A NATIONAL HEALTHY BEACHES SYMPOSIUM RESEARCH, MONITORING AND COOPERATIVE EFFORTS

Proceedings

August 7, 1997
Indiana Dunes State Park
Chesterton, IN

Sponsors

Inter-Agency Technical Task Force on *E. Coli*
Illinois-Indiana Sea Grant College Program

Sea Grant
Illinois - Indiana

A NATIONAL HEALTHY BEACHES SYMPOSIUM
RESEARCH, MONITORING AND COOPERATIVE EFFORTS

August 7, 1997
Indiana Dunes State Park
Chesterton, IN

Proceedings Editor
Leslie Dorworth
Illinois-Indiana Sea Grant College Program
Purdue University Calumet
Hammond, IN 46323-2094

Sponsors
Inter-Agency Technical Task Force on *E. Coli*
Illinois-Indiana Sea Grant College Program

Sea Grant
ILLINOIS - INDIANA

Produced by the Illinois-Indiana Sea Grant College Program, Philip E. Pope, Director. Illinois-Indiana Sea Grant College Program is a joint federal and state program of Purdue University, West Lafayette, Indiana, and the University of Illinois at Urbana-Champaign. Funding is provided by the National Sea Grant College Program, National Oceanic and Atmospheric Administration, and the U. S. Department of Commerce. The U. S. Government is authorized to reproduce and distribute reprints for governmental purposes notwithstanding any copyright that may appear. Issued in furtherance of the Cooperative Extension Service of both Purdue University and the University of Illinois at Urbana-Champaign. Purdue University and the University of Illinois offer equal opportunities in programs and employment.

Production Coordinator: Nancy Riggs, Illinois-Indiana Sea Grant
Cover Photo: David Riecks
Publication No. IISG-98-13
For additional copies, contact Illinois-Indiana Sea Grant Communications 217 333-8055

TABLE OF CONTENTS

Introduction

Leslie E. Dorworth
Illinois-Indiana Sea Grant College Program
Purdue University Calumet

The beaches along southern Lake Michigan are a source of pride in the State of Indiana. Opportunities for recreational and leisure pleasure are offered by the long stretches of sand. Besides sun and water bathers, others also derive benefits from the beach environment. An example is the economy of northwest Indiana which benefits from tourism.

Over the past ten years, the rivers, creeks, and ditches of northwest Indiana have exceeded the U. S. Environmental Protection Agency and Indiana Department of Environmental Management's criteria for safe swimming waters (less than 235 E. coli per 100 ml H_2O). The problem is not frequent or long lasting, but one that periodically hampers the full enjoyment of one of the most sought after resources in the nation and the State of Indiana. Many agencies are involved in studying E. coli and the sporadic occurrence of high bacterial levels. Specifically, the agencies are interested in protecting the public's health, the health of the Lake Michigan shoreline, and the quality of life in northwest Indiana.

Current studies in the Lake Michigan area indicate that E. coli levels primarily increase after periods of heavy rainfall. There are other factors which must be taken into consideration to completely resolve the issue. Currently, all the data is not in on how to resolve the bacterial pollution of the beaches. At this time, only a small watershed has been studied which makes it difficult to understand the nature of the problem much less derive an action strategy to combat the problem.

A National Healthy Beaches Symposium is the first meeting of it's kind nationally bringing together politicians, scientists, state and federal agencies and others concerned with the problem of beach closure due to fecal contamination. The meeting was sponsored by the Inter-Agency Task Force on E.coli. The Task Force is a collaborative effort among 17 agencies and various organizations interested in beach closures in northwest Indiana, particularly those closures affiliated with southern Lake Michigan. The meeting was coordinated by Illinois-Indiana Sea Grant College Program.

The objectives of the meeting were:

Identify and share common concerns and goals both nationally and regionally on this problem

Share information on ongoing activities both at the federal and state level of government

Provide a forum for collaboration and partnership

The meeting opened with a plenary session focused initially on a broad perspective of what is happening in California relative to polluted runoff into the Santa Monica Bay to what specifically is E. coli. The rest of the morning session provided information on the new EPA program known as the BEACH Program followed by what is being done along the Lake Michigan shoreline.

In the afternoon, concurrent sessions were held. The sessions were varied and enabled an attendee to decide which topic was more relevant to their concerns. For some of these sessions, speakers were invited from other states. One of the presenters came from Ohio to speak on the collaborative efforts underway in Maumee Bay and another presenter from the Coast Guard spoke of the current research on sanitary devices for ships to grey and ballast water from both large and small vessels on Lake Michigan. It became apparent that many of the attendees wished to go to both sessions, in the afternoon. Since this was not a possibility, the reader will find the presenters' paper or presentation for both sessions in these Proceedings.

Acknowledgements

The success of the meeting, *A National Healthy Beaches Symposium* was due primarily to the cooperative efforts of members of the E. coli Task Force, in particular Dawn Deady (IDNR), Steve Lucas (Natural Resources Commission), Leslie Dorworth (Illinois-Indiana Sea Grant College Program), Amira Loney (formerly of IDEM), Alan Dunn (Indiana State Department of Health) and Michael Kuss (IDEM). William R. Wright, Director of Conference Operations, Purdue University Calumet, handled the financial arrangements.

WELCOME TO THE HEALTHY BEACHES SYMPOSIUM

Lori Kaplan
Deputy Director for Bureau of Water and Resource Regulation,
Indiana Department of Natural Resources

Welcome to the Indiana Dunes State Park. The Indiana Department of Natural Resources supports the goals of today's Symposium. Director Larry Macklin and I are excited about helping to bring together interested parties from the sciences and among policy makers to discuss periodic bacterial contamination of our nation's beaches. Our beaches are an important resource, and we have to work together to solve this problem.

Chief Pokagan, Chief of the Potawatomi tribe, explained that the Indiana Dunes was always a sacred place to Native Americans. When the Great Council Fire met at the Dunes, it was a peaceful gathering at which time the people shared their ideas. It is particularly fitting that this sharing of ideas continues today.

Just east of the Pavilion is Dunes Creek an area identified at one time for a planned city. It was to be known as city West in the 1830's. The original concept included three hotels and 40 buildings, but the development was abandoned by the 1840's. All that remains is Dunes Creek.

When the Europeans settled the area, the environmental quality of the region was recognized. In 1889, Jens Jenner, a Danish Immigrant from Chicago, came to the Dunes to admire the beauty and diversity. He and other avid naturalists formed the Prairie Club of Chicago. In 1913 they leased some land and built a beach house for their members to use, at what we now know as the Dunes State Park. The beach was the focus of attraction for the members.

In 1916, Richard Leiber, the "father" of our conservation movement efforts in Indiana envisioned a system of state parks as a way to celebrate the state centennial. One of the first parks that he planned was the Indiana Dunes State Park.

The park opened July 8, 1926. Within the first three months of opening, over 62,000 visitors came through the gates. The Pavilion, where we are meeting today, was built in 1925. It has undergone a few renovations since that time, but it still remains a special building. The pavilion was originally conceptualized as a restaurant and beach house. Use of the pavilion for a restaurant has been sporadic, but its use as a beach house has been constant since it opened. From the beginning, Indiana Dunes State Park was a place where people came to enjoy the beach.

Today, thousands of visitors come to see and take advantage of Dunes State Park and our neighbor, the Indiana Dunes National Lakeshore, as well as other beaches along the lake that are managed and cared for by cities and counties. It continues to be an area for communal activities and an area where people come together to take advantage of the dunes, the beach and the lake. It remains a place, much like today's Symposium, where people can come together to discuss their common concerns and interests.

I would like to take this opportunity to thank and congratulate The Interagency Technical Task Force on E. coli for coordinating the Symposium. The Task Force is a unique gathering of individuals from a number of different agencies in Indiana. There was a recognition from the agencies that a common problem existed and that rather than working independently of each other they should coordinate their efforts.

I would like to thank Doug Wickersham, property manager at the Park. He and his staff have done an excellent job making this location available to us today. I can't imagine a more appropriate location for the Symposium than at the Dunes State Park.

I would like to thank Phil Pope, Director of the Illinois-Indiana Sea Grant Program, for supporting the Symposium. I would also like to thank Leslie Dorworth of the Illinois-Indiana Sea Grant Program, and Dawn Deady and Steve Lucas of our Coastal Coordination Program, for putting together today's program. It's a special effort and one I'm pleased to share.

OUR INDIANA BEACHES

Phil Pope
Director of Illinois-Indiana Sea Grant

Welcome to A National Healthy Beaches Symposium. While my role today is to introduce many of you to the Illinois-Indiana Sea Grant Program and its role in addressing healthy beaches issues, I believe it is appropriate for me to spend a bit of my allotted time acknowledging the Inter Agency Task Force on E.coli. This Symposium is a result of one of the many initiatives of the task force.

From a historical perspective - the Task Force came into existence a couple of years ago. The first meeting was called by the Lake Michigan Coastal Coordination Program, and nineteen agencies were represented. The question posed at the meeting was "Is there a coordinated approach to finding a solution to the periodic beach closures in northwest Indiana?". The question seemed to be fairly simple but the answer was more complex. From the initial meeting, the Inter Agency Technical Task Force developed. The Task Force has worked together effectively since it's inception. The original members included representatives from local, state and federal agencies. It has now grown to include non-governmental organizations, individuals and other private entities.

I believe The Task Force has taken a comprehensive approach in addressing the bacterially induced beach closure problems. The group has approached the problem by examining the methods of collection and looking for consistency in the protocol. This can then be used to develop a real time forecasting of future beach closures. Also, the Task Force has identified the need for identifying the sources of E.coli and the fate of the bacteria once released from it's source. Finally, the group has recognized that there needs to be a systematic program of remediation which includes education and outreach programs. If we can solve this problem, we will enhance the public health and improve the quality on northwest Indiana's beaches. As an added benefit, we will also enhance the economic vitality of out lakeshore.

The goal of the Symposium is to bring together scientists and policy makers to discuss a number of issues pertaining to beach closure problems. The morning session will look at the problem both nationally and locally. In the afternoon, concurrent sessions will address a variety of concerns, from monitoring and protocol issues to cooperative efforts undertaken in other states to examine the problems associated with contaminated swimming waters.

Personally, I am pleased that Illinois-Indiana Sea Grant was involved in the planning process for the Symposium. My hat's off to Leslie Dorworth who put in a tremendous amount of energy and time toward this meeting also, I would like to thank the other Sea Grant Staff that were involved in putting the program together. I would also like to give a special thanks to The Task Force members who devoted their time and energy to the Symposium. Without them this symposium would not have occurred.

