Date of Report: April 24, 2001

Date of Next Status Report: none
Date of Work Program Approval: June 23, 1997
Project Completion Date: June 30, 2000

LCMR Work Program Final Report

I. PROJECT TITLE: Ballast Water Technology Demonstration for Exotic Species Control P-1

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Total Biennial Project Budget:

$ LCMR:	$250,000	**$ Match:**	na
$ LCMR amount spent:	$250.000	**$ Match amount spent:**	na
$ LCMR Balance:	$0	**$ Match Balance:**	na

A. Legal Citation: M.L. 1997, Chap. 216, Sec. 15, Subd. 20(a).
Appropriation language: This appropriation is from the future resources fund to the commissioner of natural resources for a demonstration project in cooperation with the Duluth Port Authority to test, evaluate, and refine techniques for preventing the introduction and dispersal of exotic species from ballast water into Lake Superior.

M.L. 1998, The availability of the appropriations for the following projects is extended to June 30, 2000: Laws 1997, chapter 216, section 15, Subd. 20, paragraph (a), ballast water technology demonstration for exotic species control.

B. Status of Match Requirement: No match is required.

II. PROJECT SUMMARY AND RESULTS: This demonstration project was intended to test, evaluate, and refine promising, innovative techniques for preventing the introduction and dispersal of exotic species in Lake Superior from ballast water of commercial vessels. This LCMR project supported and accelerated an ongoing regional project that had three separate phases. The state funds recommended by LCMR were intended to assist in completing the freshwater biological study of Phase 2 and initiate Phase 3.

Phase 1 included problem definition, technology selection, analysis, and engineering aspects, as well as peer review to assure project credibility with stakeholders. The result of Phase 1 was the selection of the most promising innovative technology to test in ships — automatic backwashing screen filtration.

Phase 2 was an actual ongoing demonstration of the innovative technology selected in Phase 1 on a commercial vessel under normal operating conditions and on a barge platform. The result of Phase 2 was demonstration of the technology selected in Phase 1.

Phase 3 was the evaluation of the in ship and barge platform demonstrations, follow up demonstration of refinements to the technology demonstrated in Phase 2, and the testing of secondary technologies (determined by the project steering committee) to enhance the technology tested in Phase 2.

The results from all three phases are preliminary evaluations and recommendations regarding primary and/or secondary technologies that are proposed for retrofitting or designing into vessels to abate transfers of exotic species in ballast tanks.

III. PROGRESS SUMMARY:

A. Phase I Technology Selection *(Note: Phase I was not part of the LCMR project.)*

1997 - The primary technology selected for demonstration was automatic backwash screen filtration (ABSF). The selection was based on recommendation of ballast water experts convened by the National Research Council in 1992, an assessment by the University of Michigan/NOAA Cooperative Institute for Limnology and Ecosystem Research (Parsons 1997), and recommendations of the steering committee for the Great Lakes Ballast Water Demonstration Project.

B. Phase II Filtration Operations

1997 - In 1997, Phase II of the demonstration project was initiated by installing an automatic backwash filtration system on the *M/V Algonorth.* A season of operation on the *M/V Algonorth* was completed and several operational difficulties were encountered with the pumps, filters, and biological sampling equipment. By the end of the 1997 season, filters as small as 25 microns were performing properly and other equipment problems were resolved. The operational problems reduced the amount of biological data collected in 1997. When cold temperatures caused freezing in the water intake line, the demonstration system was decommissioned for the winter. The samples and data collected during 1997 were analyzed and the results were used to help determine the nature of testing that was still required on the existing filtration system.

1998 - The filtration experiment portion of the ballast demonstration project was modified from the original plans due to unforseen changes in the world grain markets and the subsequent effects on the vessel carrying the project's ballast technology equipment. The *M/V Algonorth* had been laid up all summer, therefore the steering committee decided to remove the equipment from the vessel and place it on a barge in the Duluth harbor. Other locations were considered, but Duluth was determined to be the best location.

During the summer of 1998, the project's demonstration equipment, including the modular ABSF system and the diesel pump, was successfully transported to Duluth after removal from the *M/V Algonorth*. The equipment was installed on a stationary barge in the Duluth Harbor. Testing of the mechanical operation and biological filtration began in August and continued until October, 1998. The barge installation better simulated continual shipboard use.

