March 1994

US Army Corps of Engineers
Waterways Experiment Station

Water Quality Research Program

compiled by Richard E. Price, Jeffery P. Holland, Robert C. Gunkel, Jr.

WES

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

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U.S. Army Corps of Engineers
Waterways Experiment Station
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Final report

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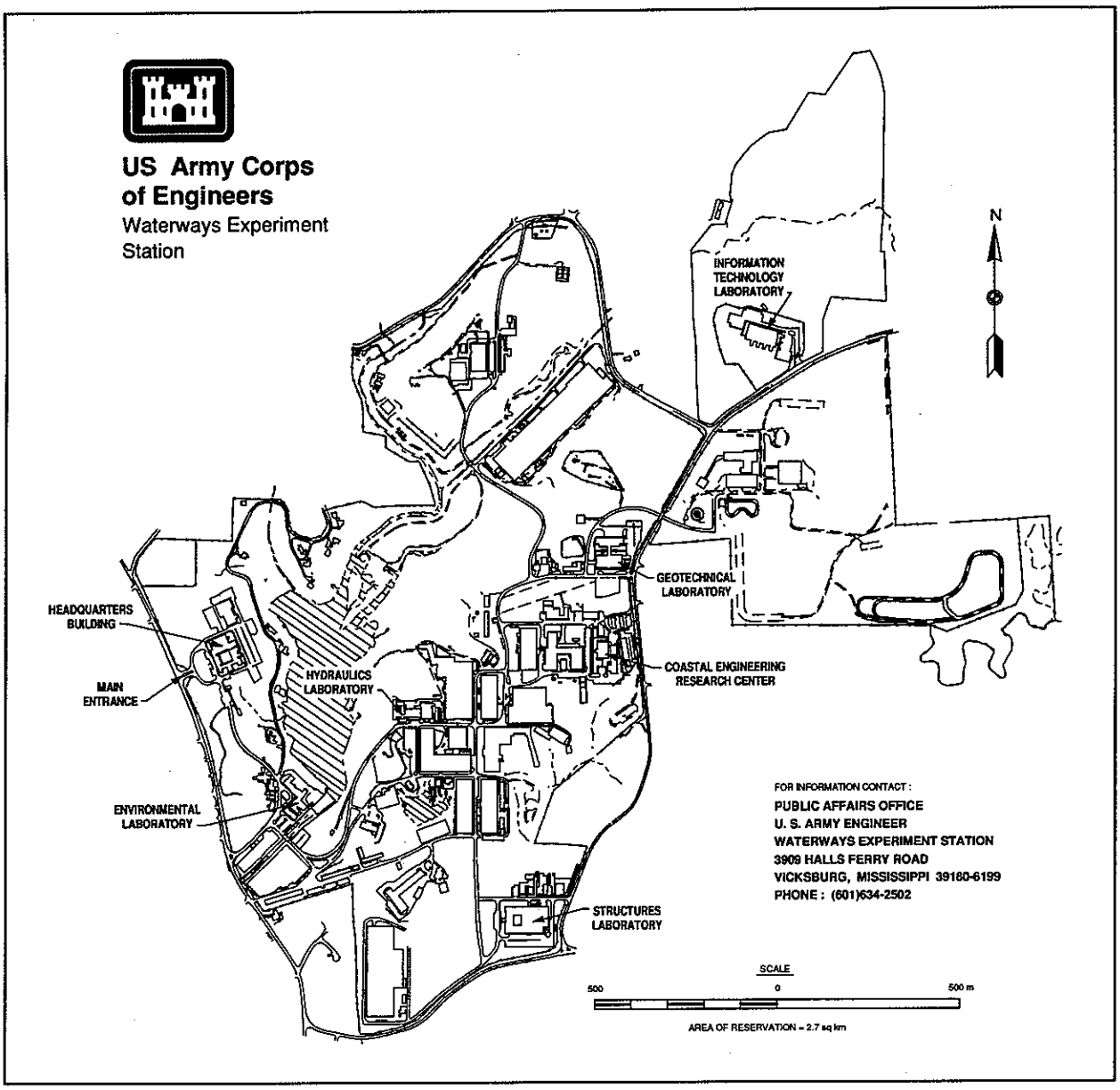
Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000



Waterways Experiment Station Cataloging-in-Publication Data

Price, Richard E.
Water Quality Research Program / compiled by Richard E. Price, Jeffery P. Holland, Robert C. Gunkel, Jr. ; prepared for U.S. Army Corps of Engineers.
51 p. : ill. ; 28 cm.
1. Water quality — Research — United States. 2. Environmental and Water Quality Operational Studies (U.S.) I. Holland, Jeffery P. II. Gunkel, Robert C. III. United States. Army. Corps of Engineers. IV. U.S. Army Engineer Waterways Experiment Station. V. Title.
TD365 P75 1994

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Preface

With the completion of the Environmental and Water Quality Operational Studies (EWQOS) Program in fiscal year 1985, the Corps of Engineers' water quality research effort focused on the timely and effective transfer of EWQOS technology through the Water Operations Technical Support Program. The Water Quality Research Program (WQRP) was initiated in fiscal year 1986 and conducted several research work units based on continuing water quality problems in Corps reservoirs.

It was evident that current technology needs to manage the Corps' water quality problems were changing. More emphasis was being placed on better management practices based on basinwide conditions, including tailwater ecology and receiving waters. Environmental considerations related to water quality management were increasing influences, which required a broader perspective of water quality than the more classical view related to water control practices.

To ensure that the Corps' WQRP focused its technology development on the currently changing emphasis as well as the future needs, a team of scientists from the U.S. Army Engineer Waterways Experiment Station (WES) were tasked to develop an enhanced WQRP. This document is intended to provide not only a direction to the Corps' future water quality research, but is designed to ensure that the results of the research will serve the future water quality management needs of the Corps, as a water resources agency. It is intended to be updated every 5 years, or sooner if changing technology needs dictate.

Acknowledgment is made to Dr. R. E. Price, Dr. R. H. Kennedy, Dr. M. S. Dortch, Mr. R. C. Gunkel, Jr., Dr. J. P. Holland, Mr. S. C. Wilhelms, Mr. S. E. Howington, and Mr. M. L. Schneider of the Environmental and Hydraulics Laboratories, WES, for their contributions in the preparation of this document. In addition, acknowledgment is made to the members of the WQRP Field Review Group and the Corps' Committee on Water Quality for their input and direction.

The WQRP is sponsored by the Headquarters, U.S. Army Corps of Engineers (HQUSACE), and is assigned to the WES under the purview of Environmental Laboratory, WES. Funding is provided under Department of the Army Appropriation No. 96X3121, General Investigation. The WQRP is managed

under the Environmental Resources Research and Assistance Programs (ERRAP), Mr. J. L. Decell, Manager. Mr. Robert C. Gunkel, Jr., is Assistant Manager, ERRAP, for the WQRP. Technical Monitors are Mr. Frederick B. Juhle, Mr. Rixie Hardy, and Dr. John Bushman, HQUSACE.

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

1 Introduction

Water quality can impact water resources uses, benefits, and operations of Corps of Engineers (CE) projects. In a similar manner, human activities, such as project operations and watershed uses, can impact water quality. Therefore, water quality considerations are an important, integral part of water resource management and maintenance of environmental quality in general.

The CE interest in water quality has traditionally centered on reservoir projects where the CE has a direct responsibility. In recent years, much attention has focused on reservoir tailwaters, recognizing them as a valuable element within the total water resource system. This attention places even more importance on reservoir release water quality. There is also concern for watershed uses and the impact of those uses on receiving waters (e.g., rivers and reservoirs). Although the CE seldom has responsibility for overall watershed management, it does work with states and other Federal agencies in planning and managing river basins, which include the watershed, streams, and reservoirs. All of this points to an increased interest and responsibility in water quality management of reservoir projects.