Illinois-Indiana Sea Grant is pleased to be involved with this symposium and to be a member of the Task Force. The Sea Grant program is administered out of Purdue University and the focus of the program is southern Lake Michigan and it's shoreline. The mission of Illinois-Indiana Sea Grant is to foster stewardship, conservation and the appropriate use of the resources of the Lake. We do this through three primary functions: 1) research; 2) outreach; 3) education.

Today's symposium engages two of our five primary focus areas of Illinois-Indiana Sea Grant--water quality and sustainable economic development. Currently The Sea Grant Program supports a water quality extension specialists housed at the Department of Biology at Purdue University Calumet in Hammond. The program also supports a number of projects in water quality, one of which you will hear about later today--a project directed by Drs. Evertt Ting and Charles Tseng also located at Purdue University Calumet.

In closing, I would like to welcome you once again to the "National Healthy Beaches Symposium".

STORMWATER RUNOFF INTO SANTA MONICA BAY IDENTIFICATION, IMPACT AND DISPERSION

Burton Jones, Libe Washburn, Steven Bay, and Ken Schiff

Introduction

Santa Monica Bay is a very complex system where concern about the recreational health of the surrounding beaches has existed for years. Initial concerns about water quality arose when it was thought that contaminated sewage from the large ocean outfalls impinged on the swimming beaches leading to various types of infection associated with contaminated water. The combined release or treated sewage from the City of Los Angeles, the County of Los Angeles, and Orange County sewage outfalls is on the order of one billion gallons (3.8×10^6 m^3) of treated waste per day. The Los Angeles County Hyperion Treatment Plant alone releases to the Bay, 3×10^8 to 3.5×10^8 gallons of treated sewage per day.

After extensive study, it was clear that beach contamination problems were not emanating from the waste water treatment plants but that storm water run off was more likely to be the primary source of contamination. Los Angeles receives most of it's rainfall in a short period of time, between November and March. During this period, the typical rainfall is twelve to fourteen inches which results in seasonally heavy runoff and strongly affects the water quality of Santa Monica Bay. During El Niño years, the amount of rainfall during this period may be at least double the annual average.

For the present discussion, we will present data from a study of the coastal ocean impact from two watersheds draining two different land types, one of which is very urbanized and the other which is mostly rural (Figure 1). The Ballona Creek Watershed drains much of the west side of Los Angeles, a highly urbanized area where 88 percent of the land is used for commercial and residential development and only 12% is considered to be open land. On the other hand, Malibu Creek Watershed drains the coastal mountains. This watershed encompasses 88% open land, which for Los Angeles is considered rural. The two watersheds each contribute about 30 percent of the annual freshwater inflow to the Bay and therefore provide a useful comparison of the impact of the two types of watersheds on the Bay.

Bathers on the beaches around Los Angeles are well familiar with the permanently posted warning signs indicating the locations where storm drain outflow enters the beach and shore area and that the water in the outflow may cause illness. Most of the year the flow is minimal and the warm fresh water is an attractant to children who play in them as well as swim near the outflow. Some are lined in concrete which enhances the rate of river flow. The river flow is directed and concentrated so that once it exits the drainage system, it may spread out across the beach on its path to the ocean. These smaller storm drain releases, although small in volume, may be highly concentrated in contaminants and pathogens.

Although the release of water from storm drains is relatively diffuse with many drain outflows spread along the coasts, the bulk of the flow comes from the two major creek systems, Ballona and Malibu Creeks. Both creeks release plumes which originate from a single source point where the creeks interface with the ocean and from which the freshwater is dispersed over large areas both offshore and alongshore depending on the coastal currents at the time of release.

The immediate primary concern with storm water releases into the coastal environment is public health. Health is followed by aesthetics which affects beach use and the tourism industry. Tourism impacts, in turn, influence the economics and the associated public decision making.

Environmental health and ecology are normally the lowest priorities, but not necessarily the least important. When considering the last two components, both short-term and long-term impacts must be considered.

The study is composed of three components each of which is discussed below. The first part of the presentation will examine at the effects of dispersion and mixing of storm water runoff from Ballona and Malibu Creeks into Santa Monica Bay. This study is being done jointly by myself and Professor Libe Washburn of UC Santa Barbara. In the second part of the presentation we will look at the movement of toxins into the receiving waters and the impacts. This work is done by Steve Bay of the Southern California Coastal Water Research Project (SCCWRP). The third component will examine the impact of the particulate matter and toxins on the benthos communities, research carried out by Ken Schiff also of SCCWRP.

Funding for the three components of the project has been provided by the Los Angeles County Department of Public Works and USC Sea Grant Program. Boat resources were generously provided by the City of Los Angeles Department of Sanitation.

OBSERVATIONS

Plume Dispersion

When stormwater enters the saline coastal environment, the freshwater remains buoyant and spreads out over the surface of the more dense, saline water. The stormwater is usually very turbid during a rainstorm and carries a large load of suspended terrigenous material. The first thing that happens when the freshwater mixes with the saline water is that the flow initially slows down. The loss of momentum and turbulence causes the larger particles to fall out of suspension. The finer material will remain in suspension and be transported over larger distances from the mouth of the discharge. Because of their large surface to volume ration, the fine particles carry with them various contaminants, bacteria and viruses, which are generally adsorbed onto the particle surface. With time and distance from the source, these particulates also will eventually drop out of suspension. While there is usually an offshore limit to the distance that the freshwater will be transported due to the presence of an offshore physical front, the alongshore dispersal distance is much less certain and is dependent on the prevailing coastal currents.

Sampling methodology for the system is the same for both watersheds. A set of sampling lines, or transects, originating from the mouth of the two creeks out into the Bay are used to map the environmental variables in the water column (Figure 1). The benthic sites that are sampled lie within the grid of water column mapping transects.

The data for this study were collected during three days of sampling following a rain event on March 4-5, 1996, when the area received 0.8 inches (2 cm) of rain in a 24 hour time period. A towyo package was used to map the distribution of environmental variables in the water column. The towyo carried a CTD to measure pressure, temperature and conductivity of the water (Washburn et al., 1992). The towyo was also equipped with optical sensors for measuring chlorophyll fluorescence, a transmissometer for measuring turbidity, and a PAR (photo-synthetically available radiation) sensor to measure the available light for photosynthesis and its penetration from the surface through the water column (Wu et al., 1994). The instrument package was towed through the water in a cyclic fashion, from the surface to the bottom. It is then possible to construct a three dimensional map of water properties in the system when water column is sampled in this manner. Horizontal resolution is approximately 250 m and vertical resolution is less than 1 m.

In the coastal ocean salinity provides a very direct way to track the dispersion of freshwater in the surface layer. Temperature may be an ambiguous tracer, depending on the temperature difference between the inflow and the coastal receiving waters. In the example presented in this discussion, both temperature and salinity provide tracers of the freshwater plume in the surface waters (Figure 1). The plume is advected northward by the coastal currents, from its source at the mouth of Ballona Creek.

Stormwater inflow carries with it a suspended load of sand, smaller particulate and plant material. The stormwater also includes dissolved components that include metals, dissolved organic material, and inorganic nutrients (nitrate, phosphate, and silicate) which enhance the growth of phytoplankton in the plume. Although we observed high chlorophyll fluorescence in the plume, it is likely that this fluorescence was due to terrigenous plant particles in the water rather than to localized immediate phytoplankton growth. Turbidity of the water column, indicated by the beam attenuation coefficient (C_{660}), tends to follow the salinity patterns. In general, high particulate concentrations are associated with low salinity stormwater runoff.

In a cross-shelf towyo section (distance in the x-direction, depth in the y-direction), the stormwater runoff is again shown to be clearly delineated by warm, fresher, turbid water spreading horizontally from the creek mouth (Figure 2). Because of the buoyant nature of the water, the fresher water plume may extend offshore from the mouth of the creek to a distance of 2.5 km with a maximum extension in some locations to as much a 4.5 km offshore from the coast. The thickness of the freshwater layer is on average 5 meters or less. In Figure 2, it is also evident that another source of particles in the water column is resuspension from the bottom. A layer of resuspended particulate is evident along the entire transect with the bottom 5 meters of the water column.

Two days after the rain event, observations of the freshwater region indicate that is still spreading upcoast near Malibu Creek as well as around Ballona Creek. At this time the plume becomes patchy or disrupted, an indication that it is dissipating. We also observed a phytoplankton bloom due to dinoflagellates off of Malibu, which results from the input of nutrients and buoyancy provided by the storm water plume.

The conclusions resulting from the plume dispersion component include: (1) turbidity from the storm water affects both the aesthetics and biological productivity due to rapid attenuation of light; (2) storm water nutrients contribute to phytoplankton growth in the surface layer; (3) the buoyancy of the freshwater and the added nutrients result in red tides in southern California and; (4) the buoyant plume may interact with the surface currents.

The overall conclusions resulting from this portion of the study are: (1) the stormwater runoff is easily mapped and is detectable in the Bay using physical, chemical and optical measurements; (2) the freshwater plume spreads offshore 2 to 5 km and continuously along the shoreline; (3) the surface plume is initially less than 5 meters thick but deepens to 10 meters as time progresses from the rain event; (4) the plume is evident for at least three days after the storm event and; (5) the suspended particles in the plume transition from terrigenous particles to biogenic particles as the storm event progresses.

Plume Toxicity

The second section of the project examined the toxicity of the stormwater runoff. The specific questions being asked are: a) Do plumes contain toxic materials? b) Specifically, what are the effects of the toxins in the water column? c) Is the sediment quality affected? d) Is it possible to isolate the contaminants?

Toxicity was measured with a sea urchin fertilization test which measures the rate of success of fertilization of the sea urchin eggs. Prior to the field work, water was collected from both Ballona and Malibu Creek and mixed in varying quantities with sea water. Laboratory grown sea urchin populations were then raised in various percentages of mixed sea water and stormwater runoff.

The sea urchin rate of fertilization success in a controlled laboratory setting is less than 10% when a 50/50 mix of runoff water from Ballona Creek and sea water are used. The toxic effects of the water decrease dramatically when the percent stormwater used is below 25%. At a 5% level, the chance of a successful fertilization is approximately 100%.

The fertilization success rate at Malibu Creek was much greater for similar dilutions than was observed at Ballona Creek. Samples collected 1 to 1.5 km from the mouth of Ballona Creek indicate a small percentage of fertilization success rates, in fact less than 15% chance of fertilization. The greater the distance from the mouth of Ballona Creek the greater the success rate for fertilization. Near the mouth of Malibu Creek, the rate of fertilization success is approximately 100%.

