Date of Report: January 29, 2000

Date of Final Status Report: June 30, 1999

Project Completion Date: June 30, 1999

LCMR PROGRESS REPORT

I. PROJECT TITLE: On-site Sewage Treatment Alternatives: Technology Transfer

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Total Biennial Project Budget: No match required.

$ LCMR	**$500,000.00**
- $ LCMR Amount Spent	**$482,544.32**
= $LCMR Balance	**$17,455.68**

A. Legal Citation: ML 1997, Chap. 216, Sec. 15, Subd. 6(a).

Appropriation Language: This appropriation is from the future resources fund to the commissioner of the Minnesota pollution control agency for the second biennium to evaluate alternative on-site sewage treatment systems for cost-effective removal of pathogenic bacteria, viruses and nutrients.

B. Status of Match Requirement: No match required.

II. PROJECT SUMMARY AND RESULTS: Twenty-seven percent of Minnesota residents rely on Individual Sewage Treatment Systems (ISTS). Conventional ISTS are effective in removing most contaminants, but they do not adequately remove nitrogen, particularly in geologically sensitive settings. Alternative ITS that remove nitrogen are needed to minimize ground water contamination in sensitive areas and allow greater flexibility for homeowners and developers when determining minimum lot sizes. Additionally, in areas with high water tables, the only ISTS option available to most people is a mound system which is more costly than other conventional designs. Development of alternatives to conventional mound systems will save ISTS owners money and increase the rate of ISTS upgrading. The transport of pathogens from ISTS to ground water and human receptors must be more clearly understood.

This study builds on last biennium's project F-10. It will continue to test and demonstrate feasible and effective alternative systems that 1) reduce nitrogen to acceptable levels and 2) adequately treat sewage above seasonally high water tables, and determine their ability to remove pathogens. An intended outcome is to have one or two affordable ISTS that can be confidently recommended for nitrogen removal in geologically sensitive areas of Minnesota and in areas where the desired lot size is between 1 and 3 acres. The other intended outcome is to have one or two effective ISTS that can be installed and maintained in areas with seasonally high water tables at a cost that is lower than conventional mound systems.

III. PROGRESS SUMMARY:

NOTE: This report represents a summary of research, education and outreach activities during the period July 1997- June 1999. These activities have been ongoing for the NERCC, Grand Lake, and Lake Washington sites since July 1995 and are currently planned for continuation until June 2001. Results from NERCC and Grand Lake from the period July 1995 – May 1997 were published as a comprehensive report in December 1997, as well as through various other publications and presentations (see attached list). Additional reports, fact sheets and manuscripts for submission to peer-reviewed journals are in preparation and will be submitted to the LCMR staff as they are completed.

A. Develop methodology for determining the efficiency of virus and enteric bacteria removal:

Bacteria: In the past 12 months since June 1998 we have continued to refine our methods used for determining the efficiency of removal of the pathogenic bacterium Salmonella typhimurium (subtype *choleraesuis*, a model bacterial pathogen) and have performed seven field-scale "seeding" experiments. A variety of assays have been adapted for our studies, including: 1) direct total cell counts (DAPI staining); 2) enrichment cultures (pour plates); 3) total Salmonella (rRNA probe); 4) viable but not culturable (rRNA + DVC). Some of this work was reported at the Minnesota Water Conference in Minneapolis in May 1998, at the Minnesota Onsite Wastewater Conference, in St. Cloud, MN in February 1999 and most recently at the Third Annual National Workshop on Constructed Wetlands/BMPs for Nutrient Reduction and Coastal Water Protection, in New Orleans, LA in June 1999. Details will be provided in a Master's thesis and as a peer-reviewed journal publication (s). results presented below remain provisional pending completion of these manuscripts and their peer-review. A textual summary is presented below.

Batches of a strain of antibiotic resistant, *S. typhimurium*, with a 23S rRNA fluorescently labeled oligonucleotide probe were semi-continuously "seeded" into the influent of the alternative treatment systems for a period of 5-7 days. After the seeding, outflow samples were taken until *Salmonella* counts were sustained at background levels. Additional samples were collected at intermediate stations along the length of the wetlands. These data were used to estimate system removal efficiency for this pathogen and for comparison with our concurrent and year-round estimates of fecal coliform removal. In some experiments, a simultaneous tracer study was conducted to characterize the hydraulics of the systems. Experiments were conducted in both winter and summer to provide an estimate of anticipated best (warm season) and worst (cold season) performance. The subsurface removal of total and culturable *Salmonella* was calculated for each system although the exact removal mechanisms were not determined. Additional monitoring data was generated for water collected from depths of 1,2 and 3 feet below research trenches loaded with effluent from the constructed wetlands, a peat filter and from the main septic tank.