A refinement from the initial ship board tests was to eliminate the 250 micron prefilter. Three filter screen sizes were tested on the barge (100, 50, and 25 microns) at flow rates of 1500 U.S. gallons per minute. The experimental barge platform included piping to three identical 175 gallon tanks with bottom outlets. Biological effectiveness was measured through comparing zooplankton, phytoplankton and microbial concentrations with and without filtration treatment.

Contracts were issued to the University of Wisconsin to analyze the zooplankton, to a Duluth laboratory to analyze chlorophyll in samples, and to a Kent State University consultant to analyze the phytoplankton.

Results were compiled during the fall and the first papers with the results were prepared for presentation at a conference on Marine Bioinvasions in January 1999 (see Dissemination). In 1998, the project produced clear results indicating the following:

- automatic backwash ballast filtration should be practical operationally for shipboard application;
- filters can be left in wet lay-up between ballasting operations without loss of performance and installation and maintenance can be within normal capabilities of ship's engineering personnel;
- there was no apparent advantage from the biological effectiveness standpoint of prefiltration at 250 microns;
- a 50 micron screen is feasible and effective for shipboard use;
- the equipment tested showed the 25 micron screen to be much less efficient from an operations standpoint than the 50 micron screen;
- a 25 micron screen has biological advantages over the 50 micron screen and should be used for shipboard if improved screen design improves operational performance to the level of the 50 micron screen; and
- secondary treatments may be necessary to supplement filtration treatment.

Additional information about the tests and conclusions through 1998 is provided in two papers: The Great Lakes Ballast Technology Demonstration Project Filtration Biological Test Program (Cangelosi et al. 1999); and The Great Lakes Ballast Technology Demonstration Project Filtration Mechanical Test Program (Parsons and Harkins 1999).

The application of ballast filtration would have additional benefits. Particle removal will reduce the sedimentation in ballast tanks, thus saving on ballast tank cleaning and allowing more cargo in draft limited vessels. Ballast water clarification will also facilitate possible secondary treatment.

The 1998 results were impressive and encouraging. Steering committee members were encouraged and pleased with these results. The performance of the filter demonstration lead to other questions about scaling up to larger pumping rates and whether screen designs can be improved from these initial designs. Project co-chairs believed these could be overcome and the project sought to continue the demonstration project in Duluth with the next generation of filter and screen designs. They sought and received additional funds for continued tests of new equipment in 2000 from National Sea Grant and EPA.

C. Phase III Secondary Treatment and Filtration Refinements

1998 - Based on the Principle Investigators' recommendations and Steering Committee concurrence, the project's short list for possible secondary technologies included UV light, ultrasound, and heat. In late winter 1998, the Great Lakes Ballast Technology Demonstration Project contracted with Battelle Corporation to undertake a review of possible secondary treatment technologies in the area of heat, ultrasonics, and ultra violet radiation. The study was intended to provide background on the likely operational and biological effectiveness characteristics of the three potential secondary treatment alternatives. The study design included:

1. A literature review and direct contact with vendors who were state of the art in each of the three technological areas as they may pertain to ballast water treatment application;
2. A description of potential performance of the state-of-the-art technologies in terms of several biological and operational parameters;
3. Analysis of potential performance above in terms of four different pretreatment scenarios;
4. Analysis that assumed that six specified physical parameters will exist;
5. A discussion of scale-up opportunities for each technology at 8,800 gpm flow rate; and
6. A description of the degree to which vendors may be available from which to obtain experimental systems in each of the three technological areas. This study was completed on May, 1998.

Battelle completed its report and concluded that ultraviolet radiation technology was

the most promising of the three technological areas for field testing at the time because this technology had matured to the point that demonstration was feasible and appeared more cost effective than heat.

1999 & 2000 - A "notice of request for proposals" was issued and subsequently a RFP was issued on September 15, 1999 by the principle investigators seeking secondary treatments that could be installed on the demonstration barge. Several firms were interested in testing their technology on the barge although their equipment would not be ready until spring 2000. Secondary technology testing that met the RFP specifications occurred in summer of 2000. Another primary treatment (hydrocyclone) and secondary treatment (ultraviolet radiation) produced by Optimarin Inc. (Cleveland) was tested at the Duluth site using National Sea Grant funds.

