(b). The CAPP Committee was granted access to this document under an arrangement that recognized the restricted status of the document.

[4] The "cost" refers to the life-cycle costs, including the construction, operation, and closure of the plant. "Schedule" refers to the 2012 treaty date in the Chemical Weapons Convention signed January 13, 1993, for the destruction of agent.

[5] BGCAPP Munitions Demilitarization Building Intermediate Design, briefing by Chris Haynes, Bechtel Parsons Team, to the CAPP Committee, National Conference Center, Lansdowne, Va., April 18, 2005.

[6] BCGAPP Redesign/Design Consideration Studies, briefing by Chris Midget, Bechtel Parsons Team, to the CAPP Committee, National Conference Center, Lansdowne, Va., April 18, 2005.

[7] The briefings cited contain source selection information that qualifies under Subsection 15(b)(3) of the Federal Advisory Committee Act, 5 U.S.C. App., as amended by the Federal Advisory Committee Act Amendments of 1997, P.L. 105-153, December 17, 1997, 111 Stat. 2689. The National Research Council has determined that to release this information to the public would disclose information described in 5 U.S.C. 552(b).

[8] Independent Assessment of the BGCAPP Design Draft Findings and Recommendations, briefing by Mitretek to the CAPP Committee, National Conference Center, Lansdowne, Va., April 18, 2005.

[9] *Interim Design Assessment for the Blue Grass Chemical Agent Destruction Pilot Plant* by the NRC Committee to Assess Designs for Pueblo and Blue Grass Chemical Agent Destruction Pilot Plants (in progress).

TABLE 1-1 Description of the Chemical Weapons in the Blue Grass Army Depot

Item	Fill	Number	Agent per Munition (lb)	Total Agent (tons)	Energetics	Energetics Weight per Munition (lb)	Total Energetics Weight (tons)
155-mm projectile, M110	H	15,492	11.7	90.63	Tetrytol	0.41	2.9
8-inch projectile, M426	GB	3,977	14.4	28.63	None		
115-mm rocket, M55	GB	51,716	10.7	276.68	Composition B	3.2	74.46
					M28 propellant	19.1	448.99
115-mm rocket warhead, M56	GB	24	10.7	0.13	Composition B		0.035
155-mm projectile, M121/A1	VX	12,816	6.0	38.45	None		
115-mm rocket, M55	VX	17,733	10.1	89.55	Composition B	3.2	25.79
					M28 propellant	19.1	153.95
115-mm rocket warhead, M56	VX	6	10.1	0.03	Composition B	3.2	0.0086

NOTES: Composition B contains 60 percent RDX, 39 percent TNT, and 1 percent wax; M28 propellant contains nitroglycerine, nitrocellulose, and 2-nitrodiphenylamine as a stabilizer; tetrytol contains 70 percent tetryl and 30 percent TNT.
SOURCE: Adapted from data provided to PMACWA on the Munition Items Disposition Action System (MIDAS) by the Munition Items Disposition Action System Team, Savanna, Ill., July 1997.

Previous attempts to reduce the cost of the Blue Grass facility, such as those described in the Mitretek study briefed to the committee on April 18, 2005, have focused on discrete changes to operations or equipment within the facility's major system design components. This has been the case because the basic requirements for the Blue Grass facility to be a total solution for the disposal of the Blue Grass stockpile, as defined by the DOD, were not subject to modification.

The committee focused on the major systems in the BPBGT design and on the integration of these systems, assuming that changes to the basic requirements defined by the DOD could be considered. Because of time constraints, it did not perform a detailed technical engineering evaluation of the unit operations, but instead assessed these in terms of technically feasible alternative configurations and their impact on cost and schedule issues. The committee considers "technically feasible" to imply that, in the committee's judgment, no obvious technical barriers exist; however, detailed analyses of the various options, including in-depth safety and risk analyses, will be necessary to provide confirmation of this assessment.

In the BPBGT design, munitions disassembly is the rate-limiting step. However, it should be noted that there are several process operations that have not been demonstrated in a fully integrated system and that may prove to be rate limiting or even challenging to operate continuously. These include the energetics batch hydrolyzer (EBH) and the supercritical water oxidation (SCWO) process steps.