During the summer, the wetlands removed 99.6-99.9994%, 2 to >5 log loss of cells) of the culturable Salmonella within 40 days. The sand filters demonstrated a >7 log removal of these cells while the peat filters were responsible for a 9 log loss of cells. Fewer *Salmonella* cells were removed by all of these systems during the winter, although the pattern of removal was similar to their summer operation. The constructed wetlands and sand filters demonstrated >1 log loss of culturable cells within 50 days, but the peat filters were responsible for a >5 log loss of cells during the same period. Based on *Salmonella* removal alone, the peat filters operated most efficiently followed by sand filters and then the constructed wetlands.

Constructed Wetland performance was considerably improved when the hydraulic loading rate was reduced in Wetland 1 to ~150 gpd in comparison to Wetland 2 which was maintained at the design rate of 250 gpd. It is noteworthy that all of the systems were being loaded with wastewater of much higher strength than originally anticipated and used as design criteria. From late summer 1998 through Spring 1999, BOD5 and TN loading rates exceeded design criteria for the wetlands by ~75% (250-365 mg BOD_5/L, 85-105 mg TN/L). The reduced application rate improved overall *Salmonella* log - removal from 2.4 to 5.3 in summer (i.e a factor of about 1000) although there was essentially no difference in winter (1.4 log – removal relative to 1.3). The Wetland 2 (250 gpd) effluent was dispersed in a research trench and we measured a cumulative removal efficiency of 99.9996% (5+ log) at a depth of 1 foot, 99.9998% (5+ log) at 2 foot, and 99.99994 (6+ log) at a depth of 3 feet. Additional supportive assays for viability are still being analyzed.

<u>Viruses</u> : Methodology development for using model bacteriophages (natural male-specific coliphage and MS-2) for estimating the removal efficiencies for enteric viruses has proven to be more difficult than anticipated. We have established linkages with other groups who have successfully used the MS-2 virus and anticipate developing the methodology successfully this spring and summer, and conducting field ("seeding") studies in late summer, fall and winter 1999. The use of these assays has now become more widely accepted and recommended for use as a surrogate for viral human pathogens.

Fecally polluted water may contain many different viruses that originate from the human gastro-intestinal tract. These types of viruses are termed "enteric" viruses and cover a wide variety of taxonomic groups. The agents primarily involved in waterborne viral disease (hepatitis and gastroenteritis viruses) are presently difficult and expensive to detect in water. It has been suggested that these entero- and reoviruses are relatively resistant to adverse environmental conditions, so the treatment processes which are capable of efficiently removing these viruses are likely to remove other viruses as well (IAWPRC Study Group, 1991). This similarity in removal efficiencies and mechanisms has led researchers to suggest the potential of some bacterio-phages as virus models ("indicator organisms") in water treatment processes (Kott et al., 1973; Grabow et al., 1984; Havelaar et al., 1993). With this in mind, we have been conducting ongoing experiments to determine the most sensitive and easily cultureable bacterial hosts to determine the presence of both somatic and F-specific bacteriophages in the various components of the waste treatment systems at NERCC and Grand Lake. Following is an outline of the steps accomplished this summer with respect to the viral component of the current project:

1. Identify and equip a safe and hygienic microbiology lab at NRRI with the necessary equipment and protocols to facilitate developing methodology for various bacteriophage detection and enumeration techniques. While the basic equipment and reagents are in place this continues as an ongoing process as different applications are tried and developed.

2. Identify the best and most current assay methods for the detection of bacteriophage plaque forming units (PFU's). The techniques experimented with and considered were a single agar layer plating technique (Anonymus, 1980), a colorimetric assay that allowed for presence-absence and most-probable-number determinations (Reneau & Hagedorn, 1997), and a double agar layer plating technique as described by Adams (1959). The double agar layer technique was by far the most effective assay. The advantages of this technique are that the host bacteria and virus particles are more uniformly distributed over the surface of the plates so a larger volume of virus may be plated. The greater porosity of the soft, top agar layer also permits more rapid diffusion of the phage particles and the development of larger plaques, permitting easier and more efficient counting.

3. Identify the viral "indicators" that will be most useful in assessing treatment efficiencies at our research sites. Two general groups of bacteriophage viruses are being targetted. The first group is the naturally occuring somatic phages which are likely to be present in domestic wastewater at low but measureable levels, but which are less similar to the most important human enteric viruses than is the MS2 virus (not typically present in significant concentrations in domestic wastewater) and other f-specific male coliphages. We have chosen to monitor somatic phage concentrations in inflows and outflows to estimate the removal of a naturally occuring virus, and in a set of summer and winter experiments to "seed" the influents of the various alternative technologies with MS2 to improve our sensitivity (as per the *Salmonella* experiments described previously) and to provide information regarding a virus more similar to human pathogens. MS-2 has been selected in Europe as the preferred model organism for assessing pathogenic virus removal.