Refinements to the filter and the backwashing system were made by Ontario Hydro. Testing of those second generation filters and backwash systems was done in Duluth during June 2000 and Two Harbors in September 2000.

EPA committed approximately $170,000, and the project co-chairs sought additional funds, to further test secondary technologies and to prepare detailed design and installation plans for the technologies that are determined to be best suited for ship application.

In June 2000, the Great Lakes Ballast Technology Demonstration Project distributed a RFP for three full-scale design studies of treatment system installations in specific new or existing ships to elucidate total system requirements. Using a grant from the Great Lakes Protection fund, two teams were awarded three design studies which will be complete by June 2001. Two of the design studies involved Seaway-size vessels. A Ballast Treatment Trade Exposition and Symposium on ballast treatment will wrap up the Great Lakes Ballast Technology Demonstration Project in 2001.

IV. OUTLINE OF PROJECT RESULTS:

Result 1: Conduct freshwater biological study on ballast water during Phase 2 to document the freshwater organisms in filtered ballast water and unfiltered control tank ballast water of the *M/VAlgonorth* and subsequently on the barge.

LCMR Budget: ~~est. $75,000~~ $83,901 Balance: $0

(The initial LCMR budget amounts listed for this project were estimates at the outset of the project. Actual project expenditures to complete each result varied from the initial estimates. The differences between the initial estimates and the actual expenditures resulted for several reasons such as: the actual costs were not possible to pinpoint at the outset of the project because the technology to be demonstrated was not selected at the time the work program was first written, many costs resulted from unforseen changes in the project location (*e.g.*, moving the project equipment from the ship to the barge), and many costs were dependant on the results of RFPs or other bids.)

Completion date: June 30, 2000

This funding supplemented the funding from the Great Lakes Protection Fund going into this part of the Phase 2 demonstration. It was necessary to complete much of this part of the demonstration project before initiating Phase 3. Biological data was gathered by biologists under contract for the project. Up to $10,000 of sampling equipment specific to this project was allowed to be purchased to enable the collection of data for this objective.

Result 2: Assess results of Phase 2 ballast water technology demonstration.
LCMR Budget: ~~est. $20,000~~ $17,759 Balance: $0
(Actual costs for this result were less that the initial estimated budget. The difference between the budget estimate and the actual expenditures was used to complete result 1.)
Completion date: June 30, 2000

A formal assessment of the Phase 2 demonstration was completed for all involved funding sources and the results disseminated.

Result 3: Test technology refinements, or secondary technologies.
LCMR Budget: ~~est. $150,000~~ $143,215 Balance: $0
(Expenditures for this result were less than the estimated budget amount because the costs to complete result 1 were higher than initial estimates. Funds from other sources were used to supplement the funds to complete result 3.)
Completion date: June 30, 2000

The project steering committee selected the technologies to be demonstrated. Contracts with naval architects, engineers, and biologists were used to design, build, install, and evaluate the technology. An RFP process was used to select the contractors for secondary treatments. The purchase of equipment necessary to initiate demonstration of the selected technologies was considerably more that the LCMR project could afford so funds from other non-state sources were necessary to purchase and test the equipment. Refinements of filtration technology were tested with LCMR recommended funds on the barge in Duluth, and secondary technologies were installed and tested using additional funds from EPA and other sources.

Result 4: Report and recommendations for ballast water technologies to prevent introduction and spread of harmful exotic species.
LCMR Budget: ~~est. $5,000~~ $5,125 Balance: $0
Completion date: June 30, 2000

A final report on the effectiveness and potential application of the technologies demonstrated during this project's time frame (through June 30, 2000) was submitted to LCMR on November 1, 2000. These and additional project results will be

disseminated to appropriate entities via other reports and papers resulting from the project (see Dissemination). Final recommendations resulting from this project and related demonstrations will be available in summer 2001 after the assessment of the 2000 data is completed and compared with data from technology such as the Hydrocyclone.