Today, water quality interests of the CE extend beyond reservoirs and their releases because of an expanded role of the CE in environmental issues. General Hatch's (Chief of Engineers, 1988-1992) vision was for the CE to become the Nation's environmental engineer. The CE is already working as an interagency partner in Superfund, military hazardous and toxic waste sites, estuarine/coastal environmental quality management (e.g., Chesapeake Bay and the New York Bight), management of large river basins, and wetlands protection and restoration. Groundwater resource activities of the CE are relatively new, and research on contaminants and groundwater modeling is under way. As a result, the CE water quality interests now span all types of water resource systems (i.e., watersheds, reservoirs, regulated streams and rivers, harbors, estuaries/coastal zone, Great Lakes, and groundwater).

The CE must have a strong technological base in water quality to handle the broad environmental tasks of the present and the future. This base must span a wide variety of water systems and must include four key components: (a) process description/understanding, (b) assessment and prediction methods, (c) decisionmaking and management, and (d) program management. These four areas are strongly dependent on each other and overlap. Decisions

concerning water quality management should not be made without assessing or predicting the impacts or success of implementing those decisions. The techniques used for the assessment/prediction must be based on a thorough understanding of the processes that relate water quality to man's activities. This decisionmaking process is of little value if the field office cannot use it; thus, efficient program direction and management, which ensures timely and effective technology transfer, is critical.

This document describes the basis used for developing a more comprehensive and integrated Water Quality Research Program (WQRP), as well as the research technology areas, thrusts, and work units to be considered in the program. Presented in Chapter 2 is the process used to identify and assess the current, as well as the future, CE water quality concerns. Chapter 3 presents the technical thrust areas within each of the three technology development areas. Program management of the WQRP is outlined in Chapter 4. Appendix A contains input generated from the 1990 Field Review Group meeting. Research and development targets identified by CE Divisions and Districts in 1991 are included in Appendix B. Appendix C contains work unit funding requirements and documentation of existing and proposed work units for the enhanced WQRP.

2 Program Assessment

The need to develop a more comprehensive and integrated WQRP has been the topic of discussions over the past 3 years among the U.S. Army Engineer Waterways Experiment Station (WES); Headquarters, U.S. Army Corps of Engineers (HQUSACE); and members of the Committee on Water Quality (CWQ). It was decided to develop a plan for a new structure and organization of the program. This plan would involve close coordination with the Division and District offices. A number of sources were used in developing the enhanced WQRP. Initially, these sources included input from the Field Review Group (FRG) and several members of the CWQ (Appendix A), and the research targets identified by Division and District offices (Appendix B). In addition, input from WES researchers, consideration of previous Civil Works R&D Program Reviews, review of Water Operations Technical Support (WOTS) assistance requests, and a CWQ survey were utilized.

The most recent effort used in development of the WQRP was a survey (by questionnaire) of all Districts and Divisions to determine research needs and priorities. This questionnaire was initiated by the CWQ in November 1991 and completed in June 1992, with results presented to the CWQ at their November 1992 meeting. During this same time, WES, through its Environmental and Hydraulics Laboratories, refined its input for developing a more comprehensive research program to address current field needs. The purposes for the survey of field and research elements conducted during the last year were to identify and assess water quality problems associated with CE water resource projects, and to recommend and direct research in the WQRP to address these problems.

Committee on Water Quality Questionnaire

The CWQ questionnaire was intended to integrate responses from all District/Division elements and from all disciplines to identify the current problems and research needs across the CE. Fourteen technology areas were provided in the questionnaire for respondents to assess the current interest from a District perspective in a given technology area and the state of development of that technology. The second part of the questionnaire requested information on specific problem areas. These environmental and water quality

problem/need identification statements also requested types of guidance or research products needed to address the identified problem/need.

The CWQ mailed questionnaires to each District and Division office in January 1992. The results from the questionnaire were analyzed by WES under support from the WOTS Program. A total of 114 responses to the questionnaire were received from 33 District and 11 Division offices.

The main part of the questionnaire focused on the relative importance and state of development of selected environmental technologies. Ideally, the questionnaire would identify a few technologies that scored high in District/Division importance, and low in state of development, which the CWQ could establish as their priority. Three areas fell into this category: databases for water quality/environmental data, biological impact assessment procedures, and linkages between water quality and fisheries/ecosystem/human health. Although laboratory/field quality assurance/quality control (QA/QC) procedures received a relatively high ranking in importance, the state of development is also relatively high. The technologies and their rankings are shown in Table 1. Groundwater quality monitoring equipment and water/wastewater treatment technologies received the lowest ranking in importance.

The problems/needs identification statements reported by the Districts and Divisions were reviewed for trends and summarized to identify common problems. Three major categories of problems were identified: those relating to policy (such as identification of criteria for a given water use), those relating to a physical, chemical, or biological process (such as sedimentation problems, low dissolved oxygen, or fishery problems), and those relating to assessment methods (such as indexes and models). These categories and the number of responses in each category are listed in Table 2.

The CWQ evaluated the problems/needs identification statements on an individual basis and responded to each statement during spring 1993. A number of the statements were considered to be technology transfer or management issues that do not require further research. However, 11 areas (highlighted in Table 2) require further research.

Program Review Input

During the annual Civil Works R&D Program Reviews, work unit interest survey forms have been used to solicit input from the Districts and Divisions as to their desires and needs in the WQRP. Each year, Division and District representatives are asked to carefully consider all work units and then indicate the level of importance (high, medium, and low) to their Division/District. The interest inputs of high, medium, and low are converted to a rating scale of 3, 2, and 1, respectively, and analyzed. Based on this analysis,

Table 1
State of Development for Selected Environmental Technologies and Relative Importance to CE Districts

Technology Area	State of Development	District Importance
Linkages between water quality and fisheries/ecosystem/human health	2.63	3.77
Databases for water quality/environmental data	2.82	3.83
Biological impact assessment procedures	2.76	3.80
Laboratory/field QA/QC procedures	3.22	3.78
Water quality monitoring equipment	3.30	3.49
Non-point pollution source control technologies	2.33	3.37
Contaminated sediment treatment technologies	2.63	3.33
River/reservoir water quality models	3.04	3.12
Remote water quality sensing equipment	2.62	3.02
Contaminant control technologies for landfills/disposal facilities	2.61	3.13
Water quality applications of GIS technologies	2.05	3.02
Groundwater quality monitoring equipment	2.43	2.85
Water/wastewater treatment technologies	2.92	2.72
Groundwater quality models	2.29	3.00

recommendations on work unit priority and funding are presented to HQUSACE each year. Table 3 presents the mean interest input for each work unit for the FY93 and FY94 Civil Works R&D Program Reviews.

Technical Assistance Requests

The WOTS Program was initiated to efficiently transfer technology developed by Environmental and Water Quality Operational Studies (EWQOS) to the field. It has continued to function for that purpose as well as transferring technology developed by the WQRP. Each year, the nature of the WOTS assistance requests is analyzed to determine if consistently recurring types of problems are being experienced by the Districts. Such problems could indicate the need for research that would have Corps-wide applications. A summary of the WOTS assistance requests for FY88 through FY93 is presented in Table 4.

Although the number of WOTS responses within each category of technology varies from year to year, the requests seem to indicate continuing research in each of the categories listed.

Table 2
Problem/Need Statement Responses and Relevant Research Area

Problem/Need	Number of Responses
Policy	3
Physical, Chemical, and Biological Processes	
Wetlands	14
Contaminants	12
Sedimentation (shoreline erosion and turbidity)	9
Non-point source	9
Dredging/confined disposal facilities	8
HTRW	6
Reaeration	5
Eutrophication	5
Fishery	4
Tailwater	4
Groundwater	4
Acid mine drainage	2
Drought contingency	1
Sediment oxygen demand	1
Salinity intrusion	1
Assessment Methods	
Methods (databases)	14
Methods (tests & procedures)	6
Methods (monitoring)	4
Models	8
Indexes	2
Total	122

Note: Shading of Problem/Need statements indicates a need for further research. Nonshaded statements were considered a technology transfer or management issue.