In situ samples were collected at various locations along a sampling grid to determine the actual impact of the stormwater on the sea urchins fertilization success rates. The results were surprising. Combined stormwater and sea water mixture was shown to be more toxic than that predicted from the laboratory mixing efforts. Using an empirical relationship between toxicity and salinity, we were able to construct toxicity maps showing both the horizontal and vertical distribution of toxicity (Figure 2).

Once the plume was determined to have toxic effects on the organisms, the next step was to perform a toxicant identification evaluation (TIE) to determine the cause of the toxicity. Water samples were collected and filtered through a glass fiber filter. The filtrate was then separated into three volumes which were each subjected to a separate test: a) pass the sample through a C18 column to remove most of the organics; b) treat the sample with EDTA to complex with the metals; and c) a thiosulfate test to examine the oxidants of metals.

Results from the Ballona Creek water samples indicated that once the sample had passed through the EDTA treatment that fertilization increased to 80%. The metals, in this case, may be coming from Los Angeles streets and highways as the stormwater washes off the roadways. Although toxicity was observed in the water column, we found very little evidence of a toxic impact on the benthic communities. EDTA did have a similar impact in reducing toxicity in the sediments where some toxicity was observed.

In summary, surface water containing more than 10% runoff appears to be toxic to sea urchin fertilization; watershed characteristics play a major role on the eventual toxicity of the receiving waters; the magnitude and characteristics of the surface water toxicity in the Bay near Ballona Creek are similar to Ballona Creek stormwater; and no significant sediment toxicity was detected in areas adjacent to the major drainage outflows.

Benthic Impacts

The third part of this project examined the stormwater impact on the benthos. The questions asked are: Is there a predictable area of influence? What is the magnitude of change? Is there a gradient of effect? Is there an impact?

As stated earlier, the stormwater contained a large suspended particulate load. Tracking the dispersion of fine particulate material from the runoff indicates that a major portion of this material may be transported offshore. In the sediments, fine particulate material is most visible at the 25 and 40 m isobath.

Heavy metal components found in the runoff from Ballona Creek include lead, silver and mercury. Also, the stormwater particulates also contain high levels of organic compounds including PCBs, DDTs, and PAHs. Malibu Creek runoff had high concentrations of chromium, cadmium, and nickel.

The sediments off of Malibu Creek indicate very low levels of PCBs. This is not unusual since the watershed encompasses a rural area. Ballona Creek, with its high residential and commercial land use, has much higher concentrations of PCBs in the runoff (6 to 7 times higher than off of Malibu).

The pattern for lead was similar to the pattern observed for PCBs. The concentration of lead off of Malibu Creek is 10 mg per gram dry weight. Near the mouth of Ballona Creek, the highest lead concentrations, 27 mg per gram dry weight, were found a short distance from the mouth at the 25 m isobath.

A regression of iron with lead concentration provides insight into the source of the lead. Because iron is so abundant in soil and rock, the primary source of iron that we observe in the sediments off of stream and river systems is terrigenous, not anthropogenic. If the abundance of a another metal is positively correlated with iron abundance, the source of that metal is then assumed to be terrigenous. However, if the concentration of this metal is independent of the iron abundance, the source of that metal is likely to be anthropogenic. Off of Malibu Creek lead abundance was correlated with iron abundance indicating a natural source for the led in the sediments found off of Malibu Creek. In contrast, samples collected off of Ballona Creek indicated that lead concentration was independent of iron concentration and therefore indicate an anthropogenic source. Copper concentration was analyzed in a similar manner for both creeks. Copper, for both systems, demonstrated a strong positive correlation with iron, indicating natural sources of copper for both watersheds.

In order to assess the impact of the stormwater within the two areas studied, biological indicators were also examined. Specifically, abundance of species was examined. Species richness and diversity were also included in this part of the study.

At Ballona Creek, the number of species was relatively high but decreased as one proceeded north. But the decrease in the number of species did not suggest a major problem within the benthic biological community. At Malibu Creek, the number of species counted was relatively uniform and high off of the mouth of the creek. The species diversity at both locations was similar.

In summary, a gradient in sediment grain size does exist, particularly for the Ballona Creek sediments, however no dramatic impact on the biological communities in the sediments was detected.

Summary

We have demonstrated that the dispersion of the plume can be mapped and examined in three dimensions, from the water column to the sediment. Oceanographically, there is an effect on the water column's turbidity which will affect the biological productivity of the system. Initially, the stormwater plume is toxic after the stormwater enters the Bay. The toxic impact on the rate of sea urchin fertilization success rates may be related to the potential impact the toxins have on invertebrates to spawning fish populations. In the case of the sediments, where problems are typically expected to occur, we were unable to detect significant impact. The greatest impact of the sediments on the biological communities is at the mouth of the river, and may be more a function of grain size variability than any toxic effects from the sedimenting of stormwater particulate matter.

REFERENCES

Jones, B. and L. Washburn. Storm water Runoff into Santa Monica Bay: Identification, Impact and Dispersion. 1997. In press, Proceedings of the California and the World Oceans Conference 97, ASCE.

Washburn, L., B. H. Jones, A. Bratkovich, T. D. Dickey, and M. Chen. 1992. Mixing, dispersion, and resuspension in the vicinity of an ocean outfall wastewater plume. Journal of Hydraulic Engineering 118:38-58.

Wu, Y., L. Washburn, and B. H. Jones. 1994. Buoyant plume dispersion in a coastal environment: Observations of plume structure and dynamics. Continental Shelf Research 14:1001-1023.

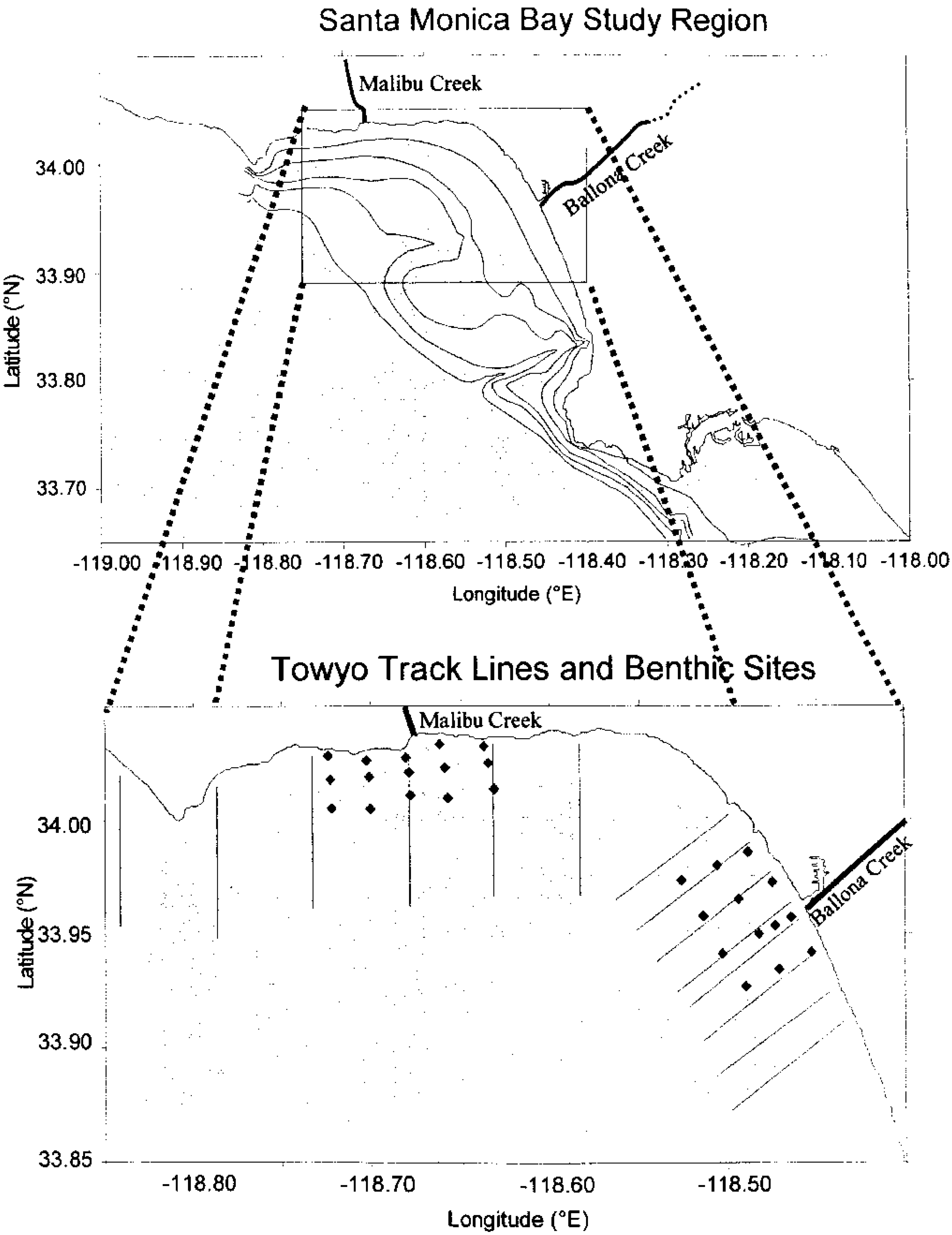
Addresses:

B. Jones, Dept. of Biological Sciences, University of Southern California, Los Angeles, CA 90089-0371, E-mail: bjones@usc.edu

L. Washburn, ICESS, University of California, Santa Barbara, CA, 93106-4060, E-mail: washburn@icess.ucsb.edu

S. Bay, SCCWRP, 7171 Fenwick Lane, Westminster, CA, 92683-5218, E-mail: steveb@sccwrp.org

K. Schiff, SCCWRP, 7171 Fenwick Lane, Westminster, CA, 92683-5218, E-mail: kens@sccwrp.org


Santa Monica Bay Study Region
Malibu Creek
Ballona Creek
Latitude (°N)
34.00
33.90
33.80
33.70
-119.00 -118.90 -118.80 -118.70 -118.60 -118.50 -118.40 -118.30 -118.20 -118.10 -118.00
Longitude (°E)
Towyo Track Lines and Benthic Sites
Malibu Creek
Ballona Creek
Latitude (°N)
34.00
33.95
33.90
33.85
-118.80 -118.70 -118.60 -118.50
Longitude (°E)