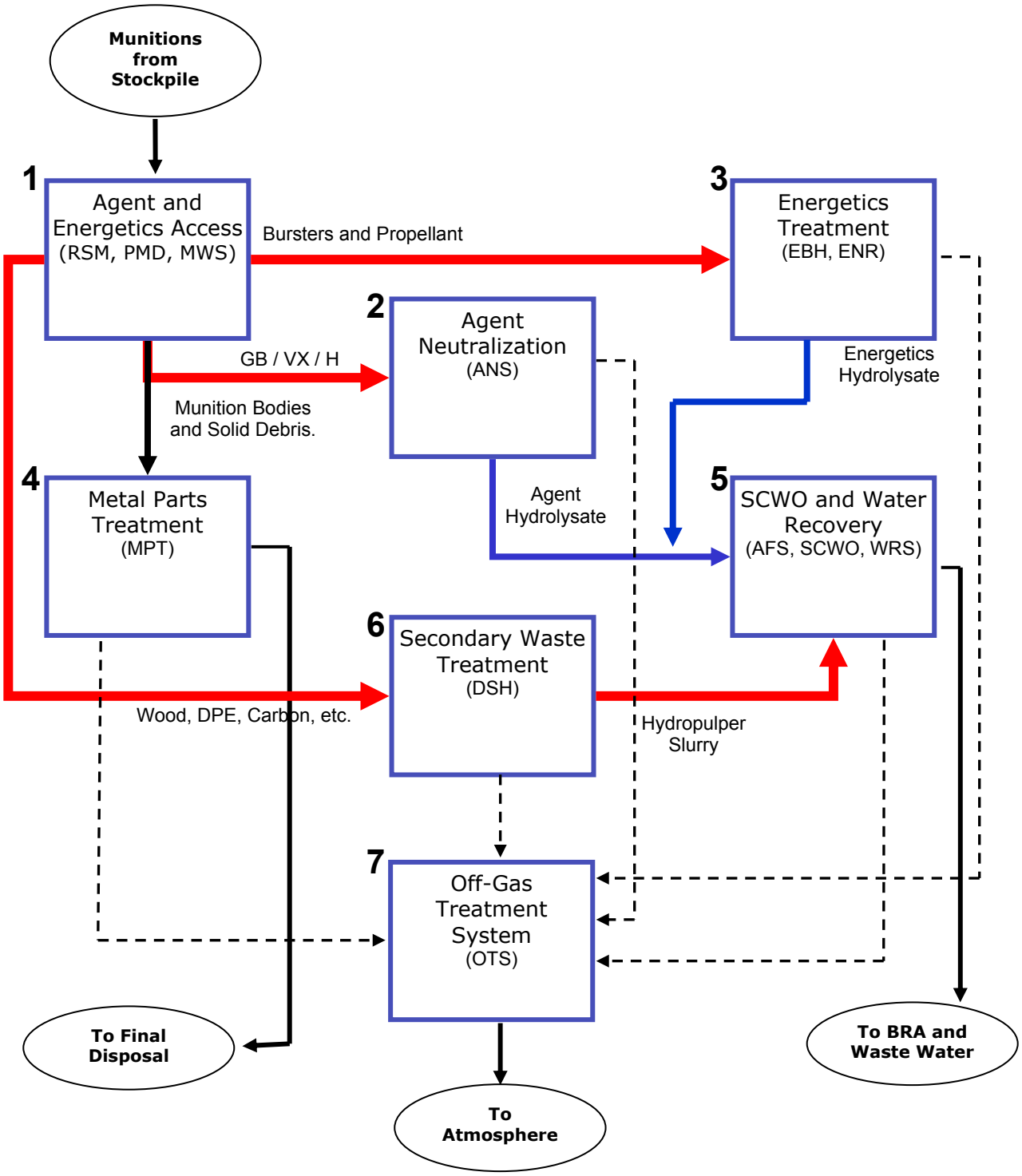

FIGURE 1-1 Major components of the BGCAPP design as proposed by BPBGT.

SOURCE: Adapted from Process Design Overview (Blue Grass), briefing by John Ursillo, BGCAPP Process Design/Technical Risk Reduction Program Manager, to the Committee to Assess Designs for Pueblo and Blue Grass Chemical Agent Destruction Pilot Plants (ACWA Design Committee), Woods Hole, Mass., September 22, 2004.