Table 3
Summary of Interest Input from the FY93 and FY94 Program Reviews

Work Unit	FY93	FY94
Sediment Oxygen Demand and Water Quality	2.42	2.00
Evaluation of Operational Alternatives for Improving Water Reservoir Quality	2.41	1.71
Hydraulic and Pneumatic Mixers and Aerators in Principle and Practice	1.86	1.92
Model of Contaminant Transport and Fate at Corps Projects	2.57	2.28
Evaluation of Remote Water Quality Monitoring Methodologies for Reservoirs and Tailwaters	2.13	1.79
Water Quality Processes in Tailwaters	2.05	1.88
Watershed Model of Non-Point Source Water Quality	1.99	2.21
Factors Mediating Biotic and Abiotic Transformations of Contaminants	1.97	2.17
Effects of Turbidity on Fishes in a Riverine Environment	1.94	2.00
Image Analysis for Reservoir Water Quality Management	1.69	2.17
Mass Transfer (Gas Absorption) in Draft Tube Flows	1.47	1.92

Table 4
Summary of WOTS Assistance Requests

Nature of Request	FY88	FY89	FY90	FY91	FY92	FY93
Water quality processes	11	9	9	14	4	4
Sample design/collection/analyses	10	6	24	9	15	7
Simulation models	10	11	8	13	8	9
Engineering techniques	5	6	4	8	16	11
Shoreline stabilization/erosion control	15	12	12	4	6	9
Presentations/workshops/reviews	15	9	20	10	8	23
Total	66	53	77	58	57	63

Waterways Experiment Station Input

WES researchers were in agreement that the WQRP was in need of development and direction. With the end of the EWQOS Program in 1985, the WQRP was initiated to carry on research in a few areas of concern to the CE.

In order for the WQRP to be responsive to the needs and problems of the CE, it should include work in reservoirs, rivers, wetlands, estuaries, and coastal areas. In addition, the research should be coordinated in a fashion to provide continuity from basic research through technology development and demonstration. The WES elements provided possible research technology areas that

would provide this continuity. Each technology area contains several research efforts that are related in terms of technical content. In cases where basic research is needed before full development of the technology can proceed, a link between research areas will be established.

Listed below are the proposed technology areas identified by WES researchers as primary needs within the WQRP:

* Water Quality Processes.
* Water Quality Evaluation and Prediction.
* Engineering Techniques.
* Reservoir Numerical Model Development.
* Estuarine Hydrodynamics and Water Quality.
* Sediment Interactions and Impacts on Water Quality.
* Reaeration.
* Mixing and Aeration.
* Groundwater Modeling.

3 Research Program

The inputs from the FRG, CWQ, HQUSACE, and WES were analyzed for areas of common concern and needs. From this analysis, three technology areas were identified as necessary to meet the technological requirements of the CE: Process Descriptions, Assessment Methods, and Management Strategies. These areas should eventually span all types of water systems, with some areas being less dependent on the type of water body and others being more dependent. Under an expanded WQRP, these areas will be better defined and prioritized through the relationships with the particular types of water systems to be addressed.

In addition, long-term demonstration sites will be established. These sites would be used to evaluate the efficacy of proposed management strategies and as a means of efficiently transferring technology. Of equal importance, many environmental and water quality processes, particularly those involving biota, occur over long time scales. The creation of demonstration sites would provide the only effective means for understanding these complex ecosystem interactions and, as such, would be invaluable to the research proposed in the Process Descriptions portion of this program.

Process Descriptions

Fundamental processes affecting water quality and the biotic structure of aquatic systems are insufficiently understood, particularly as they relate to assessment and management issues. These processes include the loading and cycling of gases, nutrients, and contaminants; mechanisms of material transport and allocation in both ground and surface water; and complex biological interactions in the aquatic environment. An improved understanding of these processes and their interactions is essential in the development of water and environmental quality assessment and management techniques for CE projects. Research for the Process Descriptions technology area is proposed in the following thrust areas.

Hydrology/hydrodynamics

a. Factors affecting transport of both surface and ground water into and from aquatic systems and their attendant watersheds.

b. Watershed and morphometric characteristics of aquatic systems that influence hydrodynamic properties.

c. Climatic considerations in hydrology and hydrodynamics as they relate to water quality issues.

d. Hydrodynamic influences on the transport, distribution, and redistribution of biotic and abiotic materials.

e. Effects of groundwater intrusion on thermal and chemical gradients in aquatic systems.

Reaeration

a. Physics of gas transfer and tracer technology.

b. Development of structural and open-water reaeration systems.

c. Design and simulation of advanced destratification, mixing, and aeration systems.

d. Development of self-aerating turbine technology and hydropower aeration systems.

Sedimentation/turbidity

a. Direct and indirect effects of sedimentation on water quality.

b. Relationships between non-point source sediment loadings, sedimentation, bioturbation, and internal cycling of nutrients and contaminants in aquatic systems.

c. Effects of turbidity on productivity and fisheries.

Material loadings and cycling

a. Relative importance of internal versus external loadings as influenced by watershed characteristics, basin morphometry, land use, non-point sources, etc.

b. Mechanisms of nutrient and contaminant cycling within and between aquatic systems.

c. Factors affecting sediment and overlying water nutrient exchanges.

d. Factors that mediate biotic and abiotic transformations of nutrients and contaminants.

e. Interrelationships between organic loadings, in situ organic matter production, and microbial degradation in affecting water quality.

f. Relationships between sediment oxygen demand and water quality.

Trophic dynamics

a. Evaluation of the role of grazers in affecting phytoplankton abundance and species composition in reservoirs.

b. Evaluation of potential improvements in reservoir water quality through biomanipulation approaches.

c. Evaluation of the role of predatory fish in structuring reservoir biotic communities.

d. Ecosystem interactions between riverine, reservoir, wetland, and groundwater.

Assessment Methods

The technology for assessing water quality has undergone a significant revolution in the past 5 years. Computational capabilities that were previously available only on expensive mainframe computers are now available on desktop computers costing a few thousand dollars. As a consequence, assessment capabilities that were previously available to a very few people can now be made readily available throughout the CE. Hand-in-hand with the hardware revolution has been a revolution in software design. Previous software development for assessment techniques paid little attention to the needs of the user, resulting in a situation wherein assessment tools dependent upon computers have been used only sparingly within the CE. In addition, the ability to remotely gather data for use in assessment has dramatically increased and will continue to increase in the future. It is imperative that the CE not only recognize but capitalize on these technology advances. This can be accomplished by developing and executing a WQRP that reflects a comprehensive framework for consistently incorporating developments and utilizing such technology for managing the projects under CE stewardship. Research for the Assessment Methods technology area is proposed in the following thrust areas.

Geographic information systems (GIS)

a. Development of GIS relating database information to modeling, assessment, and management for water quality control.

Remote sensing

a. Research to determine the ability of satellite imagery to produce data that can be used for assessment of water quality.

b. Development of a consistent means of applying data for assessment needs.

c. Techniques for real-time monitoring of water quality and data collection.

Models

a. User-friendly interfaces that operate on the latest generation of microcomputers and workstations.

b. Incorporating the latest advances in our understanding of the physical, chemical, and biological processes simulated by these codes, and including recent advances in the numerical description of these processes.

c. Continued development of numerical water quality process descriptions, ecological modeling, and higher trophic level modeling for water bodies, including watersheds and groundwater.

Indices

a. Identification of data needs for indices.

b. Processes-based indices for rapid assessment of water quality. Indices that integrate information from multiple sources and states, such as differing trophic strata and seasonal conditions, must be developed.

Decision support systems (DSS)

a. Decision support systems that integrate all of the previously described assessment tools under one consistent interface. Although this technology is still in its infancy, it is felt that the development of DSS is the key to optimizing water quality management in the CE. The advantage of DSS is that it combines GIS, remote sensing, models, and indices into a knowledge-based system (expert system) that allows the

user to easily access these technologies. A mature DSS will provide the tools to rapidly make cost-effective decisions about project operations and their impact on water quality and the environment.

b. Development of water quality database procedures. Relationship to STORET and other types of databases.