The basic requirements for bacterial hosts for the detection of naturally occurring somatic viruses are that they should be present in water environments whenever enteric viruses are present, they should be at least as resistant to water purification and disinfection processes as enteric viruses, and they should be detectable by simple, practical, reliable, rapid and economical techniques (Berg, 1978). With these requirements in mind, we chose *E. coli C* (ATCC 13706) as the indicator organism for the somatic phage component of our assays. *E. coli C* consistently produced more plaques than any other host tested in a study by Havelaar & Hogeboom (1983). We are currently in the process of evaluating the use of three different hosts for the determination of F-specific bacteriophages (including MS2). These hosts are *E. coli C3000*, *E. coli (F amp),* and a *Salmonella typhimurium* strain (WG49) developed by Havelaar & Hogeboom (1984). Factors being considered in the choice of an F-specific host include the ease of cultureability and their response to the MS2 virus. The MS2 assay using *S. typhimurium* WG49 has been more difficult than anticipated. We recently received a new batch of host culture from a Lab in the Netherlands via a Lab in California and are optimistic. Additional efforts now in progress will make use of alternative host species of bacteria.

Development of the natural somatic coliphage assay has been successful. We are using *E. coli C* (ATCC 13706) as the host bacteria strain based on several literature studies and preliminary trials using NERCC effluent and influent. As a result, we have been routinely monitoring natural somatic coliphage populations at the inflows and outflows of the NERCC wetlands, sand filters and peat filters since July 1998 and have included the aerobic treatment unit and internal wetland sampling stations since October 1998. Data are preliminary but they suggest that both the sand and peat filters can consistently reduce somatic phage concentrations from levels of about 600-14,400 pfu/mL in the influent (median = 1490 cfu/mL) to < 10 (median <1). Median values for Wetland 1 (lower flow = 150 gpd) and Wetland 2 (flow ~250 gpd) were 12.5 and 17.3 cfu/mL, respectively. These data suggest again that the peat and sand filters are superior to the wetlands in terms of disinfection. All three systems removed somatic phage viruses with ~99.9% efficiency, but the estimates are limited by the relatively low ambient concentration of virus.

Other techniques developed over the past year have been the ability to enumerate the host bacteria by DAPI staining and developing a population density correlation to spectrophotometer readings at 650 nm.

4. <u>Develop methods and procedures to prepare and store batches of high-titer MS2 bacteriophage.</u> It has been determined that the MS2 virus is the safest and most easily cultureable bacteriophage for use in seeding the treatment systems to better estimate removal efficiencies. We have modified the techniques of Loeb & Zindner (1961) and Nathans (1968) to develop techniques that provide final phage titers in the range of $1x10^9$ to $1x10^{11}$ PFU ml^{-1} which are suitable for the "seeding" experiments.

Reference List

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8. IAWPRC. Study Group on Health Related Water Microbiology. 1991. Bacteriophages as model viruses in water quality control. Wat. Res. 25(5):529-545.

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B. Monitor the 1995 test facilities for pathogen removal and other pollutants which indicate treatment efficiency

NERCC and Grand Lake sites: All systems were functional at NERCC during the third year of operation. The single-pass peat filters were slightly modified in the summer by using a coarser peat around the distribution network. The sand filters were covered with wood chips in the fall for insulation during the winter months. Both drip systems continue to operate without any major problems. The Grand Lake system continues to function adequately although vegetative cover remains sub-optimal. An intensive synoptic survey of nutrients at all 18 sampling wells and a bromide tracer study were conducted in late summer to help improve the system's performance. Since influent does not appear to completely mix up into the root zone the outlet collectors were modified and raised to mid-depth in December 1998.

Testing for conventional pollutants continued for the peat and sand filters, constructed wetlands, drip irrigation, trenches and aerobic treatment units throughout the period July 1997 to June 1999 at a frequency of ~2-3 weeks. The main parameter list includes flow, TSS, BOD5, nitrate-N, ammonium-N, DON, TN, ortho-P, TP, fecal coliforms, temp, pH, EC, D.O., with less frequent monitoring for redox potential and major ions. Monitoriung at these frequencies is expected to continue until Spring 2001 to develop an accurate assessment of long-term performance and their true operation and maintenance costs. Performance data for NERCC and Grand Lake sites through September 1997 were presented in NRRI Technical Report TR-97/10 published in Feb 1998 and in two papers published in the Proceedings of the Eighth National Symposium on Individual and Small Community Sewage Systems (Amer. Soc. Agric. Eng.), Mar 1998, Orlando, FL. These publications summarize construction, operation and maintenance, and cost details since the initiation of the project in 1995. Data through Spring 1998 were presented at the Annual Minnesota Water meeting in May 1998, at a state on-site wastewater conference held in St. Cloud in february 1999, and at a national constructed wetlands meeting in New Orleans, LA in June 1999 (see also Attachment 1). Data through April 1999 are currently being analyzed and summarized for additional reports, manuscripts, meetings, journals and fact sheets.