As a technique for assessing the BPBGT proposal, the committee developed several design alternatives to the BPBGT proposal that, if implemented, could result in substantial cost and/or schedule savings, provided some of the design criteria originally stipulated in the RFP are modified. All of the alternatives proposed by the committee are considered to be technically feasible and utilize technologies that are proven or present a lower risk than those in BPBGT's proposed design, or both. The alternative configurations developed by the committee are illustrative and certainly not exhaustive.

The committee did not restrict itself to the design criteria specified in the RFP, although it recognizes the implications of some of the committee-generated alternatives in terms of public, permitting, political, and legal considerations. Instead, on the basis of its analysis of and judgment regarding technical considerations, the committee developed and evaluated alternative configurations that could reduce cost and/or positively affect schedule.

The committee's methodology was as follows:

- It reviewed the DOD-provided BPBGT proposal for the design of the BGCAPP.
- It received presentations by the DOD sponsor, two informational briefings by BPBGT senior managers, and an introductory briefing by representatives of Mitretek Systems, whose independent evaluation of BGCAPP design alternatives is still in development.
- It identified the factors that it would use to evaluate the BPBGT proposal. After discussion, the committee identified those items in the design that might reduce cost and schedule.
- Based on these items, it developed technically viable alternative design configurations to the BPBGT proposal and possible combinations of alternatives that might reduce the cost and schedule of BGCAPP.

ASSESSMENT FACTORS FOR ALTERNATIVE CONFIGURATIONS

To assess its own alternatives to configurations in the BPBGT proposal, the CAPP Committee selected factors consistent with the overall programmatic goal of safe and expeditious disposal of the chemical weapons stockpile:

- **Technical Feasibility and Operational Risk:** Evaluation of this factor included assessing whether the technology is in commercial use or is under development following completion of detailed engineering design.
- **Integration of the Unit Operations and Availability of Equipment:** Evaluation of this factor included assessing whether a unit operation or alternative configuration could be easily integrated into the overall system and if it would impact the plant's throughput.
- **Permitting and Public Acceptance:** Evaluation of this factor included assessing whether a suggested alternative configuration might encounter barriers to obtaining permits and to the public acceptance of the modification.[10]

[10] The CAPP Committee notes that changes in permits or laws are required, and it recognizes that these processes are fraught with uncertainty and would likely lengthen the time to completion. Therefore, further consideration of any alternative requiring a permit change, new permit, or change in law or regulation should first include detailed discussion with all agencies and stakeholders involved.

- **Plant Closure:** Evaluation of this factor included assessing whether the proposed/suggested course of action would increase or reduce the cost of plant closure.
- **Safety:** Evaluation of this factor included assessing whether the alternative configuration would increase or decrease the safety of the plant's operational staff and the general public when compared with the risk associated with the storage of agent and the activities involving the destruction of the agent in BPBGT's proposed design. This was a preliminary assessment based on judgment and must be verified by detailed risk and safety assessments.

Considering all of these factors in their totality, the committee then made its assessment regarding cost and schedule for BGCAPP:

- **Life-Cycle Cost:** The life-cycle cost includes the construction, operation, and closure of the Blue Grass plant. Evaluation of this factor included assessing whether change to the BPBGT design would increase or reduce the total life-cycle cost.[11,12]
- **Impact on Schedule for Agent Destruction:** Evaluation of this factor included an assessment of the impact that changes to the BPBGT design would have on meeting the time lines for destroying agent.

RATING THE ALTERNATIVE CONFIGURATIONS

The CAPP Committee rated its alternative configurations using the BPBGT design proposal as a baseline. Each of the alternatives was assessed in terms of the factors listed above and each was given a rating of (+), more advantageous; (0), no significant change from the BPBGT proposal; or (–), negative impact. These judgments were based on the committee's joint experience and do not represent a quantitative assessment of the various criteria. However, where a (+) assessment has been made, the committee's opinion is that the impact is significant enough to merit the attention of the DOD.