Storm Water Toxicity During a Moderate Rainfall Event

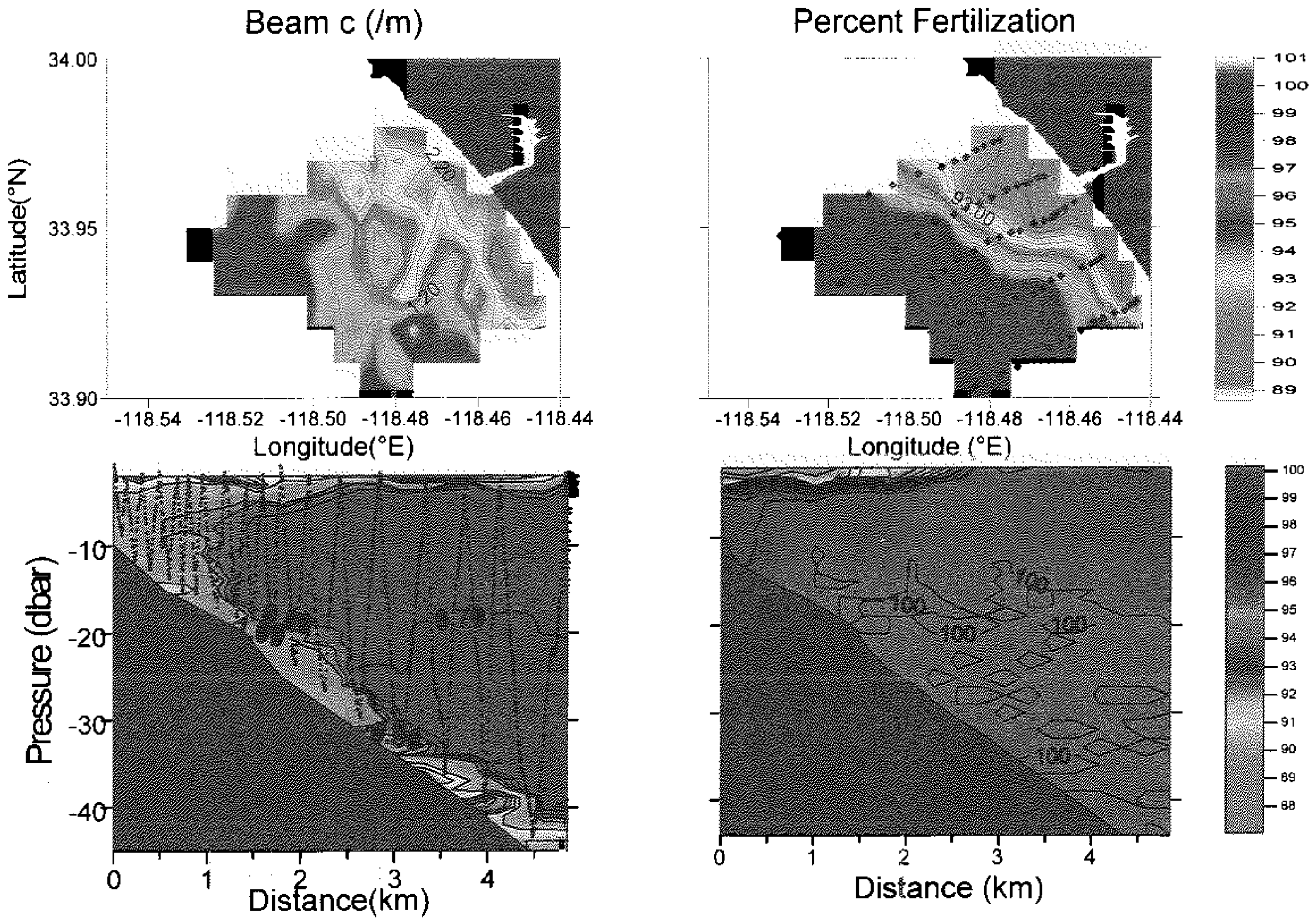


Figure 2. Surface maps of beam attenuation coefficient (an indicator of suspended particulate material [SPM]) and percentage of sea urchin fertilization from mapping of the region off of Ballona Creek on March 5, 1996. The lower left panel shows the distribution of SPM from stormwater runoff in the upper 5 meters and from sediment resuspension near the bottom. The vertical sections in lower two panels are from the center line on the surface map shown in the upper right panel.

THE OLD SWIMMING HOLE: AN EPIDEMIOLOGICAL AND BACTERIOLOGICAL PARADOX

Greg Steele
Director of the Epidemiology Resource Center

The Old Swimming Hole, an epidemiological and bacteriological paradox we are trying to get a handle on. We must, therefore, ask the following questions:

- What is the problem?
- What is the agent causing the problem?
- How do I get it?
- Are there others who are more susceptible?
- What does it do to me?
- What do I do to get rid of it?

Therefore, when we look at a variety of epidemiological investigations, we must consider the above questions, and apply the questions to various individuals within our population. Questions such as: "Does it only happen to children or are adults also at risk?"; "How does it affect those individuals who are immune compromised for whatever reason, be it disease or chemically induced?"; "Are the agents different (do they have different patterns)?".

Through recent advancements in science and technology, we now have the ability to identify potential sources of contamination. Presently, we are using DNA fingerprinting to assess the sources.

When dealing with contaminated swimming waters, one of the first questions that should be asked is , "Is there a correlation between high bacteriological counts in recreational waters and the presence of disease in swimmers?" If the answer to the first question is affirmative, then the next set of questions are: What is the source or origin of the bacteria?; Are swimmers at greater risk?; and finally, What are the routes of exposure (dermal, inhalation, or is it ingestion)?

We know two things from these studies: (1) Swimmers do have a greater overall incidence of illness when compared to non swimmers; and (2) Swimmers under the age of 10 have 10 times greater risk of illness than those over 10. You may ask, "Why do children under 10 years in age have an increased risk?" Just watch children play in a public pool and you will notice that their mouths tend to be open more frequently, which increases the chances of ingesting water.

There are generally three types of illnesses that we encounter on a routine basis at the State Department of Health. The three are reported in descending order of importance: (1) gastro intestinal; (2) ear, eyes, nose and throat; and (3) skin. In the case of skin, it is usually a minor problem in comparison to the other diseases that one may be exposed to due to swimming activities.

Combined sewer overflows, boaters and residential waste disposal from homes bordering major bodies of water are the culprits normally identified when the waters become contaminated with fecal waste. However, the number of people living along the shore or in boats, such as sailing boats, anchored house boats, on-shore resort cottages and cabin dwellers has increased significantly in the past couple of years. The quantity of waste material being produced from all these sources should also be considered.

When we talk about the boating community, we must now recognize the fact that the number of people, boats and actual hours spent on board as well as travel time have increased significantly. In the past, a marina was a place to leave from, but times have changed. Today, a marina, for the most part, is now considered to be a place to go to, where the boater or potential boater lives on the boat for the weekend but never casts off from the dock. In fact, one might consider a marina to bee a compact floating village. Therefore, when we consider waste regulations and disposal activities, we must address this new issue in marinas.

Other problems that must be considered are septic systems. Many homes are on septic systems, which, if not properly maintained, will add to the waste problems in a nearby body of water.

There are several pathogens that must be considered when dealing with water contaminated issues. The main ones are Salmonella, Shigella, Giardia, E.coli, and a host of others. When we consider human health issues and concerns, it becomes apparent that there is a variety of agents that we need to recognize and not ignore in order to assess the complete picture.

Today, I am here to talk to you primarily about E.coli. What is E. coli? E.coli is commonly referred to as a colon bacillus. It is the predominant facilitative species in the large intestine of mammals where by it facilitates the digestive process and absorption of fluids. There are six different strains of E.coli:

1. Enterohemorrhagic (EHCC)
2: Enterotoxgenic (ETCC)
3. Enteroinuasive (EIEC)
4. Enteropathogenic (EPEC)
5. Enteroaggregative (EAggEC)
6. Diffuse-Adherence (DAEC)

Some of the above are more common then others based on the speciation. It is important for us to differentiate between the strains because some are associated primarily with an aquatic environment whereas other strain may be found inhabiting multiple environments. Therefore, we need specific documentation of the exposure source, for example water or another source, to determine what strain of E.coli is the contaminant.

Enterohemorrhagic (EHCC) is probably the one strain to receive the most notoriety, thanks to a *Jack in the Box* restaurant in Washington. It is commonly associated with food, such as ground beef. In this case the E. coli strain is introduced to the meat through improper slaughter house techniques. What happens is that as the animal is slaughtered, the animal defecates and the feces may then get on the outside of the meat. As the meat is ground up, the feces can be or will be homogenized throughout the meat product. If the meat is not thoroughly cooked then human health problems usually result. Symptoms resulting from this are the following:

1. Diarrhea ranging from mild and non-bloody stools to stools that predominantly blood (3-4 stools/hr)
2. Hemolytic Uremic Syndrome (HUS) - young children are proned to HUS
3. Bacteria has very potent cytotoxins
4. The bacteria can attach to intestinal wall
5. The bacteria can be identified by their inability to ferment sorbitol in media.

The main infectous agent is serotype 0157:H7 also 026:H11, 0111:H8 and 0104:H21. The last three have also been implicated in the above symptoms. Serotype 0157:H7 is identified cattle.

Laboratory technology is very important in the identification process. A laboratory technique to identify the different strains of E. coli is pulse gel-electrophoresis. The basis of the technique is to use DNA material from the bacteria and place it across a gel. An electric charge is then added. If the charge is pulled through the gel, then the DNA will actually fingerprint. The State Department of Health is currently identifying the specific genetic fingerprint on all cases in order to identify the specific source of the contaminant. This has become an invaluable tool for the health departments in identifying the sources of contamination.

Another issue of concern is the possible importation of E. coli from one country into another country. Due to our healthier life styles, we are eating more fruits and vegetables, especially in the winter months. A lot of this food is being imported from other countries which may be a reason for concern. When an individual case of E. coli contamination occurs, the Indiana State Department of Health works jointly with the Center for Disease Control in order pinpoint the source of contamination. Indiana is not alone in working with the Center; other states are also involved. The information is being pooled, and the information is being used as a resource base for identifying sources, be it within the country or from another country.

Other sources for Enterohemorrhagic bacteria besides raw ground beef include undercooked hamburger , unpasteurized milk, unpasteurized fruit juices, swimming in small lakes under certain conditions and unchlorinated municipal drinking water. Therefore, the main source is cattle. Man, however, can also be a bacterial source due to poor hygiene practices. The mode of transmission for this strain of bacteria includes ingestion of contaminated food, ingestion of contaminated water and person-to-person transmission. Incubation period ranges from three to eight days. The median time is three to four days, but we would need to assess the exposure times to determine how the infected people acquired the contaminant.