In addition to ongoing work at NERCC and Grand Lake, two donated Bord-na-Mona modular recirculating peat filters, an Irish package system, were installed in June 1998 and are being monitored. One uses imported Irish peat and the other has been filled with peat similar to that used in the single pass NERCC peat filters. A Minnesota peat producer may provide the peat for the Bord Na Mona filters, if found to be of acceptable quality. The peat filters have operated without any problems since July 1998 and are being monitored to determine treatment performance. A fabric textile filter (also recirculating) made by Orenco Systems, Inc. is currently scheduled for installation in late June 1999. All systems are commercially available in other parts of the U.S. and will be monitored through spring 2001.

NERCC Performance Summary:

At the northern Minnesota location, replicated test systems include; gravel bed constructed wetlands (CWs), single pass sand and peat filters, and recirculating peat filters. Other systems include; standard drainfield trenches (monitored at three depths) receiving septic tank effluent (STE) and treated effluent (CWs and peat filters), subsurface drip irrigation, an aerobic treatment unit with subsurface drip irrigation and a textile filter (to be installed in spring 1999). The systems have operated from about 0.5 to more than 3.5 years. Systems were dosed at ~250 gal/d (~950 L/d), typical of a single family household, with a common septic tank effluent and were designed, based upon available literature, to treat to 2^{o} standards (25 mg TSS/L, 30 mg BOD_5/L, and fecal coliforms to 200 cfu/100 ml). The STE strength was somewhat higher than that of a typical household (250-365 mg BOD_5/L, 85-105 mg TN/L) and ~75% stronger than design.

The replicated CW's consisted of two 400 m^2 cells in series, each lined. The upper cells were planted with local cattails (*Typha latifolia* and *T. angustifolia*) and were designed to achieve 2^{o} standards with a nominal HRT of 6.5 days. Excluding the first winter (plant-less gravel beds), cell-1 removed 73-82% TSS, 81-89% BOD_5, and 96-99% of fecal coliform bacteria. Due to higher than anticipated strength (BOD_5 ~75% stronger than design) and concentration effects from evapotranspiration in summer, cell-1 has met 2° standards consistently only for TSS. Cell-2 (planted with greenhouse-raised softstem bulrushes *Scirpus taebermontani*) was intended to enhance nutrient removal by providing additional retention time (total HRT of 13 days) and has allowed the CW's to consistently meet the 2° standards for BOD_5 in the summer. The average two cell mass removal in the summer was 84% TSS, 93% BOD_5, 99.8% fecal coliforms, 58% TP, and 50% TN. During winter the average removals were 80% TSS, 88% BOD_5, 98% fecal coliforms, 25% TP, and 27% TN. The microbially mediated N removal decreased to half of the summer value during winter; TP removal showed the same magnitude reduction. Water out-flow was reduced an average of 38% in summer with some days experiencing complete evap-otranspiration of the influent. This large reduction in flow concentrates nutrients and makes it more difficult to achieve concentration-based standards even though the mass of pollutants may be greatly reduced.

The intermittent sand filters (1996-98) have operated without significant problems for ~` 2.5 years with removal efficiencies of 89-97% for TSS, 96-99% for BOD_5, >99.9% for fecal coliform bacteria, 8-33% for TN, and 35-61% for TP. The intermittent peat filters (1995-98) hydraulically failed in 1997 after 18 months of operation due to a clogging mat and compaction of the underlying peat. They were redesigned with a pressure distribution system surrounded by coarse peat screenings in 1998. Performance after the retrofit was similar to the first 1.5 years with 85-98% TSS removal, 87-99% for BOD_5, >99.99% for fecals, 22-67% for TN, and 23-61% for TP. The recirculating peat filters (1998) contain coarse peat, are operated with a recirculation ratio of 1:1, and have been operated successfully for ~1.5 years . Removal efficiencies were 90% for TSS, 96-99% BOD_5, 99% fecals, 18-21 % TP, and ~45% TN.