Management Strategies

Management of the environmental aspects of water resources projects is an integral part of the CE mission. To support this activity, tools must be developed that allow field personnel to accurately and efficiently integrate environmental and water quality considerations with other project purposes. In a very real sense, any multipurpose water resources project can be thought of as a system with multiple objectives, constraints, and components whose resources are to be allocated. Most of these resources, particularly those related to environmental and water quality objectives, are highly coupled. The result of these interrelationships is that a design or operational decision for one component strongly affects several additional components and objectives. Utilization of recent advances in the field of decision support software can provide the CE with the means to effectively include environmental considerations in decision-making. Research for the Management Strategies Technology area is proposed in the following thrust areas.

Systems optimization

a. Methods for quantifying the relative effects of project decisions on multiple project purposes and objectives, and for interfacing environmental technology with existing or proposed water control software developments.

b. Techniques to manage interactions between multiple project purposes, or multiple projects, incorporated into a trade-off analysis framework.

c. Specific tools for specialized cases, such as for drought contingency.

d. Interfaces between these frameworks and sources of ecosystem or habitat information, such as GIS, remote sensing, and models.

e. Knowledge- or rule-based systems that allow the user to incorporate site-specific rules therein for management of the environmental resource of choice.

Management techniques

a. Continued development of engineering technologies that can be used to manage project water quality, such as mixing and aeration systems.

b. Development of engineering systems that can be implemented to affect specific environmental quality concerns, such as habitat restoration and enhancement, or selected algal productivity.

c. Development of structural, operational, and in-pool techniques for environmental quality enhancement. Several techniques that have thus far received little attention at CE impoundments, such as biomanipulation, will be evaluated.

Environmental and water quality strategies

a. Development of risk-based strategies for the environmental and water quality management of projects that reflect project purposes and their ecological resources.

b. Development of interfaces between assessment indices, management strategies, and management techniques.

4 Program Management

Program management will provide the integration and coordination needed for the technical and administrative management of the WQRP. It will review and recommend problem-oriented research to address CE needs. The enhanced WQRP includes existing FY94 funded work units, proposed new work units for FY95, and possible future work units. Program documentation for existing and proposed work units is included in Appendix C.

Technology transfer of research results and developed techniques to the Districts will be accomplished through the existing WOTS Program activities designated for Technical Assistance, Technology Transfer, Technology Maintenance, and Demonstrations.

Technical Assistance

Specific assistance associated with water quality assessment or management problems encountered by CE personnel will be available through the WOTS Program.

Technology Transfer

Aggressive technology transfer will provide a mechanism for widely disseminating the information and techniques developed in the three technology development areas of the WQRP. This technology transfer will be carried out using a variety of channels.

Information exchange bulletin

a. Bulletin will be used to transfer current developments and ongoing research to the field.

b. Information will be general in scope and suitable for Project Resource Managers as well as the general public.

c. Bulletins will be published in a format suitable for inclusion in a notebook format.

Technical reports, articles, and manuals

a. Technical reports, articles, and manuals will be prepared to document details of research and development and results of each research work unit.

Instructional videotapes

a. Where field and laboratory techniques are developed to assist in water quality and environmental management, instructional videotapes will be prepared.

b. Information developed will also be incorporated into training courses that reflect field needs.

Workshops

a. Workshops will be conducted to further identify current water quality and environmental problems and to assist in interactions with the public and other agencies on water quality and environmental management issues.

b. In addition, research results and developed technology will be presented and discussed.

Electronic bulletin board

a. An electronic bulletin board will be installed to provide an open forum for CE personnel to discuss ongoing problems and solutions.

b. Transfer of software and data sets across the bulletin board, as well as general information regarding CE projects, their water quality, and environmental management, will be available.

Knowledge-based software

a. Knowledge-based software (expert systems) will be developed for assessment and management techniques.

b. Systems will be customized to specific problems or geographic areas that can be modified by users as information is developed.

c. Software will be integrated so simpler techniques can be incorporated into more sophisticated analyses as more data become available.

Technology Maintenance

Technology developed under the WQRP will be maintained under this functional area of the WOTS, to ensure that the technology being transferred under the other functional areas is the current state of the art.

Demonstrations

Sites will be chosen for detailed development and verification of management strategies and techniques initiated in this program. Extensive evaluation of these strategies and their efficacy, as measured against desired environmental objectives, will be conducted. At these demonstration sites, evaluation of various physiobiochemical processes will be conducted in support of other items within this program. These demonstration sites will be used to supply data for development and verification of process descriptions. Where appropriate, various assessment techniques will be verified using the demonstration sites as verification points.

Appendix A
Field Review Group Input

On 29-30 May 1990, the Field Review Group (FRG), several members of the Committee on Water Quality, the Technical Monitors, a Directorate of Research and Development (HQUSACE) representative, and representatives from WES met to discuss the development of a more comprehensive and integrated WQRP. The goal of this meeting was to examine what research has been done in the past, to review what we are currently doing, and to identify what we should be doing to better meet the current and future needs of the CE operating elements.

All participants agreed that the work units in the current WQRP have good application to project water quality problems. However, they felt that the program should be expanded to meet present as well as future water quality demands. Listed below is a summary of research areas identified by the FRG and their suggestions for transfer of technology.

Research

Techniques to mitigate water quality problems due to urbanization.
Relationships between hydrodynamics and water quality.
More holistic approach (basinwide system modeling).
Biomanipulation; use natural ways to lessen water quality problems.
Reaeration.
Groundwater.
Water quality and fisheries relationships.
Technology to enhance instream flow effects prior to problems.
Water quality impacts due to project reauthorization/reallocation.
Relicensing of hydropower.
Non-point sources.
Lake restoration.
Sediment resuspension, turbidity, and sedimentation.

Technology Transfer

Handbook of EWQOS summaries.
Improved form of technology transfer.
Expert system that accommodates user feedback.
Technology transfer for resource managers and rangers.
A more simplified version of research work units and technology transfer products.
System for problem/solution/guidance analysis.

Appendix B
Division/District R&D Target Input

In 1991, R&D target input was received from 2 Division and 14 District offices. Of the 28 R&D targets identified, 20 were considered appropriate to be conducted under the WQRP. The remaining targets were deemed to be more appropriately addressed by other ongoing CE research programs. Included in the 20 R&D targets were problems that may not require any significant research as well as problems that are more project-specific, but from which national benefits could be obtained.

All R&D problem statements were classified into functional elements of quality and assessment. Problems were classified corresponding to their adverse influence on characteristics that define water quality, or because of their negative effect on the ability to assess water quality. A summary of the R&D problem statement input is presented as Table B1. The problems were partitioned into area types (reservoir, waterway, and groundwater). The "waterway area" type includes riverine, coastal, and estuarine environments.