Methods of control include managing slaughter house operations, pasteurizing dairy products and fruit juices, adequately cooking ground beef (no pink meat) and chlorinating municipal water supplies. Adequate level of hygiene must be maintained or reinforced, especially at day care centers. In terms of public health education, hand washing is the most important way to prevent transmission.

Another strain of E.coli that the Indiana State Department of Health deals with is the Enterotoxigenic (ETEC) form, commonly referred to as travelers diarrhea or dehydrating diarrhea in young infants. The symptoms include profuse water diarrhea without blood, abdominal cramping, possible a low grade fever and dehydration. It is generally not a toxic since this E.coli strain does not breath through the cell membrane and result in blood in the stools. Infectious agents are alot of the common O serogroups (06, 08, 015, 020, 025, 027, 063, 078, 080, 0114, 0115, 0128ac, 0148, 0153, 0159, and 0167). These strains elaborate a heat labile toxin, a heat stable toxin or both.

The mode of transmission of the ETEC strain is similar to that reported previously: contaminated food supplies, contaminated drinking and or swimming water, and direct contact via fecal material. ETEC is rarely transmitted through unwashed hands (person to person). Incubation period can be as short as 10 to 12 hours but is usually between 24 and 72 hours. ETEC is usually seen in young children. Obviously the incubation period will be determined by the amount of material ingested and also by the number of bacteria that are in the material ingested. In the case of this disease, the health department may not even be notified. Notification comes from physicians and laboratories, and they will see the individual only if that individual is sick enough to see a doctor. The hemorragic form is reported frequently to the health departments due to the presence of blood in the stools.

Control of the ETEC strain is best done by preventing fecal-oral spread and pophylactic antibiotic therapy for travelers going to high risk areas. In areas considered to be high risk, it is best to drink bottled water, canned juices, etc. One of the things that we have noticed is that travelers to these areas heed the warnings but still come down with the disease. After inquiry, it turns out that they will have had a drink on the plane. The water on the plane comes from the area they just left and that water be it in varied forms (ice) may be contaminated.

Enteroinvasive bacteria (ETEC) is an inflammatory disease of the gut mucous and submucosa. It resembles an infection caused by Shigella. Symptoms include severe abdominal cramps, malaise, watery stools, tenesmus (the urge of defecate but unable to), and fever. It progresses if left untreated to multiple stools with blood and mucous (similar to hemorrhagic but not as severe). The primary source for this strain of bacteria is human (fecally-orally). Young children are usually the source and the transmitter. The main mode of transmission is by food and water. The incubation period is on the order of 10 to 18 hours. Methods of control are the same as ETEC.

Another form is Enteropathogenic (EPEC) E.coli. This is probably the most noticeable strain. It is the oldest, recognized category, mainly associated with "infant summer diarrhea". It is virtually confined to infants less than one year of age. Diarrhea can be severe and prolonged and may be associated with a high case of infant mortality rates due to the loss of fluids. Humans are the main reservoir for this strain. The mode of transmission is primarily contaminated infant formula as well as poor hand washing techniques. The incubation period is nine to twelve hours. This strain is rarely seen in a daily, beach swimming activity. Methods of control for EPEC are to encourage mothers to breast feed, especially in developing countries, and stress overall proper personal hygiene.

Enteroaggregative (EAggEC) E.coli is found dominantly in developing countries. It is an important cause of infant diarrhea in these countries. An interesting and important feature of this strain is that it produces a heat stable enterotoxin that is not killed by cooking. Incubation time is relatively short, 20 to 48 hours.

The least well defined strain is Diffuse-Adherence (DAEL) E.coli. Again this strain occurs predominantly in less developed countries. This form tends to be more pathogenic in school aged children than in infants. Again, this form is rarely reported from activities centered around beach activities.

Therefore by looking at all the various E.coli strains, the receptors and the specific serotypes and based on the knowledge that we have, we can get an idea on the types of exposures that are associated with them and narrow down the investigation. Public bathing beaches and swimming activities can be associated with some of the E. coli strains, but this is usually rare. Generally, when they do happen, the concentrations are at such high levels that we have multiple cases.

What happens if you do have the problems? The disease is self limiting in most people meaning that the E.coli are usually shed from the body due to the immune system responses. Several drugs (sulfonamides, ampicillin, cephalosporins and tetracqline) are available to assist in recovery.

Drug resistant strains can and do develop. This is a major concern in the world today. Generally the drugs work by destroying the lipid metabolism in the E.coli cell wall. It, therefore, stops the metabolism of the bacteria and results in the bacteria's death . As technology changes, it enables us to look at the various components of the bacteria and identify the next level of control.

How do we deal with the various strains of bacteria from a public health aspect? There are three things that we think can be done:

Level 1 - Prevention - Be true to your stool
- Make sure the septic systems are properly working.
- Know where the waste material is going to prevent these problems (once they are in a body of water it is very hard to treat them).

Level 2 - Esthetics (visual, odors, etc.) - visible floating excrement will send a swimmer out of the water faster than a shark fin.

Level 3 - Safeguarding - need to bring about a change in social values, governmental structures, and services in managing our environment.

We have to get legislatures, cities, towns to become more aware of the problems and how they need to be managed to prevent these events from happening. This type of sewage, whether it contains E.coli or Shigella or any other fecal based material is not being disposed of properly or the systems are not working properly and are therefore contaminating our water supplies and beaches. We are going to have to bite the economic bullet and do alot of corrective development to correct the problems associated with combined sewer overflows as well as educate homeowners who live on or want to build near bodies water, about maintaining properly operating septic systems. We need to work with marinas to help them control waste problems so that we do not have inappropriate dumping of waste materials from boats into bodies of water. Another area of concern is the agriculture community. This community needs to be educated about the problems associated with having livestock wandering through streams and the eventual outcome if the animal defecates in the water.

All of these things come into play and it needs to be an integrated approach. It is a job that needs to be taken on and in fact it will be something on our agenda in the not too distant future because it is becoming more of a problem and cannot be dealt with in small increments.

The U.S. Environmental Protection Agency's Beach Environmental Health (BEACH) Program - An Introduction

Rick Hoffman
Beach Health Protection Team Leader
US EPA

The EPA is currently in the process of setting up a National Beach Program. One of the many things that my office is currently doing is setting up a web page to identify who is currently working in this area and also to coordinate various activities across the country. We did a search on the Internet to see who had sites specific to the topic of beach closings and related E. coli contamination of the beach waters. Indiana was one of the first sites we came across in the search as well as Southern California. The EPA Beach site is linked to the few sites currently found on the web. In the next 15 to 20 minutes, I would like to speak to you about the EPA's National Program on Healthy Beaches.

The EPA program is called the **BEACH** Program: The **B**eaches **E**nvironmental **A**ssessment **C**losure and **H**ealth Program. The purpose of the **BEACH** Program is to: (1) improve the overall health of the beach for users through federal assistance to the state, tribal and local health and environmental officials; (2) assist with the design, development and implementation of beach monitoring and advisory programs; (3) inform the public; (4) areas of emphasis in the program include improving the scientific method, strengthen beach standards and testing, finding better testing methods and indicators, and working to improve better predictions of pollution.

The major driving force for the program resulted from a Consumer's Report in August 1996. Last August, the magazine had an article called "Finding A Clean Beach" . The first paragraph began with a sentence similar to the following:. "You are looking forward to spending time at the beach but are the microbes going to keep you out of the water..... Standards for the enforcement of water quality at recreational beaches varies widely...". What caught the attention of the EPA was a statement indicating that the EPA was not overseeing water quality standards for consistency and has not been overly involved in other aspects of the issue.

I had hoped to have a copy of the Water Quality Standards. However, at this time it is still not finished. The survey will present the bacteriological standards currently used by the states as well as the monitoring techniques being used. The report should be complete within the next month and be available through the EPA. The report will be available on the Internet as well as in hard copy.

The NRDC reported thåt 3,000 beaches nationally closed in 1995. The summary of closings includes more than a one day event. A map put out by the NRDC summarizes the closing s as well as a chart describing the state standards as well as types of monitoring efforts undertaken by the states.

Why is EPA interested in this problem or rephrased why is there renewed interest nationally? A report written a short time ago, "EPA Summary of US Great Lakes Beach Closings 1981-1994" shows that the problem still persists: In the report it was noted that over the last 14 years, 40 to 60 beach closures had occurred and some of these are permanent closures. In 1994, 66 of the 276 beaches monitored were closed at least one or more days. Determined causes are turbidity, combined sewer overflows, algae, and detritus. Similar trends in the beach closing issues around the Great Lakes is again noted in the 1996 NRDC report.

Besides a beach closure, the public is reminded of the issue in another important way. Scientific research revolving around contaminated swimming waters is frequently reported in the newspapers. Santa Monica Bay Epidemiology Study (May 1995) indicated that there was a greater risk to human health problems when swimming / recreational water activities took place near a storm drain. The study showed increased risk of gastrointestinal diseases as well as significant respiratory diseases. An additional study, from the United Kingdom (United Kingdom Epidemiological Study, 1994, 1995), showed not only gastrointestinal incidence of diseases but non-gastrointestinal problems as well.

Finally, media attention about the beach closures keeps the issue in the public mind. Cryptosporidium outbreaks, pathogenic strains of E.coli, and others such as mad cow disease and drug resistant bacteria, generally not related to swimming activities, have helped to keep this problem out in the media where the public can get information. I have been in this job for seven or eight months and have found that when I am reading an article, flipping through the newspaper or watching the news, my attention is peaked when a microbial issue is mentioned. In fact, microbial issues have been in the media as recently as last week due to the dinoflagellate Pfiesteria piscicida.

I would like to give you a brief history of the **BEACH** Program. In the fall of 1996, the program was under development as well as review. The initial mission of the program was to identify what people were doing nationally to identify the problem. In the spring of 1997, the Assistant Administrator sent out a letter to all of the state representatives on The Environmental Council explaining that the EPA would be an active participant in this area. Memorial Day 1997, Carol Browner, Director of the U.S. EPA officially announced The EPA's **BEACH** Program to the nation.