Drainfield trenches (1996-1998) were loaded with STE (0.8-1.0 gal/ft^2/day), peat filter effluent (4-5 gal/ft^2/day), and constructed wetland effluent (4-5 gal/ft^2/day) using gravity distribution, and are monitored at 1, 2, and 3 feet below the trench bottoms. Ponding has occurred in all trenches except the trench receiving peat filter effluent. The drip systems (1996-98) have tubing placed at 0.5, 1, 1.5, and 2 feet depths and have generally operated successfully, although freezing problems occurred within the pump chamber and supply/return lines. Thermocouple temperatures also indicate that the 0.5 foot drip tubing was near freezing in Jan/Feb 1999 during a cold spell when snow cover (i.e. insulation) was below normal.

Grand Lake Performance Summary:
This data set is currently being updated and will be included in a separate technical report that will be submitted to LCMR . Briefly, the system has continued to function and has eliminated the human health risks associated with failing systems that had historically occurred for the 9 homes that now constitute a cluster system. Performance, however, has not achieved design predictions which we attribute to relatively poor cattail growth in Cell- 1 (lined) and possibly poor water distribution within the cell due its length:width ratio being <1 . This geometry was necessitated by the small amount of suitable land at the site and was of concern during the initial design phase. The effluent collection pipes were re-designed in fall 1998 and insufficient data has been collected to evaluate its success.

Lake Washington Site: Monitoring continued on the sand filters (recirculating and single pass), peat filters, constructed wetlands, and research trenches. The sand filters continue to function very well with the recirculating sand filters providing the best performance. We are increasing the number of dosing cycles and reducing the volume of effluent applied in any one dose to evaluate the effect on performance. Our attempt to rejuvenate the failed gravity-fed peat filter by using pressure distribution did not succeed. The wetlands continue to function with increased vegetative growth indicating they are moving toward maturity. . Equipment was upgraded to prevent the freezing problems experienced last winter.* Fecal coliform removal over time for the constructed wetland was 99.8%, for the recirculating sand filter 96.9%, for the single pass sand filter 94.9% and the peat filter 93.8%. Phosphorus removal for the constructed wetland was 99.8%, for the recirculating sand filter 83.3%, for single pass sand filter 24.9% and the peat filter 62.8%. Total suspended solids removal for the constructed wetland was 73.9%, for the recirculating sand filter 74.5% the single pass sand filter 74.3% and the peat filter 58.7%. Total Nitrogen removal for the constructed wetland was 63.0%, for the recirculating sand filter 76.4%, for the single pass sand filter 87.8% and for the peat filter 82.5%.
Research trenches here continued to be a problem. Effluent is ponded in all trenches getting adequate samples remains difficult. While there appears to be significant improvement in treatment the data are too sketchy to draw final conclusions.*

C. Develop and implement a technology transfer plan, including audiovisual tools and workshops, for rapidly transferring the alternative systems technology to the private sector.

Data from this project were used to develop the 7080 performance standards that are proposed as part of the rules update process. This process is in the final stages the performance standard approach is being implemented in several counties.

On June 21, 1999 a local workshop for county staff and others working with wastewater treatment issues was conducted in cooperation with the Blue Earth River Basin Initiative. The purpose of the workshop was to help local staff and administrators understand the principles and potential applications of various wastewater treatment technologies and management options. Additional sessions have been scheduled for Lino Lakes and Apple Valley later in the summer. Additionally this information will be presented and discussed at the On-site sewage treatment continuing education workshops being scheduled for various locations during the winter and spring of 2000.

IV. OUTLINE OF PROJECT RESULTS:

A. Develop methodology for determining the efficiency of virus and enteric bacteria removal. The project will make use of the biotechnology advances of molecular biology to develop assays for viruses and pathogenic bacteria, including a strain of bacteriophage (virus which infects bacteria) and *Salmonella typhimurium*, a gastroenteritis-causing disease organism. The assay procedures developed in this step will be used in determining treatment efficiencies for the alternative systems in Result B.

Budget for this Result:

$ LCMR	**$75,000**
- $ LCMR Amount Spent	**$75,000**
= $LCMR Balance	**$0**

Completion Date: December 30, 1998

B. MONITOR THE 1995 TEST FACILITIES FOR PATHOGEN REMOVAL AND OTHER POLLUTANTS WITH INDICATE TREATMENT EFFICIENCY. The removal rate for each of the alternative systems of seeded bacteriophage (virus) and *Salmonella typhimurium* will be quantified using the assays developed in Result A. The fate of pathogenic microbes will be determined after each of the alternative treatment devices, in conventional treatment systems and at different soils depths under soil treatment systems to evaluate environmental health risks of inadequate or saturated soils. Of particular importance is the fate of disease-causing organisms at different depths under soil treatment systems and whether pre-treatment of wastewater with the alternative technologies reduces the load of pathogens entering the soil/groundwater system. All systems will be concurrently monitored for removal of fecal coliform bacteria which are the standard indicator organism for human wastes.