Table B1
Summary of R&D Problem Statements

Problem Element	Reservoir	Waterway	Groundwater
Chemical	7	3	2
Physical	1	0	0
Biological	2	0	0
Data requirements, collection, and analyses	3	0	0
Simulation models	2	0	0

Appendix C
Funding and Work Unit Documentation

Work Unit Funding Requirements

Table C1
WQRP Technology Areas, Work Units, and Funding (X1000)

Work Unit	FY94	FY95	FY96	FY97	FY98	CMPL
32746 Program Management	50	50	50	50	50	NA
Process Descriptions						
32694 Sediment Oxygen Demand (SOD)	170	160	128	54	0	0
32854 WQ Processes in Tailwaters	100	200	200	75	0	0
339-2 Transformations of Contaminants	0	50	160	175	170	155
339-8 Effects of Turbidity on Fishes	0	40	175	200	0	0
339-7 Mass Transport and Mass Transfer	0	70	100	80	0	0
Land Use Impacts on WQ	0	0	75	150	200	150
Trophic Interactions	0	0	0	75	150	800
Relationships Organic/In situ/Microb	0	0	0	80	170	650
Bioturbation on Sediment	0	0	0	0	70	275
Assessment Methods						
32808 Contaminant Model	165	165	165	150	0	0
32809 Remote Monitoring	140	140	65	0	0	0
339-6 Watershed Model of Non-Point Source	0	75	175	200	200	250
339-4 Image Analysis for Reservoir WQ	0	50	150	200	200	150
Model User Interface Development	0	0	75	100	100	0
Modeling Bubble Transport	0	0	80	100	100	80

(Continued)

Table C1 (Concluded)

Work Unit	FY94	FY95	FY96	FY97	FY98	CMPL
Indices for Assessing Sediment	0	0	75	150	200	175
Improved Methods for WQ Studies	0	0	75	150	175	225
WQ Data Screening & Analysis System	0	0	25	100	50	0
Modeling of Oxygen Absorption	0	0	0	100	130	175
Integrated WQ Modeling System	0	0	0	50	100	70
Integrated Systems Analysis	0	0	0	80	100	75
Management Strategies						
32514 Mixers and Aerators	100	0	0	0	0	0
Reservoir System Optimization	0	0	75	100	150	150
Integrated Approaches for WQ Mgmt	0	0	100	150	150	600
Risk-Based Management	0	0	0	75	150	375
Knowledge-Based Systems Management	0	0	0	0	125	200
Program Total	725	1,000	1,948	2,644	2,740	4,555

Program Management

Work Unit # 32746

Work Unit Title Management and Technical Publications

Performing Lab WES **Principal Inv** Lewis Decell 601-634-3494

Address 3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Problem

This work unit provides effective management and documentation of a major research program, as well as coordination of technology transfer and timely publication and distribution of research results.

Objective

To provide technical and administrative management of the Water Quality Research Program (WQRP). To furnish continuous input and review of research being conducted to provide the user with effective technology in a timely, cost-effective manner.

Description

Management of the WQRP includes planning, fiscal management, programming, and technical monitoring of in-house and contractual research efforts. The assistance and direction given will be at the Program Management level to the in-house organizations performing the work. Research results will be incorporated into useful, usable products for solving project water quality problems. Emphasis will be given to the transfer of WQRP technology throughout the Corps and other pertinent users.

Benefit

Ensuring effective technology for user-based planning; timely, cost-effective R&D, and timely publication and distribution of products.

Accomplishments

Obtained approval of the improved, more comprehensive WQRP from Technical Monitors, CERD-C, Committee on Water Quality, and Field Review Group members. Completed document on the new WQRP and submitted for

publication. An organized and coordinated WQRP has been developed through effective planning, fiscal management, programming, and technical monitoring of in-house and contractual efforts. Water quality tools are continuously being put in the hands of the users (CE District personnel). Technology transfer in the form of reports, a biennial meeting, public information, operations manuals, workshops, and field demonstrations is continually beign effected.

Milestones

Title	Sched	Rescd	Comp
See Individual WU Documentation for Program Milestones	0001		

Technology Transfer

Non-Mission Related Technology Transfer Potential--An application assessment of the potential for successful transfer of the technology or data resulting from this work unit to state and local governments and to private industry, in accordance with Public Law 96-480, has been performed. The assessment indicates that a product resulting from this work unit has high potential for non-mission technology transfer.

Funding	Prior Years	FY94	FY95	FY96	FY97	FY98	To Compl	Total
In-house	50	50	50	50	50	50	NA	NA
Contractual	0	0	0	0	0	0	NA	NA
Total	50	50	50	50	50	50	NA	NA

Process Descriptions

Work Unit # 32694

Work Unit Title Sediment Oxygen Demand (SOD) and Water Quality

Performing Lab WES **Principal Inv** Doug Gunnison 601-634-3873
Carl Cerco 601-634-4207

Address 3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Problem

Interactions between sediment and the water column are dominant factors contributing to poor surface water quality conditions. SOD is a large contributor to low dissolved oxygen levels which control many other water quality mechanisms. Understanding the SOD process is critical to assessing the impacts of sediment-water interactions and developing solutions to SOD-related problems. A coherent framework does not exist within the CE for sampling, assessing, and predicting SOD. Modeling activities use values for SOD without a clearly defined, universally accepted basis for their estimation and method of simulation. Consequently, much uncertainty is given to any prediction using present technology for determining SOD.

Objective

Universal principals and mechanisms will be identified for a wide variety of situations. Procedure(s) will be developed for sampling, measuring, and predicting SOD and assessing its relationship to, and impact on, the water quality of CE water resource projects. The procedure(s) will be suitable for CE-wide application to reservoir, riverine, and estuarine environments.

Description

Examine the scientific literature and confer with leading authorities on SOD to determine the most important processes underlying exertion of SOD. Synthesize available information pertaining to SOD sampling, measurement, prediction, and water quality impact assessment. Conduct laboratory studies to determine the most appropriate method for sampling and measuring SOD. Develop quantitative procedures for ecosystems having varying types of sediment and flow conditions. Evaluate conceptual and mathematical SOD models using laboratory and field data to determine which model(s) best reproduce the data, while accurately describing major SOD processes.

Benefit

This work will provide definitive, reproducible methodologies for measurement of SOD under field and laboratory conditions. Results will also provide an indication of the relationship of sediment properties (particle size, organic matter content, microbial biomass) to SOD. A major product of the work unit is a computerized sediment SOD model. Application of this model to situations where SOD is of concern will enable the user to predict the impact of activities on SOD and SOD-related water quality parameters in CE water quality projects. In addition, the model will permit application of various remedial strategies to determine their potential for success in aquatic systems.

Accomplishments

Completed laboratory studies to describe and predict SOD. Completed draft TR describing lab experiments. Published an MP on review of existing techniques and a TR on sediment/water relationships and DO in the Big Eau Pleine Reservoir. Published one newsletter article in the WOTS Information Exchange Bulletin. Completed draft of newsletter article describing SOD modeling.

Milestones

Title	Sched	Rescd	Comp
MP - Review of Existing Techniques for SOD Evaluation and Prediction	9106		9106
TR - Sediment/Water Relationships Affecting DO Conditions	9106		9106
IXB - SOD and Water Quality Impact Assessment	9209		9209
TR - Results of Initial Laboratory Studies	9303		9304
IXB - Model Description	9306		9307
MP - Application of Sediment Model to Laboratory Measures, Initial Iron and Manganese Model	9312		9402
TR - Recommendations for Field Measurement, Data Report	9503		
IXB - Predictive Modeling of SOD in Freshwater	9612		
TR - Report on SOD Research: Measurement Methods, Observations, Diagenetic Model	9709		

Technology Transfer

Non-Mission Related Technology Transfer Potential—An application assessment of the potential for successful transfer of the technology or data resulting form this work unit to state and local governments and to private industry, in accordance with Public Law 96-480, has been performed. The

assessment indicates that a product resulting from this work unit has medium potential for non-mission technology transfer.

Funding	Prior Years	FY94	FY95	FY96	FY97	FY98	To Compl	Total
In-house	337	135	130	58	10	0	0	670
Contractual	100	35	30	70	44	0	0	279
Total	437	170	160	128	54	0	0	949

Work Unit # 32854

Work Unit Title Water Quality Processes in Tailwaters

Performing Lab WES **Principal Inv** Steven L. Ashby 601-634-2387

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Vicksburg, MS 39180-6199

Problem

Adverse water quality conditions in reservoir tailwaters (e.g., elevated nutrients, reduced metals, sulfide) impact downstream users and biotic communities. Little is known about the chemical processes in reservoir releases. Methods currently used to distinguish between oxidized and reduced forms are often insufficient for accurate speciation. Additionally, impacts of reservoir operations and site-specific interactions on water quality of tailwaters have not been adequately described. Delineation of the fate and distribution of constituents in reservoir releases, evaluation of operational impacts, and identification of substrate/site interactions are necessary for better management of releases and for improving habitat for the biotic community.