CONCLUSIONS

The CAPP Committee had neither the time nor the resources needed to validate all of the approaches and assumptions made by the BPBGT proposal. The committee used the data from the BPBGT and Mitretek briefings, in addition to the BPBGT proposal, because these sources provide the most recent analyses of cost and schedule available. However, the committee is not in a position to endorse the accuracy of these data. While the committee considers that the proposed BPBGT design is technically feasible, given the complexity of the equipment, the prototypical nature of some equipment and systems, and externalities such as funding streams

[11] The CAPP Committee notes that when it discussed processing at another site, it was not able to estimate the additional costs or schedule impacts of processing at these sites. Therefore, the estimated cost savings and schedule impacts presented in this report should be adjusted for such impacts.

[12] "Life-cycle costs" as used in this report refer to the total cost of building, operating, and closing the facility for the life of the facility. No life-cycle cost analysis was done for this report.

and community concerns, it is not possible to definitively predict the schedule and cost of the project.

After reviewing the BPBGT proposal and the supplementary analyses, the committee believes that opportunities exist for significant cost reductions in the construction phase, which represents a major portion of the total life-cycle cost in the BPBGT design. However, the schedule must be sacrificed in order to realize these cost savings. Increasing the schedule will increase operating costs and could affect safety. If single-train or single-point failure options are implemented, the risk of an extended operating period could increase costs significantly.

> **Finding:** There are some modifications to the BGCAPP facility and equipment design that could achieve savings in capital and operating cost and in schedule. Significant savings are possible only if the specifications stipulated in the DOD's request for proposal are relaxed in one or more ways. Further, the committee believes that modifications to the design of the facility and equipment that could have a significant negative impact on the safety of the operations staff or the public, compared with the proposed design, should not be considered.

The CAPP Committee identified several alternatives to the design proposed by BPBGT that could offer opportunities for positive impacts on cost and schedule for the Blue Grass facility, but these alternatives require relaxation of some of the original DOD RFP requirements. Some of these alternatives also involve issues with respect to permitting and community acceptance but seem worthy of further evaluation since they all appear to be technically feasible. The committee appreciates that there are challenges associated with continued efforts by the DOD to balance cost savings with requirements to meet existing statutory time lines and previous agreements with the public. The committee believes that the following alternatives to the BPBGT proposal should be considered by the DOD:

- Implementation of three-agent monitoring,
- Solid waste management, including treatment and disposal,
- Use of an explosive destruction system or a controlled detonation chamber for leakers and rejects,
- Elimination of mustard agent processing,
- Replacement of catalytic oxidation treatment of off-gas from energetics treatment and metal parts treatment with bulk oxidation,
- Movement of the off-gas treatment system outside the munitions demilitarization building,
- Reduction of processing rates,
- General design and operations improvement—moving of the fence line and/or moving of facilities out of the chemical limited area, and
- Hydrolysate management, including treatment and disposal.

The committee believes that all of these alternatives are technically feasible and that they would decrease cost and in some cases have a positive effect on the schedule. Combinations of these options (see Tables D-7 through D-10) could produce cumulative savings and should be considered. In some cases incorporating a series of these alternatives could result in significant additional cost savings and/or schedule savings because entire operations might be eliminated,

with the same end results as those anticipated with the current BPBGT design proposal. However, all of the alternatives listed above could require some changes in the current permitting documents and would probably face some public opposition. The alternative of shipping energetics-free mustard munitions to another, existing, chemical demilitarization facility, while saving a large amount of capital, would require significant changes in existing statutes; it would also likely raise public acceptance concerns at Blue Grass and at the receiving site that could negatively affect both cost and schedule if this option were pursued and then ultimately rejected. That same alternative would also require a careful evaluation of the risks associated with the shipment of the munitions and of any additional risks to the workers and the public at the site receiving the munitions. However, the committee believes that shipping mustard-filled munitions can be done safely. If that alternative is adopted, the timing of its implementation becomes very important, since maximum cost and schedule benefit overall can be obtained only if the Blue Grass Army Depot projectiles are available at the receiving facility during its 155-mm H projectile campaign. While shipping munitions filled with the other agents could be accomplished technically, it does present additional challenges and was not considered a viable alternative.

It was a pleasure to undertake this study. We trust that it will be helpful to you and your agency in further deliberations in this challenging arena.