Testing for conventional pollutants will necessarily continue through spring of 1999 at the facilities because, as biological systems, they will not have fully matured during the first two year's project. The continued testing will allow researchers to assess the viability of these types of systems for long-term, year-round use in the harsh climate of Minnesota. Researchers will determine economic costs, design criteria and seasonal performance data for each system for the removal of organic matter (BOD), solids, nitrogen, phosphorus, and fecal bacteria from typical domestic wastewater. This is a major activity of this phase of the project. Through monitoring, the effectiveness of treatment for each of the alternative systems over time will be determined. This work will also provide data on the practical aspects of the technology, such as maintenance techniques and frequency.

Budget for this Result:

$ LCMR	**$360,000.00**
- $ LCMR Amount Spent	**$342,544.32**
= $LCMR Balance	**$17,455.32**

Completion Date: April 30, 1999.

C. Develop and implement a technology transfer plan, including audiovisual tools and workshops, for rapidly transferring the alternative systems technology to the private sector (contractors, consulting firms, realtors, resort/food service industry), the public (individual property owners, lake associations), local regulatory authorities (planning and zoning administrators, environmental health specialists, local water planners) and state regulatory agencies (MPCA, MDNR, MDH, BWSR). The current project has generated in-kind services, cash and materials from the private sector (total match of $807,000) which demonstrates the high level of interest and need for the results to be rapidly and effectively communicated to all appropriate parties. Possible elements of the plan include: tailored publications for specific clientele groups, construction demonstration field days to facilitate construction of the alternative systems, and including the new technologies in workshops currently taught by the University of Minnesota for ISTS professionals.

Budget for this Result:

$ LCMR	**$65,000**
- $ LCMR Amount Spent	**$65,000**
= $LCMR Balance	**$ 0**

Completion Date: June 30, 1999

V. DISSEMINATION: Information dissemination will occur through tours of the research sites, final reports, fact sheets and presentations at regional and national conferences, in addition to the means identified in Result C immediately above. Copies of the project final report will be sent to interested parties. All monitoring data will be stored by the principal investigator on computer and will be made available in report appendices at the end of the project.

VI. CONTEXT

A. Significance: Much of the research about how individual sewage treatment systems perform hydraulically and in treatment efficiency has been conducted over the last 25 years. The principal investigator was involved with the early efforts at the University of Wisconsin-Madison where the current sewage treatment mound design and construction parameters were developed. While this particular kind of system has been able to overcome problems associated with certain limiting soil conditions such as high water table and shallow depths to bedrock there continues to be a need to investigate and refine additional cost-effective options to address these characteristics. In recent years, there have been claims made by alternative systems (to mounds or standard trench systems) that they will accomplish the same level of treatment and hydraulically accept effluent at less cost. It is important that these "alternative solutions" be subjected to rigorous analysis and scrutiny before being presented to contractors, site evaluators, designers, local government officials and the public as bona fide solutions.

The principal investigator has worked for 16 years within the state of Minnesota with the on-site industry, state agencies, and the scientific community to ensure that the Minnesota ISTS standards are technically sound, cost effective and protect the water resources of the state and the health of the residents. The systems proposed to be evaluated were selected based on scientific studies reported in recent literature and at national symposia dealing with ISTS technology.

B. Time: This project will be completed by June 30, 1999.

C. Budget Context:

	July '95-June '97 Prior expenditures on this project	July '97-June '99 Proposed expenditures on this project	July '99-June '01 Anticipated future expenditures on this project
1. LCMR	**$425,000**	**$500,000**	**$550,000**
2. Other State	**$10,000**	**$10,000**	**unknown**

(MPCA staff time- approximately 10% of a position per year for project management and participation on Technical Advisory Team- No MPCA budget initiative for this project)

3. Non State Cash	**$807,000**	**$199,000**	**unknown**
TOTAL	**$1,242,000**	**$709,000**	**unknown**

LCMR Budget Expenditures:

Personnel $275,000
Part of a full-time technician and students (grad and undergrad) at U of M St.Paul campus,
Part of 3 full-time researcher at NRRI, lab technician(s) time, student time (grad and undergrad)

Equipment $40,000
Scale models of alternative systems .. $30,000
Shaker/incubator for pathogens .. $7500
Field meter DO/T/EC/pH .. $2500

Acquisition $0

Development $75,000
Pathogen assay development

Other

Supply	$30,000
Travel	$15,000
Tech. Transfer	$65,000
TOTAL	**$500,000**

VII. COOPERATION:

University of Minnesota: The University of Minnesota (at St. Paul) Department of Soil, Water and Climate is managing this project by a pass-through contract. All funds go to this entity. The principal investigator is responsible for subcontracting with other entities to accomplish the workplan.