The emphasis of The **BEACH** Program is to look at and strengthening the nation's beach standards and testing in relation to human health concerns. Presently, the EPA is attempting to get the states to adopt risk based water quality standards. Another area for involvement concerns policy and technical assistance. The EPA plans to work with state, local and interested stakeholders to identify where assistance is needed i.e., is more research needed or is more technical guidance needed? In addition, we will be working with The Association of State and Territorial Health Officials to design a conference in mid October. The purpose of the conference is to pull together a cooperative federal and state action plan which identifies the long and short term needs at the local, state and national levels.

I will present briefly some of the areas that the **BEACH** Program is interested in addressing now and in the near future.

The **BEACH** Program will be working with the states on their research methods. One of the things the EPA was able to expedite was the publishing of a 24 hour Enterococcus Test Method. The original method included required 48 hours. The original method was published in *Water Quality Test Standards*. The new method is available as of May 1997. The major change in the original method was a change in the media that samples are plated on. Another step forward in achieving success with this problem is to improve EPA's overall research agenda. Keeping this in mind, the labs of research and development are to focus more of their attention on beach specific concerns.

We also are working with those individuals who do predictive modeling. The anticipated results is to determine ahead of time when a problem will arise not after the actual event. Model validation will be done at selected sites across the nation or where sampling is more intensive.

Another area the EPA is interested in is keeping the public aware of the problems. This, presently has been done primarily through our web site: "http:// www.epa.gov/ost/beaches". The site provides an overview of the program, who are the partners and a section on the most frequently asked questions. The EPA also encourages this site to be used for sharing resources and ideas. Also, at this web site will be the National Survey. EPA will survey state and local agencies to determine the nature and extent of beach contamination problems. This will also include monitoring efforts, posting closures, etc. The information will be compiled into a database that will be made available for public use.

The future agenda will involve the following steps: (1) Fall of 1997 we will be doing The National Survey and database; training on the new methods; reviewing water quality standards. (2) planning on additional monitoring projects; (3) Summer of 1998, doing research on new indicators and any other ideas that may have come out of the October conference.

A Microview: Dunes Creek

Richard Whitman
Lake Michigan Ecological Station
National Biological Service

Editor's note: The following presentation was given on the beach overlooking Dunes Creek at Indiana Dunes State Park.

We are looking at Dunes Creek as it enters Lake Michigan, and we are witnessing a disturbed stream system degraded to such an extent that it has lost equilibrium with the extensive wetlands that it drains and the vast riparian ecosystems that it once supported. This equilibrium became unbalanced largely due to human disturbances of the once natural drainage system in the Great Marsh.

The Great Marsh once extended from Portage to Michigan City (Figure 1). It averaged about one half mile in width and approximately 16 miles in length. Today only a remnant of the original wetland still exists. Two major ditches, Kintzele Ditch and Derby Ditch, were created to drain the Great Marsh, and Dunes Creek—the only natural stream draining the Great Marsh—was ditched extensively. Ditches were developed to remove water quickly and thoroughly and to make land more suitable for human endeavors. In the process, contaminants were much increased, both natural and human-derived. Much of the present stream flows would have been retained in the Great Marsh historically, but it now flows directly to Lake Michigan without benefitting from the contaminant-reducing biological processes in the marsh. These pollutants include sediments, nutrients, iron, and *E. coli*. This, in large part, underlies the present water quality problems in Dunes Creek.

Once this system of ditches was created, the basic ecology of the stream and wetlands was critically changed. One hundred years ago, Dunes Creek was a small creek system with a predominantly clean sand bottom that had few branches and limited interaction with lands outside of its immediate drainage (Figure 1). Due to extensive ditching, however, scientists now would characterize this as a third or fourth order stream—more branches indicate a higher order stream. In higher order streams, increased shoreline area is present for the introduction of contamination because the area of contaminant-reducing wetland has decreased relative to stream drainage. Today, there are hundreds of small ditches, both surface and underground tiles, instead of the former few branches of a natural stream (Figure 2). Thus, there is that much more riparian habitat directly affecting the creek. In these habitats, rodents, deer, rabbits, muskrats, beaver, and other animals introduce feces and *E. coli* into the stream system. Without wetlands filtering effects, runoff adds these bacteria and other pollutants to Lake Michigan, and because of this, swimming beaches must occasionally be closed.

The area at the outfall of Dunes Creek is one of the most popular beaches in Indiana, and for that matter, the whole Great Lakes. Bacteria closures at this site are, in one form, simple to understand because it is a small creek, a small watershed, and probably simpler than the two previously mentioned ditches. It is far simpler than Burn's Ditch, the Grand Calumet River, or Trail Creek, which are extraordinarily difficult to characterize and resolve. These systems are closer to the Santa Monica model described earlier in this symposium. On the other hand, resolution of the Dunes Creek bacteria problem is complex because finding the source and controlling it can be extremely difficult. Options for remediation are limited by present land use, the natural course of the creek and the morphology of the land. Total hydrological restoration of the Great Marsh by removing ditches would inevitably cause flooding of valuable residential or recreational lands. Directing the outfall of the creek to a less populated portion of the beach would be financially and environmentally costly.

At this time the creek is at a seasonal low flow—about the lowest that you will see it during the year. At this rate of discharge, sand impounds the creek, causing a natural sand filtration system before the creek water enters Lake Michigan. Dunes Creek has a generally sandy substrate, especially along the lower course of its drainage. Sandy creeks tend to be cleaner and clearer along this stretch since the sands filter out particulates, including bacteria.

At regular flow, the creek has about 500 to 2,000 *E. coli* per 100 ml water. At high flow, the *E. coli* can dramatically increase (Table 1). According to the state of Indiana limits, 236 *E. coli*/100 ml would result in closing the beach to swimming. A few years ago, we were asked by the Indiana Dunes State Park to determine why there is a bacteria problem and where the bacteria originated. We just finished a study at Derby Ditch, which lies to the east, similar to the examination of Dunes Creek. I was interested in comparing the two creeks because their watersheds are closely related. The streams share many characteristics, and most importantly, they respond similarly to *E. coli* loading. We examined both streams all the way up to their headwaters by checking all of the obvious sources of *E. coli*: septic fields and runoffs, household wastes, showers, and sewage treatment. We looked at water quality associated with human pollution, detergents, surfactants, optical brighteners, ammonia, and salinity. We analyzed the water for other bacteria and calculated ratios between bacteria types. We discovered that the two creeks did indeed behave similarly. The final determination was that we could not find any evidence of a human source. Does it mean it is not a human source? Not necessarily. Because there is no smoking gun, you cannot prove a positive with many negatives. All you can do is make inferences by eliminating hypotheses.

So all we can say is that we have no evidence that the *E. coli* problem in Dunes Creek is directly caused by humans. Indirectly, the problem was certainly caused by humans because of ditching over the last 70-80 years. We can ask many questions about the problem with the data we collected. What factors control the *E. coli*? When were concentrations high? Can we use these factors to predict *E. coli* contamination and beach closure? How would restoration of the Great Marsh affect *E. coli* loading.

In the course of another study that addressed the efficacy of a bacteria-monitoring program for the beach areas around these creeks, we found that rainfall was a very important factor. In a lot of other, more complex watersheds, it is difficult to find correlations with rainfall. But on small creeks, we are able to relate rainfall and bacteria more accurately. We used twelve years of weekly data, almost 2,000 readings at different beaches, taken at the same place by the same person using the same protocols, and we added rainfall and wind direction to the analysis. *E. coli* concentrations were correlated with amount of rainfall over different time periods. The results indicated that rainfall was an important factor in increasing *E. coli* density, but when wind direction and water temperature were taken into consideration, predictability increased substantially.

The people who manage the State Park already know that if there is a gentle wind out of the northwest, the plume from the creek will hug the southeast side of the shore. This nice warm creek water will stay on top of the cool lake and thus result in higher *E. coli* concentrations due to the lack of mixing and diffusion. The west side of the outlet would be clear and the east side would be turbid. If there is a south wind, the creek water is directed further into the lake, and sometimes there are beach closures on both sides of the outlet.

A third factor that is important for *E. coli* concentrations is temperature. August is the month with the most beach closures. We think that in the warmer months creek discharge is down, but the higher temperature increases the survival time for *E. coli*. *E. coli* does not survive long in cold temperatures—sunlight and cold temperatures are very stressful to these bacteria.

With the twelve years of data we tried to predict the monitoring program's effectiveness in terms of its ability to protect the public health of beachgoers. We found that there was little relationship between the *E. coli* reading of the previous day and the day of beach closure. Often, the beach water was lower in *E. coli* concentrations the next day during closure than the day it was first tested. This can be attributed to the constantly changing weather patterns. Throughout the United States, beach managers are trying to develop real-time bacteria determinations. We can do this with a surrogate of some sort, whether that surrogate is a physical, chemical or biological substitute. That surrogate could also be a parameter such as a virus associated with coliforms and humans, color, iron, turbidity, suspended solids, or caffeine. It also may be a model that takes into effect stream velocity, wind, or temperature, or it may be a more rapid bacteria assay.

The specific sources of *E. coli* in Dunes Creek were not definitively determined. Relationships between weather and land use and seasons were drawn, and potential solutions were explored. We know that *E. coli* in Dunes Creek is consistently high, and it is clear that beachgoers are occasionally exposed to excessive *E. coli* contamination. Finally, we know that we are not doing our job in informing and protecting the public, but it is because collectively, we do not know how to do it. Hopefully, research will eventually provide that answer.

Acknowledgments

I thank Meredith Becker for her assistance in preparing this manuscript and gathering figures and tables. I also thank Lou Brennan for creating the map of Dunes Creek ditches and Jason Butcher for providing the Great Marsh figure.

Figure 1. The three main creeks of the Great Marsh.