Sincerely,

Peter B. Lederman, *Chair*
Committee to Review and Assess the Proposals
for Design and Operation of Designated Chemical
Agent Destruction Pilot Plants

Attachments:
A. Statement of Task
B. Committee Membership—Roster and Biographies
C. Acknowledgment of Reviewers
D. Assessment (source selection information; not available to the public)

ATTACHMENT A

STATEMENT OF TASK

In response to the request by the Department of Defense and the Program Manager, Assembled Chemical Weapons Alternatives, the National Research Council (NRC) established the Committee to Review and Assess the Proposals for Design and Operation of Designated Chemical Agent Destruction Pilot Plants (CAPP Committee). Those appointed to the expert committee (see Appendix B) included members from various NRC committees familiar with the destruction of chemical munitions. Following is the statement of task for this review:

> The NRC will establish an ad hoc Committee to Review and Assess the Proposals for Design and Operation of Designated Chemical Agent Destruction Pilot Plants (CAPP Committee). This new committee will receive, review, and assess the proposals submitted by Bechtel National, Inc. for the Pueblo Chemical Agent Destruction Pilot Plant in Pueblo, Colorado and the Blue Grass Chemical Agent Destruction Pilot Plant in Richmond, Kentucky to consider the desirability of alternate configurations with respect to cost and schedule. The committee will provide a review to the Army of these proposals to advise them in their procurement decisions regarding award of the task order.

ATTACHMENT B

COMMITTEE MEMBERSHIP—ROSTER AND BIOGRAPHIES

Committee to Review and Assess the Proposals for Design and Operation of Designated Chemical Agent Destruction Pilot Plants

PETER B. LEDERMAN, *Chair,* New Jersey Institute of Technology (Retired), New Providence, New Jersey
CHARLES I. McGINNIS*, Vice Chair,* U.S. Army (Retired), Charlottesville, Virginia
RICHARD J. AYEN, Waste Management, Inc. (Retired), Jamestown, Rhode Island
ROBERT A. BEAUDET, University of Southern California, Los Angeles
RUTH M. DOHERTY, Naval Surface Warfare Center, Indian Head, Maryland
WILLARD C. GEKLER, PLG, Inc., Los Alamitos, California
MARTIN GOLLIN, Carmagen Engineering, Inc., St. Davids, Pennsylvania
DAVID S. KOSSON, Vanderbilt University School of Engineering, Nashville, Tennessee
JAMES F. MATHIS, Exxon Corporation (Retired), Franklin, New Jersey
CHANDRA M. ROY, Exponent Failure Analysis Associates, Inc., Irvine, California
OTIS A. SHELTON, Praxair, Inc., Danbury, Connecticut

National Research Council Staff

BRUCE A. BRAUN, Director, Board on Army Science and Technology
MARGARET N. NOVACK, Study Director
JAMES C. MYSKA, Research Associate
NIA D. JOHNSON, Research Associate
DETRA BODRICK-SHORTER, Senior Program Assistant

Biographies of Committee Members

Peter B. Lederman, *Chair*, who holds a Ph.D. in chemical engineering from the University of Michigan, recently retired as executive director of the Hazardous Substance Management Research Center and as executive director of the Office of Intellectual Property, New Jersey Institute of Technology. He continues to teach environmental management, policy, and site remediation at the institute. He is active as a consultant and is the principle of Peter Lederman & Associates. Dr. Lederman has more than 50 years of broad experience in all facets of environmental management, control, and policy development; considerable experience in hazardous substance treatment and management, as well as in process design and development in the petrochemical industry; and more than 18 years of experience as an educator. He has industrial experience as a process designer and managed the development of new processes through full-scale plant demonstrations. He is well known for his work as a professor in chemical process design. He led his company's safety program in the early 1980s. Dr. Lederman is a registered professional engineer, registered professional planner, certified hazardous material manager, and a diplomat in environmental engineering. Dr. Lederman has also worked at the Environmental Protection Agency and in environmental protection organizations at the state

level, with particular emphasis on environmental policy. A National Associate of the National Academies, he has substantial expertise in chemical engineering, hazardous waste treatment, and educational and corporate leadership.