Dr. James Anderson (Department of Soil, Water and Climate- St.Paul) will be the overall Principal Investigator for the study. Co-Principal Investigators from the University are: David Gustafson (Agricultural Engineering Department - St.Paul), Barbara McCarthy and Dr. Richard Axler (Natural Resources Research Institute - Duluth) and Dr. Randall Hicks (Biology Department, University of Minnesota Duluth).

Other members of the Technical Advisory Team on this project are Jeff Crosby, St. Louis County Health Department; Pete Weidman, Western Lake Superior Sanitary

District; Terry Bovee, LeSueur County Environmental Services; Randy Stoppleman, Minnesota On-Site Sewage Treatment Contractors Association; and Joe Magner, Mark Wespetal and Gretchen Sabel, Minnesota Pollution Control Agency.

VII. LOCATION: See attached map.

IX. REPORTING REQUIREMENTS: This is the third semiannual six-month work program report. The final six-month work program update and final report by June 30, 1999.

X. RESEARCH ADDENDUM: Submitted September 20, 1997.

ATTACHMENT 1

NRRI Education and Outreach Activities, July 1997 through June 1999

(Revised 6-11-99)

DATE	Organization/Description	Approx. Attendance
Jul 2, 1997	Arrowhead Water Quality Team tour Duluth, MN	15
Aug 26, 1997	*The Compendium , Ltd* tour Duluth, MN	15
Sep 9, 1997	Lake County Commissioners Meeting Two Harbors, MN	25
Sep 25, 1997	Minnesota Planning and Zoning Administrators Annual Meeting; Grand Rapids, MN	40
Oct 25, 1997	Minnesota Sea Grant staff	2
Oct 31, 1997	IRRRB/NLTA Resort Septic System Conference Eveleth, MN	80
Nov 1997	Northern Lights Resort design assistance	8
Dec 2, 1997	Minnesota Peat Association Annual Meeting	35
Jan 23, 1998	Training on sand filter technologies 1-day workshop; Duluth, MN	115
Mar 10, 1998	American Society of Agricultural Engineers Conference, Orlando, FL Two papers presented	~160

Apr 28, 1998	EPA Sustainable Development Conference Superior, WI.	80
May 4, 1998	Rice County Planning and Zoning Workshop on alternative technologies Faribault, MN	75
May 5, 1998	Minnesota Water '98 -2 poster presentations Minneapolis, MN	~300
May 7, 1998	Minnesota Environmental Health Association Annual Meeting- poster presentation	20
May 7, 1998	Central States Water Environment Federation (State of Wisconsin Annual Meeting)	100
May 21, 1998	Lake Superior College, tour students	30
Jun 4, 1998	Ohio and Wisconsin Group tour Duluth, MN	10
Jun 18, 1998	League of Minnesota Cities Duluth, MN	50
Jun 18, 1998	North Shore Management Board Citizens Advisory Committee meeting Two Harbors, MN	20
Jun 1998	FOCUS 10,000 magazine article entitled "Grand Lake Wetland Treatment System"	>1,000
Jul 9, 1998	Caribou Lake Association Duluth, MN	3
Jul 25, 1998	Minnesota On-site Sewage Treatment Contractors Assoc. (MOSTCA) Annual Summer Seminar-tour, Duluth, MN	100
Jul 28, 1998	Tour for 3 companies, Duluth, MN	3
Jul 31, 1998	Minnesota Association of Professional Soil Scientists (MAPSS) Summer Tour Duluth, MN	40
Aug 11, 1998	Minnesota Peat Association Master Gardeners Tour	25
Aug/Sep 1998	FOCUS 10,000 magazine article entitled "Filtering Wastewater with Sand"	>1,000

Sep 17, 1998	Minnesota Department of Health staff tour; Duluth, MN	10
Sep 25, 1998	Cass County and 10-mile Lake residents Duluth, MN	6
Oct 1, 1998	Western Lake Superior Sanitary District Staff tour; Duluth, MN	5
Oct 6, 1998	Minnesota Extension Service tour Duluth, MN	15
Oct 13, 1998	County and BWSR tour (N. Central Minnesota) Duluth, MN	8
Oct 15, 1998	Minnesota Sea Grant-National Program Review Panel Duluth, MN	10
Oct/Nov 1998	FOCUS 10,000 magazine article entitled "Constructed Wetland Treatment Systems"	>1,000
Nov 5, 1998	Conference on the Environment Central States Water Environment Federation Bloomington, MN	10
Dec 7, 1998	Minnesota Association of Soil and Water Conservation Districts; Bloomington, MN	140
Dec 8 , 1998	Minnesota Peat Association Annual Meeting	60
Dec 16, 1998	NW Minnesota, District A County Zoning Administrators and guests Meeting	15
Jan 12, 1999	Minnesota Environmental Health Association Winter Meeting; St. Cloud, MN	70
Feb 1-3, 1999	Minnesota Onsite Wastewater Conference St. Cloud, MN (coordination and poster presentation) 470 attendees and 68 exhibitors; poster presentation treatment systems in northern Minnesota.	538
Feb 17, 1999	1st Annual Iowa On-site Waste Water Conference Clives, Iowa	80
Feb 18, 1999	Land Application of Biosolids, Residuals and Effluents Bloomington, MN	60
Feb 22, 1999	Lake County Contractor Meeting	20