Objective

Develop improved laboratory/field analytical techniques for distinguishing oxidized and reduced forms of selected chemical constituents in reservoir releases, improve the modeling capability of Tailwater Quality Model (TWQM), assess water quality of reservoir releases relative to the fate and distribution of constituents which impact downstream uses and biotic communities, delineate operational impacts on discharge quality, and evaluate the effect of site characteristics (geologic settings) on chemical processes.

Description

Review of present methods available for differentiation of oxidized/reduced constituents, development of new or modified methods of analyses, application of these new methods at selected field sites to describe the fate and distribution of constituents in reservoir releases as influenced by operations and site characteristics, and application of TWQM at selected field sites to test modifications to kinetic subroutines.

Benefit

Benefits from this research include improved analytical techniques for assessment of tailwater quality and associated impacts. These techniques will assist in the decision making necessary for better management of tailwater resources.

Accomplishments

New work unit.

Milestones

Title	Sched	Rescd	Comp
TR - Analytical Tech. for Measuring Chemical Constituents in Tailwaters	9509		
TR - Applic. of Tailwater Quality Model for Selected Chem. Constituents	9612		
TR - Impacts of Reservoir Operations and Site Charac. on TW Quality	9612		

Technology Transfer

Non-Mission Related Technology Transfer Potential—An application assessment of the potential for successful transfer of the technology or data resulting from this work unit to state and local governments and to private industry, in accordance with Public Law 96-480, has been performed. The assessment indicates that a product resulting from this work unit has high potential for non-mission technology transfer.

Funding	Prior Years	FY94	FY95	FY96	FY97	FY98	To Compl	Total
In-house	0	100	200	200	75	0	0	575
Contractual	0	0	0	0	0	0	0	0
Total	0	100	200	200	75	0	0	575

Work Unit # 339-2

Work Unit Title Factors Mediating Biotic and Abiotic Transformations of Contaminants

Performing Lab WES **Principal Inv** Doug Gunnison 601-634-3873

Address 3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Problem

Organic contaminants in CE reservoir and waterway projects may enter the system from a variety of urban, agricultural, and industrial sources. Biotic and abiotic transformations are known to destroy most of these compounds under certain environmental conditions. No CE-wide approach exists for assessing the factors mediating the rate and extent to which these compounds are degraded in project waters. Thus, the CE is unable to address questions which deal with the impact of these compounds through biotic and abiotic means.

Objective

Develop a procedure for determining the factors mediating the rate and extent at which organic contaminants are biodegraded in CE projects. Develop procedures that use these data to predict the biotic and abiotic removal of the contaminants from CE project waters.

Description

The objective of this work will be to provide a simplified procedure for use in determining the rate and extent of biodegradation and abiotic destruction of major organic contaminants in CE projects. Literature and interactive laboratory and predictive studies will be used to select and refine the most suitable procedures for field use. Following this, WES scientists and engineers will develop predictive models for use with the procedure. These tools will enable CE field offices to use data obtained with the procedure to predict biotic and abiotic removal of the organic contaminants from their water resources projects.

Benefit

This methodology will provide the CE with a means for determining the factors mediating the rate and extent at which contaminants are removed from soils, sediments, and the water column. This will enable CE field offices to

evaluate and accelerate the removal of organic contaminants from spills, industrial releases, or agricultural runoff that enters CE project waters.

Accomplishments

New work unit.

Milestones

Title	Sched	Rescd	Comp
IXB - Methods for Assessment of Biodegradation	9509		
MP - Proc. to Determine Factors Mediating Contaminant Transformations	9609		
TR - Lab Methodology for Determining Rate and Extent of Transformation	9709		
MP - Predictive Tech. for Lab-Based Evaluation of Contaminant Removal	9809		
TR - Tech. to Determine and Predict Biotic and Abiotic Transformation	9909		

Technology Transfer

Non-Mission Related Technology Transfer Potential—An application assessment of the potential for successful transfer of the technology or data resulting from this work unit to state and local governments and to private industry, in accordance with Public Law 96-480, has been performed. The assessment indicates that a product resulting from this work unit has high potential for non-mission technology transfer.

Funding	Prior Years	FY94	FY95	FY96	FY97	FY98	To Compl	Total
In-house	0	0	50	130	145	145	155	610
Contractual	0	0	0	30	25	25	0	100
Total	0	0	50	160	175	170	155	710

Work Unit # 339-8

Work Unit Title Effects of Turbidity on Fishes in Riverine Environments

Performing Lab WES **Principal Inv** Jan Hoover 601-634-3996

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Vicksburg, MS 39180-6199

Problem

Increased levels of turbidity, frequently associated with water resource projects, affect fishes in various ways. Moderate turbidities exert sublethal effects, primarily through loss of visual acuity which can impair feeding. High turbidities abrade eggs and larvae, clog gills, and may be lethal. These effects influence behavior, abundance, and condition of individuals, and ultimately population structure and biodiversity of fishes. Many channelized rivers in the U.S. are highly turbid, but levels of turbidity that impact local fishes are undocumented. Resource agency personnel know that project-associated increases in turbidity coincide with changes in fish communities, but have no means of predicting degree and nature of impacts. Sublethal and lethal effects of turbidity on fishes need to be described quantitatively.

Objective

To describe interactions between turbidity and fish in riverine environments and develop quantitative relationships for use in planning, impact prediction, and environmental engineering guidelines.

Description

A literature review on turbidity-fish interactions will be conducted; summaries will be provided for turbidity effects on feeding, behavior, growth, reproduction, survival, and biodiversity of fishes. Field surveys and laboratory experiments will be performed to determine lethal and sublethal levels of turbidity that impact fishes. Species will be evaluated that are environmentally sensitive (e.g., minnows and darters), and important commercially (e.g., suckers) and recreationally (e.g., basses and sunfishes). Predictive relationships will be developed for use in planning and operating water resource projects in rivers so that impacts from turbidity are minimized.

Benefit

Correlations between turbidity and relative fish abundance will be developed for individual species. Changes in fish behavior and condition influenced

by turbidity will be described. These data will provide managers and planners with data for predicting short-term and long-term effects of turbidity on fish assemblages.

Accomplishments

New start.

Milestones

Title	Sched	Rescd	Comp
IXB - Review of the Potential Effects of Turbidity on Riverine Fishes	9509		
MP - Field and Laboratory Studies of Lethal and Sublethal Turbidities on Riverine Fishes	9609		
TR - Field and Laboratory Studies of Lethal and Sublethal Turbidities on Riverine Fishes	9709		

Technology Transfer

Non-Mission Related Technology Transfer Potential—An application assessment of the potential for successful transfer of the technology or data resulting from this work unit to state and local governments and to private industry, in accordance with Public Law 96-480, has been performed. The assessment indicates that a product resulting from this work unit has high potential for non-mission technology transfer.

Funding	Prior Years	FY94	FY95	FY96	FY97	FY98	To Compl	Total
In-house	0	0	40	125	175	0	0	340
Contractual	0	0	0	50	25	0	0	75
Total	0	0	40	175	200	0	0	415

Work Unit # 339-7

Work Unit Title Mass Transfer (Gas Absorption) in Draft Tube Flows

Performing Lab WES **Principal Inv** Steven C. Wilhelms 601-634-2475

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Problem

Several properties or characteristics are required to calculate the reaeration occurring in a vented hydroturbine. Among these are the bubble size distribution (to be studied in a sister research effort) and the turbulent mixing that defines the oxygen absorption characteristics in the bubbly flow. Without the capability to predict oxygen absorption, gas transfer cannot be modeled, and design capability will not exist.

Objective

To develop relationships between the gas transfer characteristics and the turbulent mixing (turbulence intensity) of high-shear flows typical of draft tubes. These relationships will be inroporated into a mass transfer model as part of a multiagency model development effort.

Description

Past experimental studies on the relationship between turbulence and gas transfer will be evaluated. Results, which are appropriate for the high-shear conditions in a turbine draft tube, will be applied to simple geometries for experimental verification and further development. Measurements of gas transfer and turbulence will be compared to develop a relationship between the gas exchange coefficient and mean turbulence level (a parameter predicted by numerical flow models). The results of this effort will be coded into a gas transfer algorithm for inclusion in the numerical model of draft tube flows.