Charles I. McGinnis, *Vice Chair*, who holds an M.Engr. in civil engineering from Texas A&M University, retired from the U.S. Army as a major general. He was a former director of civil works for the U.S. Army Corps of Engineers, and more recently served in senior positions at the Construction Industry Institute in Austin, Texas. General McGinnis has also served as the director of engineering and construction for the Panama Canal Company and later as vice president of the company and lieutenant governor of the Canal Zone. As director of civil works for the U.S. Army Corps of Engineers, he was responsible for a $3 billion per year planning, design, construction, operation, and maintenance program of water-resource-oriented public works on a nationwide basis. He has considerable experience with engineering and construction. He is a registered professional engineer in Texas and Missouri.

Richard J. Ayen is current chair of the National Research Council (NRC) Committee on Review and Assessment of the Army Non-Stockpile Chemical Demilitarization Program: Workplace Monitoring, and a former member of the NRC Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons (I and II). Dr. Ayen received his Ph.D. in chemical engineering from the University of Illinois. Now retired, he had served as director of technology for Waste Management, Inc., and managed all aspects of the company's Clemson Technical Center, including treatability studies and technology demonstrations for the treatment of hazardous and radioactive waste. His experience includes 20 years at Stauffer Chemical Company, where he was manager of the process development department at Stauffer's Eastern Research Center. Dr. Ayen has published extensively in his fields of interest. He has extensive experience in the evaluation and development of new technologies for the treatment of hazardous, radioactive, industrial, and municipal waste.

Robert A. Beaudet received his Ph.D. in physical chemistry from Harvard University in 1962. From 1961 to 1963, he was a U.S. Army officer and served at the Jet Propulsion Laboratory as a research scientist. He joined the faculty of the University of Southern California, Los Angeles, in 1963 and has served continuously in the Department of Chemistry since that time. He also has served on Department of Defense committees that have addressed both offensive and defensive considerations regarding chemical warfare agents. Dr. Beaudet was chair of an Army Science Board committee that addressed chemical detection and trace gas analysis. He also was chair of an Air Force technical conference on chemical warfare decontamination and protection. He has served on NRC studies on chemical and biological sensor technologies and on energetic materials and technologies. Most of his career has been devoted to research in molecular structure and molecular spectroscopy. Currently, Dr. Beaudet is chair of the Committee to Assess Designs for Pueblo and Blue Grass Chemical Agent Destruction Pilot Plants. Previously, he served as a member of the Board on Army Science and Technology (BAST), as a member of the NRC Committee on Review of the Non-Stockpile Chemical Materiel Disposal Program, and as a BAST liaison to the Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program (Stockpile Committee).

Ruth M. Doherty, currently a technical adviser for the Research and Technology Department, Naval Surface Warfare Center, Indian Head, Maryland, received a Ph.D. in physical chemistry from the University of Maryland. Since 1983, she has coauthored almost 60 publications in various subjects in the physical chemistry arena, including the chemistry of underwater explosives. Over the past 6 years, Dr. Doherty has conducted more than 30 presentations in various aspects of the science and technology of explosives. She has worked extensively in the research and development of energetics materials and explosives with the Naval Surface Warfare Center for more than 15 years. She is a member of the editorial advisory board of the journal *Propellants, Explosives and Pyrotechnics.*

Willard C. Gekler graduated from the Colorado School of Mines with a B.S. in petroleum refining engineering and pursued graduate study in nuclear engineering at the University of California, Los Angeles. Mr. Gekler is currently an independent consultant working for his previous employer, ABS Consulting, Inc. His extensive experience includes membership on general NRC committees on assembled chemical weapons alternatives and on the expert panel reviewing the quantitative risk assessments and safety analyses of hazardous materials handling, storage, and waste treatment systems for the Anniston, Umatilla, Pine Bluff, Aberdeen, and Newport chemical disposal facilities. He was also project manager for development of facility design criteria for the Johnston Atoll Chemical Agent Disposal system. Mr. Gekler's expertise is in hazard evaluation, quantitative risk analyses, reliability assessment, and database development for risk and reliability. Mr. Gekler is a member of the Society for Risk Analysis, the American Institute of Chemical Engineers, the American Nuclear Society, and he is the author or coauthor of numerous publications.

Martin Gollin, an independent consultant with an association with Carmagen Engineering, Inc., and previously with ARCO Chemical Company, has more than 20 years of experience in process engineering and management of capital projects, risk assessment, process safety, loss prevention, and product development. From 1988 to 1999 he served as process design manager and principal engineer at ARCO; there he developed the design basis for a novel catalytic incinerator system and was the environmental, health, and safety manager for a $1 billion grassroots capital project in Holland. He earned a B.S. and M.S. in chemical engineering from Loughborough University of Technology.