	Two Harbors, MN	
Feb 5,1999	Central States Water Environment Federation, St. Cloud,16th Annual Minnesota Meeting - Innovative Approaches to Wastewater Operational Problems : "Operation and maintenance of innovative wetland facilities"	100
Mar 23, 1999	1-day Design Workshop on Peat Filters Duluth, MN	74
Mar 25, 1999	Design Workshop on Peat Filters Faribault, MN	110
Apr 20, 1999	Vermillion Community College Tour NERCC Duluth, MN	20
May 1999	FOCUS 10,000 magazine article entitled "Wastewater Treatment by Peat Filters"	>1,000
Jun 8-11, 1999	Third Annual National Workshop on Constructed Wetlands/BMPs for Nutrient Reduction and Coastal Water Protection, New Orleans, LA (2 presentations)	100
Aug 22-27, 1999	Fourth Annual Symposium on Subsurface Microbiology Amer. Soc. For Microbiology, Vail, CO (Microbial Transport)	~800
Nov 3-6, 1999	8th Annual National Onsite Wastewater Recycling Association (NOWRA) Conference & Exhibition, Jekyll Island, GA (2 presentations)	~350

List of Articles, Manuscripts, Fact Sheets during the grant period:

1. Crosby, J., B. McCarthy, C. Gilbertson, R. Axler. 1998. A regulatory perspective on impediments and solutions to the use of performance standards for on-site wastewater treatment. Pages 259-267, In: On-site Wastewater treatment, Proceedings of the Eighth International Symposium on Individual and Small Community Sewage Systems, Orlando, FL, March 1998, American Society of Agricultural Engineers, St. Joseph, Missouri. 49085-9659 USA.

2. McCarthy, B., R. Axler, S. Monson Geerts, J. Henneck, D. Nordman, J. Crosby, P. Weidman. Performance of alternative treatment systems in Northern Minnesota. Pages 446-457, In: On-site Wastewater treatment, Proceedings of the Eighth International Symposium on Individual and Small Community Sewage Systems, Orlando, FL, March 1998, American Society of Agricultural Engineers, St. Joseph, Missouri. 49085-9659 USA.

3. Axler, R., D. Gustafson and B. McCarthy. 1998. Constructed wetland treatment systems. Focus 10,000- Minnesota's Lakeside Magazine (Oct/Nov 1998) 15-19.

4. McCarthy, B. 1998. Filtering Wastewater with Sand, Focus 10,000- Minnesota's Lakeside Magazine (Aug/Sep 1998) 19-21.

5. McCarthy, B. 1998. Grand Lake Wetland Treatment System, Focus 10,000- Minnesota's Lakeside Magazine (June 1998) 18-21.

6. Anderson, J. 1998. Another alternative: Lake Washington cluster drainfield**,** Focus 10,000- Minnesota's Lakeside Magazine (July 1998) 16-19.

7. Monson-Geerts, S. and B. McCarthy. 1999. Wastewater treatment by peat filters, Focus 10,000- Minnesota's Lakeside Magazine (May 1999) 16-20

8. Pundsack, J., R. Axler, R. Hicks , J. Henneck, D. Nordman and B. McCarthy. In Draft. Seasonal pathogen removal by on-site alternative wastewater treatment systems. to be submitted to Water Environment Research (July 1999).

9. Pundsack, J., R. Hicks, R. Axler, J. Henneck and B. McCarthy. In Prep. Effect of on-site alternative wastewater treatment on the culturability and viability *of Salmonella choleraesuis*. to be submitted to Journal of Environmental Quality (August 1999).

10. Axler, R., J. Henneck, D.Nordman, B.McCarthy, S. Monson-Geerts, J. Crosby and P. Weidman. In Prep. Cold climate performance of constructed wetlands for removing pathogens and nutrients from domestic wastewater in Northern Minnesota. To be submitted to J. Environ. Quality (October 1999).