V. DISSEMINATION:

A. General.

The information gained from the entire Great Lakes regional project , including several funding sources, will be summarized in a final report available in summer 2001. The final results will be distributed to the maritime industry, U.S. Coast Guard, Canadian Coast Guard, the Great Lakes Panel on aquatic nuisance species, the federal Aquatic Nuisance Species Task Force and others interested in ballast water management and regulations. Results from this project will add to the information used to: modify ship design and retrofitting; develop federal and international guidelines or regulations regarding ballast water exchange; and develop a new annex regarding ballast water to the International Maritime Organization Maritime Pollution agreements.

B. Papers and Presentations.

In 1999, the project's participants began to present the results of the mechanical and biological tests from phase II and refinements under phase III. Project filtration results were presented at in regional, national, and international scientific and marine engineering fora and have been published in maritime publications.

Completed Presentations and Publications

A partial listing of presentations and publications of the project findings, excluding those from 2000, includes:

- The First Marine Bioinvasions Conference. Boston, MA. January 1999 (Biological and Mechanical Findings);

- The 9th Annual International Aquatic Nuisance Species and Zebra Mussel Conference. Duluth, MN. March 1999 (Biological and Mechanical Findings);

- Presented at The International Convention for the Exploration of the Sea Ballast Working Group. The Hague, Netherlands. March 1999 (Biological Findings);

- Presented at The Ballast Working Group of the International Maritime Organization - London, England. March 2000 (Biological Findings);

- Presented at The Ballast Water and Shipping Committee of the Aquatic Nuisance Task Force. July 2000 (Biological Findings);

- Published in *International Ship Operator* Issue No 3 and Issue No 4 1999 and 2000

(Mechanical Findings);

• "The Great Lakes Ballast Technology Demonstration Project Filtration Mechanical Test Program" published in Society of Naval Architects and Marine Engineers MARINE TECHNOLOGY Vol 37, No 3 Summer 2000 issue;

• Presented at Marine Log Conference, Maritime Legislation, Regulation and Policy. Washington DC. September, 2000 (Biological and Mechanical Findings);

• Presented/published "Technologies for Ballast Water Management" Presented /Published at the 8th International Cooperation on Marine Engineering Systems and Society of Naval Architects and Marine Engineers, New York May, 2000 and at the Annual Society of Naval Architects and Marine Engineers Meeting. Vancouver, BC. October, 2000. (Mechanical Findings);

• Presented at The 20th Anniversary Conference of the International Convention for the Exploration of the Sea. Brugge, Belgium. October 2000 (Biological Findings).

Future Presentations
Findings from summer 2000 tests will be presented at:

• the 2nd Marine Bioinvasions Conference;

• International Convention for the Exploration of the Sea,

• International Maritime Organization; and

• an international conference on ballast treatment technology to be held by the United Nations Global Ballast Water Management Program.

C. Trade Expo and Symposium.
International Ballast Technology Investment Fair (September 20-21, 2001 - Chicago Navy Pier) on ballast treatment will wrap up the Great Lakes Ballast Technology Demonstration Project in 2001 (see http://www.nemw.org/fair_about.htm). The maritime industry, investors, regulators, vendors, and the project participants and sponsors are invited to participate in an effort to bring together business interests and technical experts.

VI. CONTEXT:
A. Significance: ***The problem*** - Exotic species can inflict irreparable damage to the native ecology of the Great Lakes basin, including Minnesota. The zebra mussel alone has led to the endangerment on native fauna and has cost utilities and water suppliers millions of dollars a year in added maintenance costs. Ballast water is considered the leading vector for unintentional transfers of exotic species in the Great

Lakes and other U.S. coastal waters. Once discharged into Lake Superior or the St. Louis River estuary, the exotic species can be dispersed by other means to aquatic habitats through out the state.

High seas ballast exchange, currently required by federal law to reduce the probability of such introductions into the Great Lakes is helpful, but unreliable and not comprehensive. Vessels which enter the Great Lakes system with no ballast on board (NOBOBs) escape the current U.S. Coast Guard's (USCG) high seas ballast exchange requirement even though exotic organisms may be present in sediment in empty ballast tanks. These NOBOB vessels discharge exotic species in subsequent ballasting operations within the Great Lakes system. Under the National Invasive Species Act of 1996, new regulatory authority has been given to the USCG to address all ships with ballast tanks.