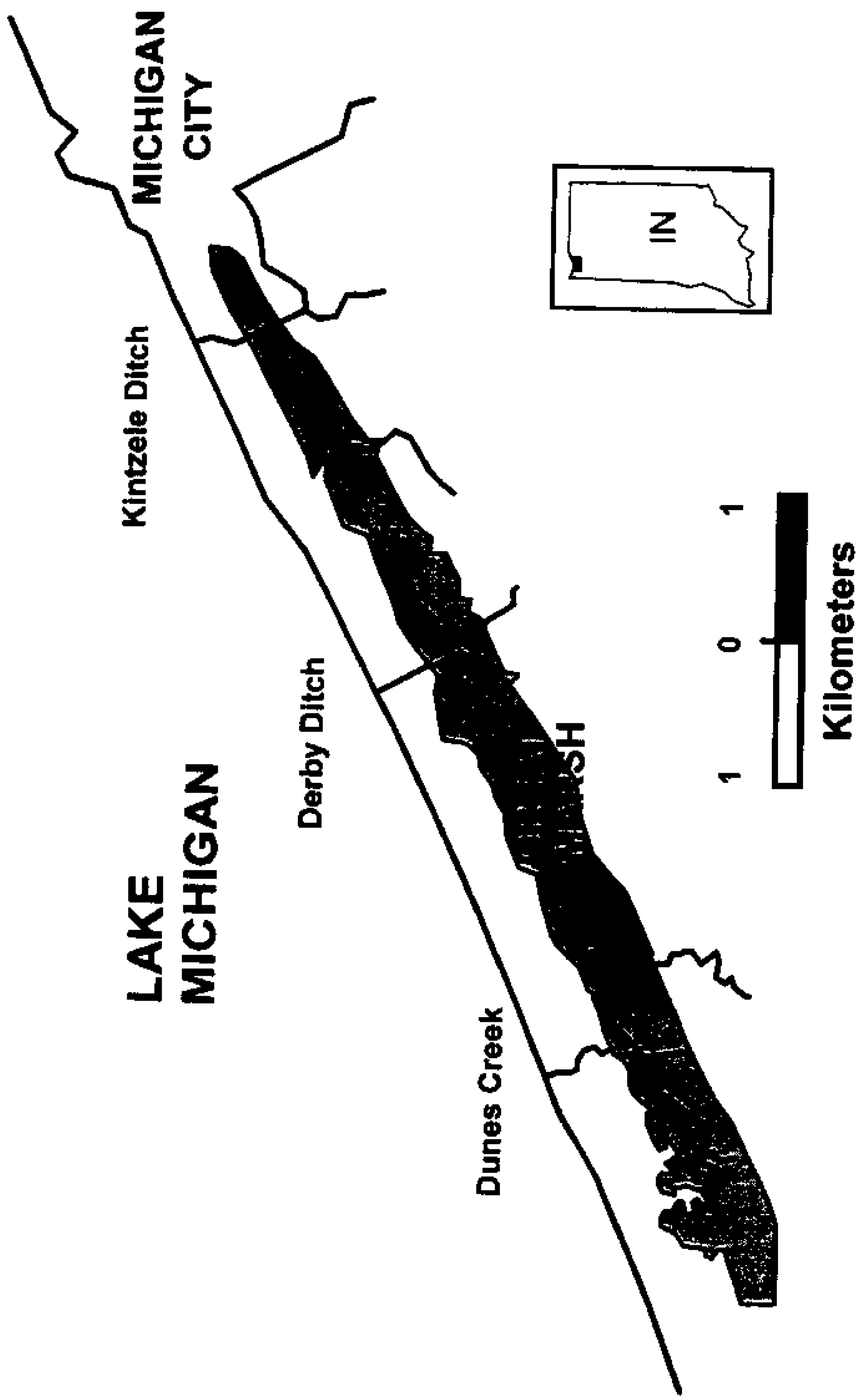
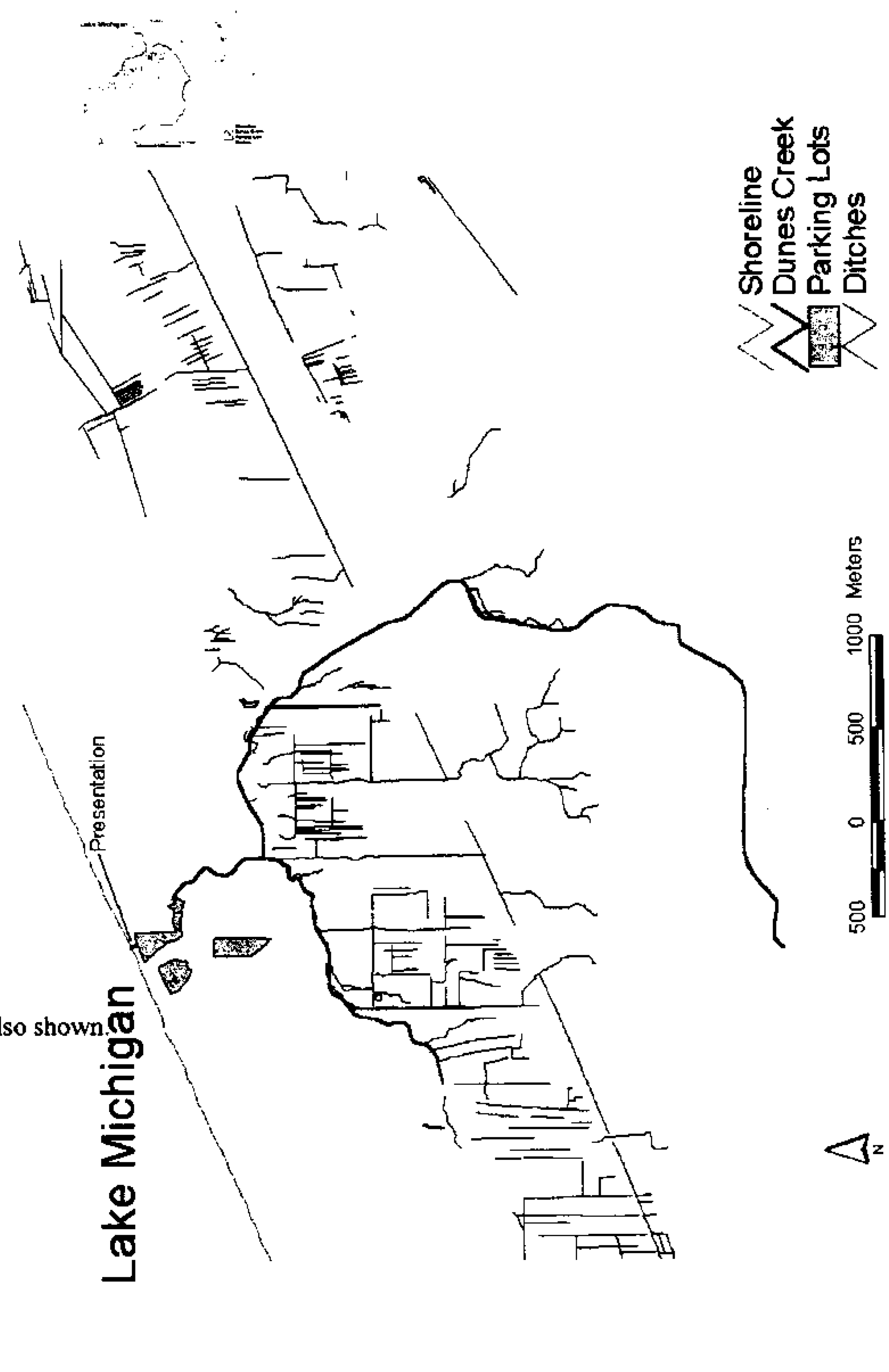


Figure 1. The three main creeks of the Great Marsh.

Figure 2. The main branches of Dunes Creek. Extensive ditching around the watershed



is also shown.

Figure 2. The main branches of Dunes Creek. Extensive ditching around the watershed is also shown.

Table 1. Mean *E. coli* counts in CFU/100 ml. The State Park West site was located to the west of where Dunes Creek enters Lake Michigan, and the State Park East site was located to the east of the Dunes Creek mouth.

State Park West

Year	Mean	Minimum	Maximum
1984	21	21	21
1985	42	1	162
1986	92	11	266
1987	99	18	188
1988	179	6	923
1989	153	2	820
1990	164	24	312
1991	283	34	888
1992	388	1	3200
1993	86	2	428
1994	129	1	960
1995	117	23	442

State Park East

Year	Mean	Minimum	Maximum
1989	258	4	1074
1990	210	2	772
1991	129	4	314
1992	206	4	1040
1993	97	4	480
1994	193	1	910
1995	213	8	876

VISION STATEMENT FOR THE INTERAGENCY TASK FORCE ON E.COLI

Amira Loney
Office of Water Management
Indiana Dept. of Environmental Management

The Interagency Task Force on E. coli consists of technical experts from local, state, and federal agencies who have banded together in an effort to solve northwest Indiana's bacteria induced beach closure problem. A comprehensive approach to the problem will include consistent methods of data collection for the development of a real-time forecasting system, identification of the sources and fate of the bacteria, and a systematic program of remediation. These measures are necessary to ensure for the State of Indiana the safety of public health and the economic vitality of the recreational use of the Lake Michigan shoreline.

E coli Sampling Sites by Department

HAMMOND CITY HEALTH DEPARTMENT

Wolf Lake
- Wolf Point
- First Bench
- Third Bench
- Last Point

INDIANA DUNES NATIONAL LAKESHORE

Beaches
- West Beach
- Ogden Dunes
- Porter Beach
- Dunes Acres
- Dunes St. Park W
- Dunes St. Park E
- Kemil Road
- Lakeview
- Central Ave.
- Mount Baldy
- Marquette Park

Streams
- Dunes Creek @ Lake
- Derby Ditch @ Lake

PORTER COUNTY HEALTH DEPARTMENT

- Spectacle
- Long
- Wauhob
- Edgewater
- Flint (Burlington)
- Shorewood
- Hillcrest
- Burns Harbor Lakeland Park

LAKE COUNTY HEALTH DEPARTMENT

Whihala Beach
- East Beach
- West Beach

LaPORTE COUNTY HEALTH DEPARTMENT

- Clear Lake-Westville
- New Stone Lake (Avg.)
- Old Stone Lake
- Stone Lake Launch
- Pine Lake-Waverly
- Pine Lake-Kiwanis
- Hudson Lake
- Upper Fish Lake
- Lower Fish Lake
- Michigan City Washington Park (Avg.)
- Long Beach: Stop 24
- Shoreland Hills: Stop 31
- Michiana Shores: Stop 37
- Michigan City California Ave. (Avg.)

BENEFICIARIES

Local Agencies
State Agencies
Federal Agencies
Researchers
Industries
Private and Public Organizations

ULTIMATE BENEFICIARIES...

Standard Operating Procedures for Recreational Water Collection and Analysis of E.coli

Danielle A. Livinghouse
Environmental Planner
LaPorte County Health Department

Sample analysis procedures for the draft Standard Operating Procedure were derived from:

- Standard Methods for the Examination of Water and Wastewater, 19th Edition
- The US EPA Test Methods for *Escherichia coli* and Enterococci in Water by the Membrane Filter Procedure (EPA 600/4-85/076).

Both procedures utilize membrane filtration and very similar media and solutions.

- mTEC agar
- Urea substrate
- Buffered water

Both test procedures require 22-24 hours of incubation time.