Benefit

The development of the relationships described earlier will provide a means to design the most effective turbine venting system possible. With accurate predictions, the economies of alternative venting schemes can be compared to develop an economical design. Understanding the relationship between turbulence and gas transfer in a bubbly flow is paramount in vented turbine flows, but also has application in other air-entrained flow situations, such as hydraulic jumps, spillway flows, and reservoir aeration systems.

Accomplishments

New work unit.

Milestones

Title	Sched	Rescd	Comp
MP - Interim Results Presented to CE Water Quality Seminar	9603		
TR - Turbulence and Gas Transfer in High-Shear Flows	9708		

Technology Transfer

Non-Mission Related Technology Transfer Potential—An application assessment of the potential for successful transfer of the technology or data resulting from this work unit to state and local governments and to private industry, in accordance with Public Law 96-480, has been performed. The assessment indicates that a product resulting from this work unit has high potential for non-mission technology transfer.

Funding	Prior Years	FY94	FY95	FY96	FY97	FY98	To Compl	Total
In-house	0	0	70	100	80	0	0	250
Contractual	0	0	0	0	0	0	0	0
Total	0	0	70	100	80	0	0	250

Assessment Methods

Work Unit # 32808

Work Unit Title Model of Contaminant Transport and Fate at Corps Projects

Performing Lab WES **Principal Inv** Mark S. Dortch 601-634-3517

Address 3909 Halls Ferry Road
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Problem

Management of CE projects is often complicated by the presence of toxic substances and chemical contaminants in the aquatic environment. Mathematical models for contaminant transport, exposure, and fate in surface waters provide a means for assessing the severity of contaminant problems and evaluating remediation alternatives. The CE has experienced the need to use contaminant transport models but currently has very limited capabilities for modeling contaminants.

Objective

Develop a contaminant transport/fate model for use at CE projects. Provide guidance on model use.

Description

A contaminant transport/fate model will be developed using an existing CE water quality model (i.e., CE-QUAL-ICM, a general purpose, multi-dimensional time-varying model). CE-QUAL-ICM is based on the integrated compartment method (ICM) which is highly flexible for coupling to any hydrodynamic and sediment transport model. Existing algorithms for describing contaminant processes will be extracted from other models and incorporated with CE-QUAL-ICM. Model interfaces will be developed to allow coupling with existing hydrodynamic and sediment transport models. Contaminant processes will be modular allowing simulation of organics, trace metals, and low-level radioactive substances. Verification work will focus on sediment and contaminant variables since existing hydrodynamic models have been previously verified.

Benefit

The availability of a general-purpose contaminant transport/fate model will give the CE the capability to determine the impact of various projects on contaminant concentrations and to evaluate various options for managing systems that receive or contain contaminants. Such a model will also provide a sound basis from which to resolve conflicts arising from contaminant issues.

Accomplishments

Coupling of the CE-QUAL-ICM code with a revised version of EPA's TOXI Code was initiated during FY93. An approach for linking the contaminant model to an existing CE finite element hydrodynamic model has been formulated. Approaches for suspended solids transport/linkage have been formulated.

Milestones

Title	Sched	Rescd	Comp
MP - Process Descriptions for a Contaminant Transport and Fate Model	9409		
MP - Linking Cont. Transport/Fate Model with Existing Transport Models	9509		
TR - Verification and Application of Contaminant Fate Model	9609		
IR - Model Documentation and User Guide	9709		

Technology Transfer

Non-Mission Related Technology Transfer Potential—An application assessment of the potential for successful transfer of the technology or data resulting from this work unit to state and local governments and to private industry, in accordance with Public Law 96-480, has been performed. The assessment indicates that a product resulting from this work unit has high potential for non-mission technology transfer.

Funding	Prior Years	FY94	FY95	FY96	FY97	FY98	To Compl	Total
In-house	110	140	140	140	125	0	0	655
Contractual	0	25	25	25	25	0	0	100
Total	110	165	165	165	150	0	0	755

Work Unit # 32809

Work Unit Title Evaluation of Remote WQ Monitoring Methodologies for Reservoirs and Tailwaters

Performing Lab WES **Principal Inv** Joe Carroll 803-447-8561

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Problem

Water quality studies in reservoirs and rivers often require the collection of environmental data on a frequent or semi-continuous basis (e.g., daily or hourly) over relatively long periods of time (e.g., weeks to months). Personnel requirements, costs, and logistic difficulties severely limit collection efforts. This is particularly true for studies involving several widely separate and/or remote locations. The use of remote monitors is an alternative approach to data collection. However, previous experience indicates a number of significant difficulties (calibration, reliability, availability of equipment, etc.). While several methodological limitations still exist, and while not appropriate in all situations, recent equipment developments provide potentially valuable remote monitoring tools.

Objective

The objective of this work unit is to evaluate methods for remotely collecting selected water quality data for tailwaters and reservoirs. This evaluation will include determination of sampling strategies, determination of sampling station location, equipment and calibration, and data management.

Description

Evaluations of selected water quality monitoring methodologies for reservoirs and tailwaters will be conducted. Included will be the development of guidelines for site selections, recommendations for calibration, and methods for data handling. Applications to both tailwaters and reservoirs will be included. Appropriate demonstration sites will be utilized in achieving objectives.

Benefit

Benefits of this research include reduced data collection costs, increased data availability, and improved data quality. Techniques developed and guidelines provided will improve water quality data collection capabilities.

Accomplishments

Equipment was purchased and field studies were initiated.

Milestones

Title	Sched	Rescd	Comp
TN - Use of Dissolved Oxygen Monitoring Data for Managing Tailwater Quality: Case Study - St. Stephens	9403		
TN - Evaluation of Methods for In situ Monitoring of Releases from Hydropower Projects	9503		
MP - Application of Selected Remote Monitoring Technologies for Reservoirs and Tailwaters	9509		
TR - Guidelines for Remote WQ Monitoring of Reservoirs and Tailwaters	9609		

Technology Transfer

Non-Mission Related Technology Transfer Potential—An application assessment of the potential for successful transfer of the technology or data resulting from this work unit to state and local governments and to private industry, in accordance with Public Law 96-480, has been performed. The assessment indicates that a product resulting from this work unit has high potential for non-mission technology transfer.

Funding	Prior Years	FY94	FY95	FY96	FY97	FY98	To Compl	Total
In-house	102	140	140	65	0	0	0	447
Contractual	0	0	0	0	0	0	0	0
Total	102	140	140	65	0	0	0	447

Work Unit # 339-6

Work Unit Title Watershed Model of Non-Point Source Water Quality

Performing Lab WES **Principal Inv** Patrick Deliman 601-634-3623

Address 3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Problem

Water quality of receiving waters (e.g., CE reservoirs) depends upon land use and other activities in the watershed. Increasingly, the CE must interact with other agencies on land use/management practices in the watershed to reduce non-point source pollution. Watershed models offer a means of predicting non-point source runoff for land management alternatives. The CE currently lacks capabilities for watershed water quality modeling.

Objective

Develop a CE capability for determining non-point source water quality (i.e., nutrients, solids, chemicals) runoff through watershed modeling and provide guidance on model use.

Description

Existing watershed models (e.g., ARM, NPS, HSPF, and others based on the Stanford Watershed Model) will be reviewed, and the most applicable model will be selected as a basis for future improvement and development. Other Models (e.g., CREAMS, GLEAMS, PRZM, ARMSED, and HEC1) will also be reviewed as potential building blocks. Improved process descriptions and algorithms will be incorporated where feasible; for example, most watershed models use rather crude methods for in-stream routing which can lead to errors in loading estimates. The resulting model will be further enhanced by interfacing it with other capabilities, such as GIS, remote sensing, and water quality assessment methods (e.g., reservoir water quality models). The watershed model will be verified against existing data and documented with guidance for use.