The solution - Innovative technologies that can be retrofitted into existing vessels or designed into new vessels are needed to provide a safer and more dependable approach to control the introduction and dispersal of exotic species into the Great Lakes. In selecting technologies, a steering committee will seek technologies that: 1) may be retrofitted on existing vessels or incorporated in new designs; 2) are operationally practical; 3) are safe for a vessel and crew; 4) are environmentally sound; 5) are cost-effective; 6) a vessel is capable of monitoring; and 7) are effective against a broad range of exotic (nonindigenous) nuisance aquatic species.

B. Time:

Phase I (Determine innovative technology) - January 1996 to Spring 1996
Phase II (Apply innovative technology on vessels) - Spring 1996 to Fall 1998
Phase III (Assess effectiveness of phase II demonstration and refine innovative technology or test supplemental technologies) - Fall 1997 to June 30, 2000

C. Budget Context: State funds have not previously been invested into this issue. The U.S. Coast Guard supported ballast exchange and shipping studies and the USFWS
supported biological studies called for by the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990. A National Research Council Marine Board study of ballast technologies was funded by federal agencies at $220,000. Before July, 1995, approximately $500,000 had been invested by federal agencies on this topic. Since July 1, 1995 several agencies (U. S. Coast Guard $20,000; USFWS $20,000; NOAA $20,000; Environmental Protection Agency $50,000; and the Great Lakes Fishery Commission $5,000) have invested $115,000 in phase 1 of this project. The following funds have been committed to support phase 2: State of Michigan $20,000 through its Coastal Zone Management; GLFC $1,000; Environmental Protection Agency $50,000; and the Great Lakes Protection Fund $1,300,000. Approximately $170,000 from the U.S. Environmental Protection Agency was committed to phase 3 of the project and the Co-chairs of the project's steering committee sought additional

funds from the Great Lakes Protection Fund to match the EPA funds.

	July 1995 - June 1997	July 1997 - June 1999	July 1999 - June 2001
	Prior expenditures on this project	Proposed expenditures on this project	Anticipated future expenditures on this project
1. LCMR:	none	250,000	none
2. Other State	none	none	none
3. Non State Cash			
Various agencies	115,000	71,000	$178,000
Michigan CZM	none	20,000	none
National Sea Grant	none	none	$200,000
GLPF	$800,000	$500,000	$378,000
Total	**$915,000**	**$841,000**	**$756,000**

BUDGET (LCMR):

Personnel none

Equipment est. $125,000

(The project purchased equipment or contracted with companies to build necessary equipment. At the conclusion of the biennium, the future use of the equipment purchased with state funds will be evaluated. It is possible that the equipment will be tested further in another phase of the demonstration project. Some of the equipment purchased may have application only for this project and would not have application for other uses. In the event that the equipment is not needed for further demonstration efforts and can be sold, the amount for which the equipment is sold will be paid back to the state fund.)

Acquisition none

Development none

Other est. $125,000 (Contract with naval architects, engineers, and biologists)

Total $250,000

VII. COOPERATION:

This project was part of a larger, regional, cooperative effort lead by the Lake Carriers Association and the Northeast-Midwest Institute. The Great Lakes Commission will be the fiscal agent for phase 2 of the project. A multi-stakeholder Steering Committee (including the project manager for this LCMR proposal) oversaw all phases of the project, and included members of industry, states, and NGOs from the region, along with representatives of the National Research Council Marine Board panel, federal agencies (Coast Guard, Fish and Wildlife Service, National Oceanic and Atmospheric Administration, and the EPA among others) and the Canadian Government.

The steering committee members are listed below. There were no costs associated with the steering committee activities.

Alfred Beeton, Director, Great Lakes Env. Research Lab, NOAA-U.S. Department of Commerce;

Joseph P. Botos, Vice President and Manager, Corporate Environment, Health and Safety Department, Cargill, Inc.