David S. Kosson, chair and professor of the Department of Civil and Environmental Engineering and professor of chemical engineering at Vanderbilt University, has a B.S. in chemical engineering, an M.S. in chemical and biochemical engineering, and a Ph.D. in chemical and biochemical engineering from Rutgers, the State University of New Jersey. Previously, he was professor of chemical and biochemical engineering at Rutgers. Dr. Kosson has carried out research and published extensively on subsurface contaminant transport phenomena, leaching phenomena, physical, chemical, and microbial treatment processes for hazardous waste, and waste management policy. He has been a member of the NRC Committee on Alternative Chemical Demilitarization Technologies, Panel on Review and Evaluation of Alternative Chemical Disposal Technologies, and the Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program, for which he served as chair for 2 years.

James F. Mathis, NAE, graduated from the University of Wisconsin with a Ph.D. in chemical engineering. Dr. Mathis was vice president of science and technology for Exxon Corporation, where

he was responsible for worldwide research and development programs, and chair of the New Jersey Commission on Science and Technology until his retirement in 1997. Dr. Mathis's expertise is in research and development and chemical engineering.

Chandra M. Roy is a managing engineer in Exponent Failure Analysis Associates, Inc., a mechanics and materials practice in Irvine, California. Dr. Roy specializes in the application of qualitative and quantitative risk assessment methodologies to engineered and business systems and processes. He also conducts consequence analysis for the release of hazardous chemicals. He has conducted source-term analysis, dispersion analysis, and fire and explosion analysis for accidental releases of airborne chemicals. Additionally, he is skilled in the analysis of failure and incident data for use in risk modeling. Dr. Roy has experience in the application of computation fluid dynamics methods to solve engineering problems. He is also familiar with a wide range of chemical processes and has experience in the operational management of the chemical process industry. He has authored or coauthored several technical publications and presented a number of papers and short courses. Dr. Roy received his Ph.D. in chemical engineering and an M.S. in nuclear engineering from the University of California, Santa Barbara; an M.S. in chemical engineering from Pennsylvania State University; and a B.E. in chemical engineering from the University of Roorkee, India.

Otis A. Shelton holds an M.S. in chemical engineering from the University of Houston. He is associate director for the Safety and Environmental Services Compliance and Operational Assessments Program for Praxair, Inc., a position that he has held since 1992. In this position, Mr. Shelton is responsible for managing Praxair's assessment program that focuses on environmental, operational safety, personnel safety, industrial hygiene, emergency planning, distribution, and medical gases programs. Previously, Mr. Shelton was audit manager in Union Carbide Corporation's (UCC's) Corporate Health, Safety, and Environmental Protection Audit Program. This program reviewed UCC's health, safety, and environmental compliance in the corporation's operations, worldwide. He also worked for Union Carbide for 25 years in a variety of positions in manufacturing, distribution, and financial management. He is a fellow and past member of the board of directors of the American Institute of Chemical Engineers, and he is a member of the National Society of Black Engineers National Advisory Board. He is currently serving as secretary of the American Institute of Chemical Engineers.

ATTACHMENT C

ACKNOWLEDGMENT OF REVIEWERS

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Gilbert F. Decker, Walt Disney Imagineering (Retired),
Elisabeth M. Drake, Massachusetts Institute of Technology,
Stephen Drew, MMA Scientific Partners,
Hank C. Jenkins-Smith, George H.W. Bush School of Government and Public Service,
Paul F. Kavanaugh, U.S. Army (Retired),
Michael Ladisch, Purdue University, and
Douglas Medville, MITRE (Retired).

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Robert Frosch, Harvard University. Appointed by the NRC, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

ATTACHMENT D

ASSESSMENT

The assessment contained in this attachment is not available to the public under Subsection 15(b)(3) of the Federal Advisory Committee Act, 5 U.S.C. App., as amended by the Federal Advisory Committee Act Amendments of 1997, P.L. 105-153, December 17, 1997, 111 Stat. 2689. The National Research Council has determined that to release this information to the public would disclose information described in 5 U.S.C. 552(b).