Benefit

Benefits include capabilities for predicting non-point source runoff for land management practices to reduce non-point source pollution.

Accomplishments

New work unit.

Milestones

Title	Sched	Rescd	Comp
MP - Review and Recommendations for Watershed Models	9609		
TR - Improvements to a Watershed Mod. of Non-Point Source Runoff WQ	9712		
TR - Verification and Applic. of a Watershed Mod. for Non-Point Source	9909		
IR - Watershed Model Documentation and User Guide	0009		

Technology Transfer

Non-Mission Related Technology Transfer Potential—An application assessment of the potential for successful transfer of the technology or data resulting from this work unit to state and local governments and to private industry, in accordance with Public Law 96-480, has been performed. The assessment indicates that a product resulting from this work unit has high potential for non-mission technology transfer.

Funding	Prior Years	FY94	FY95	FY96	FY97	FY98	To Compl	Total
In-house	0	0	75	125	150	150	200	700
Contractual	0	0	0	50	50	50	50	200
Total	0	0	75	175	200	200	250	900

Work Unit # 339-4

Work Unit Title Image Analysis for Reservoir Water Quality Management

Performed Lab WES **Principal Inv** Robert H. Kennedy 601-634-3659

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Vicksburg, MS 39180-6199

Problem

Routine water quality monitoring programs for reservoirs involve sample collection at only a limited number of "representative" sites due to expense and logistic difficulty. This often provides insufficient data for adequate assessment of water quality conditions. Such sample designs also overlook the potential importance of spatial patterns in water quality response. This is particularly true for projects that are impacted by a variety of local land use activities or that have complex basin geometry (i.e., many coves and embayments). Detailed descriptions of spatial patterns in water quality are important in assessing the impacts of local land use activities on water quality, defining potential impacts on project operation and user benefits, and evaluating management decisions.

Objective

The objective of this work unit is to develop and evaluate methods for interpretation of image (e.g., Landsat and fixed-wing sensors, optics, video, etc.) data as a means of assessing water quality conditions in reservoirs. The efficacy of the use of such methods as a means for reducing routine monitoring costs and calibrating numerical or empirical models will also be evaluated.

Description

Relations between selected water quality conditions and remotely sensed image data will be evaluated for optically distinct projects (e.g., low- and high-turbidity projects, low- and high-chlorophyll projects, etc.). Methods for incorporating and analyzing such data using GIS will be evaluated. Data to be linked using GIS will include information describing reservoir water quality, land use patterns, local topography and hydrology, and optical or sensor images.

Benefit

Benefits include improved methods for water quality monitoring data collection, and techniques for collecting water quality information for incorporation in GIS and/or as model input. Sampling cost for many applications will be greatly reduced through the use of such techniques.

Accomplishments

New work unit.

Milestones

Title	Sched	Rescd	Comp
Workshop - Application of Image Analysis and GIS for WQ Investigations	9606		
MP - Review of Applications of Image Analysis for WQ Investigations	9703		
TR - Methods for Image Analysis/Data Interpretation for WQ Investigations	9909		

Technology Transfer

Non-Mission Related Technology Transfer Potential—An application assessment of the potential for successful transfer of the technology or data resulting from this work unit to state and local governments and to private industry, in accordance with Public Law 96-480, has been performed. The assessment indicates that a product resulting from this work unit has high potential for non-mission technology transfer.

Funding	Prior Years	FY94	FY95	FY96	FY97	FY98	To Compl	Total
In-house	0	0	50	150	200	200	150	750
Contractual	0	0	0	0	0	0	0	0
Total	0	0	50	150	200	200	150	750

Management Strategies

Work Unit # 32514

Work Unit Title Hydraulic and Pneumatic Mixers and Aerators in Principle and Practice

Performing Lab WES **Principal Inv** Steven C. Wilhelms 601-634-2475

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Problem

Several in-reservoir and release WQ problems have been partially addressed largely by laboratory research aimed at identifying the impacts of reservoir destratification, hypolimnetic oxygenation, and localized mixing. These technologies act to prevent the occurrence of an anoxic hypolimnion or minimize its effect on release quality. There is little predictive capability available to evaluate the effectiveness of these alternatives when proposed for implementation at a project.

Objective

To characterize the in-reservoir impacts and effects on release quality of hypolimnetic aeration systems, destratification systems, and localized mixing systems, and to identify the potential for application of commercial equipment to these techniques; to develop predictive techniques that will permit preliminary evaluation of the potential effectiveness of these systems and, subsequently, guidance for the design, construction, installation, and operation of such systems.

Description

Conduct a technology survey of applicable design guidance on pneumatic destratification, hypolimnetic oxygenation/aeration, and localized mixing systems. Review pertinent information about field experiences to identify operations information on these alternatives that is currently available. Coordinate with users the design, installation, and testing of several small-scale prototype systems. Refine evaluation, design, and operational guidance and synthesize into a calculator- or computer-aided design methodology with feasibility-level and design-level options.

Benefit

(a) The in-reservoir impacts and effects on release quality of a destratification, hypolimnetic aeration, or localized mixing system can be quantified before installation; (b) alternative techniques can be evaluated and compared relative to achieving the in-lake or release quality goals; (c) low capital outlay can be achieved when commercially available equipment can be used in a system; (d) by understanding and quantifying the relationships of important system/reservoir parameters, the most appropriate system can be designed; and (e) guidance is provided on systems that are easily constructed, installed, and operated.

Accomplishments

Completed literature review of hydraulic and pneumatic mixing devices in stratified environments. Assisted in prototype tests of surface mixers and assessment of impacts. Completed model tests of the effects of mixer spacing and distance from the project intake on system efficiency. Conducted survey of manufacturers of mixers and aeration equipment. Designed pneumatic destratification system for East Sidney Lake and monitored destratification progress. Tested aspirating aerator in Lake Texoma tailrace. Developed tailwater aerator design procedure. Developed numerical algorithm for CE-QUAL-R1 that predicts mixing effects of pneumatic destratification system. Designed, installed, and tested tailwater aeration system at Eufala Lake, OK.

Milestones

Title	Sched	Rescd	Comp
IXB - Application of Mechanical Pumps and Mixers to Improve WQ	8809		8809
IXB - Methods to Eval. Commercially Available Destrat. Devices	8902	8908	8908
IR - Design and Opera. of Axial Flow Pumps for Localized Mix. & Destrat.	8911	9006	9006
IXB - Pneumatic Destratification System Design	9011		9010
MP - Reservoir and Release Response to In-Lake Mixers and Aerators	9110		9204
IXB - Design of Localized Mechanical Mixing Systems	9205		9206
MP - Design of Pneumatic Destratification System	9307		9310
IR - Design Concepts for Reservoir Mixers and Aerators	9409		

Technology Transfer

Non-Mission Related Technology Transfer Potential—An application assessment of the potential for successful transfer of the technology or data resulting from this work unit to state and local governments and to private industry, in accordance with Public Law 96-480, has been performed. The assessment indicates that a product resulting from this work unit has high potential for non-mission technology transfer.

Funding	Prior Years	FY94	FY95	FY96	FY97	FY98	To Compl	Total
In-house	740	100	0	0	0	0	0	840
Contractual	15	0	0	0	0	0	0	15
Total	755	100	0	0	0	0	0	855

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	March 1994	Final report

4. TITLE AND SUBTITLE

Water Quality Research Program

5. FUNDING NUMBERS

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Corps of Engineers
Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Over the past few years, one of the important topics of discussion among representatives from the U.S. Army Waterways Experiment Station, the Headquarters, U.S. Army Corps of Engineers, and the Committee on Water Quality has been the need to develop a more comprehensive and integrated Water Quality Research Program (WQRP). The basis used for developing a more comprehensive and integrated WQRP, as well as the research technology areas, thrusts, and work units to be considered, are presented in this document.

14. SUBJECT TERMS

Research planning
Water quality

15. NUMBER OF PAGES

51

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		