Allegra Cangelosi, (Co-Chair) Senior Policy Analyst, Northeast-Midwest Institute, Washington, DC;

James Carlton, Professor of Marine Science and Director Williams-Mystic, Williams College - Mystic Seaport;

Gary Edwards, Assistant Director for Fisheries, U.S. Fish and Wildlife Service;

Rich Gaudiosi, Commander, U.S. Coast Guard;

Chris Goddard, Executive Secretary, Great Lakes Fishery Commission;

Rick Harkins, (Co-Chair) Vice President of Operations, Lake Carriers' Association;

Paul Horvatin, Senior Science Advisor, Great Lakes National Program Office, U.S. Environmental Protection Agency;

Captain Ivan Lantz, Manager - Marine Operations, The Shipping Federation of Canada;

Gail McDonald, Administrator (Seven Hung, Designee), St. Lawrence Seaway Development Corp.;

Tracy Mehan, Director of the Office of the Great Lakes, Michigan Department of Environmental Quality;

Mike Parsons, Professor of Naval Architect, University of Michigan;

Jay Rendall, Exotic Species Coordinator, Mn Department of Natural Resources;

Ray Skelton, Foreign Trade Zone Manager, Seaway Port Authority of Duluth;

Chris Wiley, Sarnia Regional Office, Transport Canada - Ship Safety;

The project's fiscal agents are listed below (there are no costs associated with these individuals):

Phase 1: Guy Meadows, Associate Director, Cooperative Institute for Limnology and Ecosystems Research

Phase 2: Michael Donahue, Executive Director, Great Lakes Commission

Phase 3: Jay Rendall, Exotic Species Coordinator, MN DNR.

The steering committee, through the fiscal agents for each phase, contracted with various biologists, naval architects, engineers, and others qualified to design, build, test, and evaluate the selected ballast technologies and their effectiveness.

A contract with the Northeast-Midwest Institute was prepared by the LCMR program manager. The contract allowed the Northeast-Midwest Institute to pay for:
1. A secondary treatment technology review (approximately $30,000);
2. Certain operational expenses associated with testing for biological effectiveness (approximately $95,000);
3. A second [and third] season of testing of filter and refinements in 1998 [and 2000] (approximately $120,000); and
4. a final report and recommendations (approximately $5,000).

These amounts included a total of $6,250 to the institute for accounting and budgeting costs.The Northeast-Midwest Institute and the other co-chair of the steering committee jointly submitted valid invoices to the LCMR program manager and Seaway Port Authority of Duluth for approval prior to expenditure of Minnesota funds.

VIII. LOCATION:

This demonstration project was initiated on an ocean-going "salty" that operates in Lake Superior and other Great Lakes. The ship *Algonorth* was used for the Phase 2 of the regional demonstration project (A map showing the typical routes of the *Algonorth* was provided on initial work programs.). However, the ship did not operate during the summer of 1998 because of unexpected changes in the world grain market. During fall of 1998, the project was moved to a leased barge in the Duluth harbor. Continuation of the LCMR project and expansion of the filtration test in spring of 2000 also occurred on the barge in Duluth.

IX. REPORTING REQUIREMENTS:

Periodic work program progress reports will be submitted not later than February 1, 1998, July 1, 1998, and February 1, 1999, and September 1, 1999. A final work program report and associated products will be submitted by June 30, 2000, or by the completion date as set in the appropriation.

X. RESEARCH PROJECTS: NA

XI. REFERENCES CITED:

Cangelosi, A., I.T. Knight, M. Balcer, X. Gao, A. Huq, J.A. McGreevy, B. McGregor, D. Reid, R. Sturtevant, J.T. Carlton. 1999. Biological Test Results from Great Lakes Ballast Technology Demonstration Project. Northeast-Midwest Institute, Washington D.C.

Parsons, M. G., R.W. Moll, T. P. Mackey, and R.B. Farley. 1997. "Great Lakes Ballast Demonstration Project — Phase I Final Report." CILER, University of Michigan, Ann Arbor, MI.

Parsons, M. G., and R. W. Harkins. 1999. "The Great Lakes Ballast Technology Demonstration Project Filtration Mechanical Test Program" *Marine Technology*, Vol. 37, No. 3, pp. 129-140.