Preparation of mTEC media

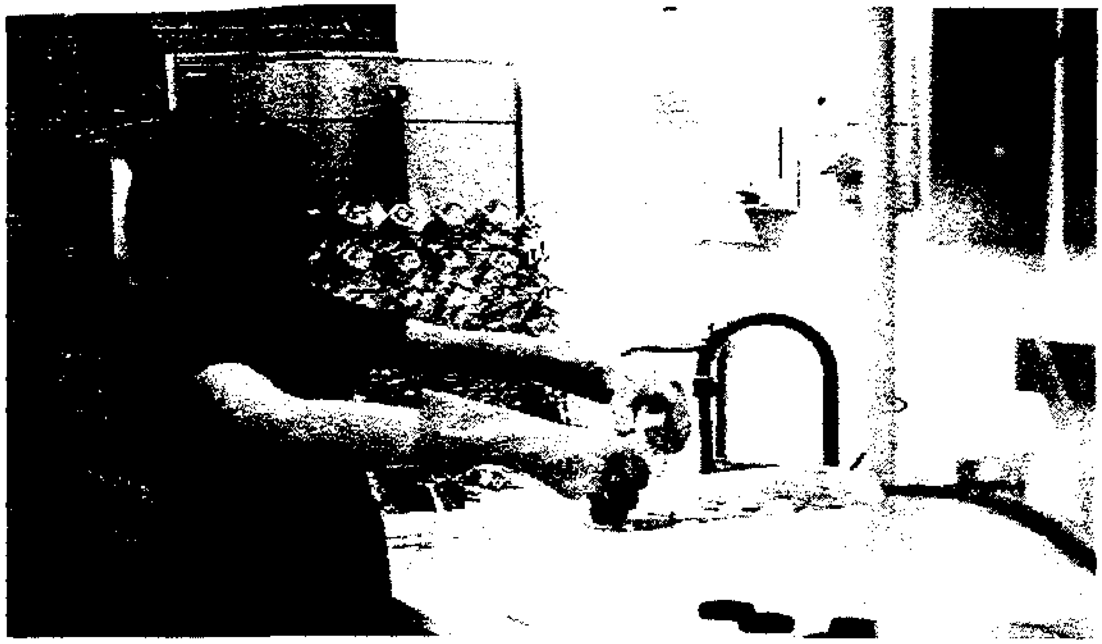
mTec agar is prepared by heating mTEC dehydrated medium with reagent water until dissolved.

MTEC media is then sterilized through autoclaving at 121°C (15 lb pressure) for 15 minutes.

Liquefied agar (4 to 5 ml) is poured into 50 x 10 mm culture plates.

Final pH should be 7.3 ± 0.2.

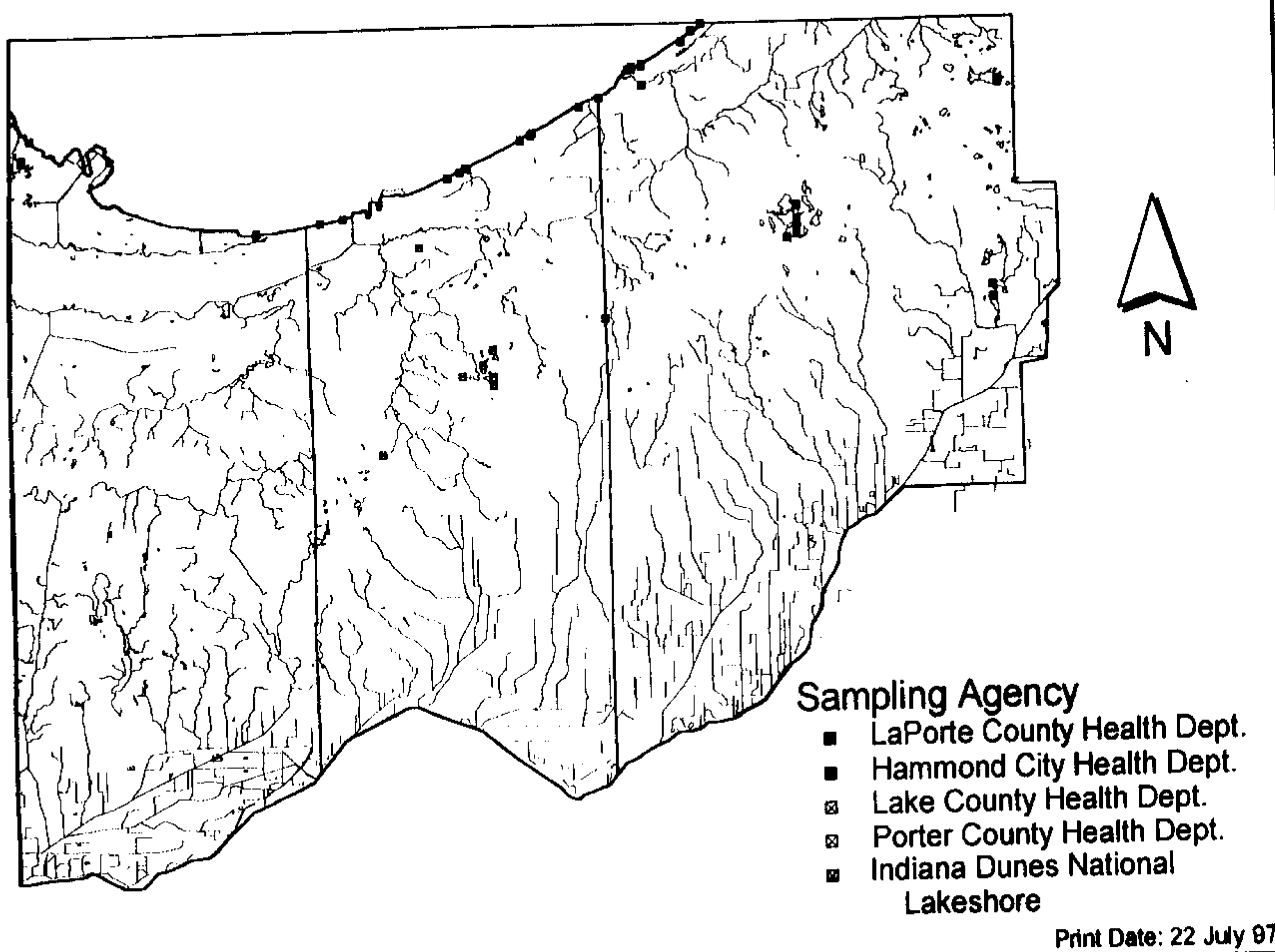
Plates may be stored under refrigeration for up to 1 month.

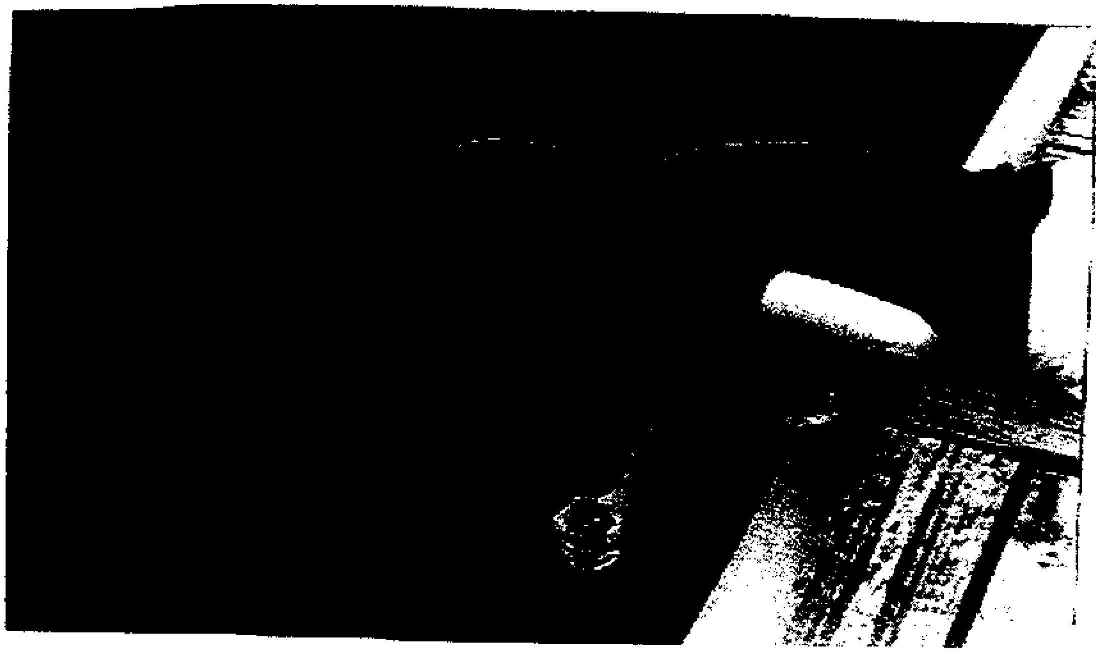


Samples should be collected in a disposable or non-disposable container that will hold at least 100 ml of sample water. Containers should be clean and sterile.

Non-disposable sample containers must be sterilized, either by UV or autoclave.
Sterile buffer rinse water, filtering apparatus, membrane filters and mTEC media must also be sterilized.

Northwest Indiana Bathing Beach Sampling Sites





Collect samples from inland lakes from a pier if possible. Open sample bottle just prior to collecting the sample. When collecting the sample, sweep down through the water to elbow depth in a U-shaped motion. Avoid cutting across the thermocline.

Avoid touching the inside of the sample container or lid during sampling. Before closing the container, make sure there is ample air space in the bottle (at least 2.5 cm).

Samples should be collected in waters about 1 meter in depth, or about mid-thigh. Sample where the highest concentration of swimmers are. Care should be taken to avoid areas with small children and to avoid kicking up the bottom of the sampling site. Do not sample in the "swash" zone.

Sample containers should be labeled with the location, date and time the samples were collected.
Samples should be immediately refrigerated or stored on ice in a cooler, out of sunlight, until they can be analyzed.
The maximum holding time for samples prior to analysis is 6 hours.

LaPorte County Health Department Water Laboratory
809 State Street LaPorte, IN 46350-3329

Lab No. ______ Date Rec. ______
Time Rec. ______ Name ______

SAMPLE DATA
To Be Completed by Client)
PLEASE read instructions on back

Examination Results Should Be Sent To:

Name ______

Street ______

______ INDIANA ______
CITY/TOWN ZIP CODE

PWS/POOL ID# [ ][ ][ ][ ][ ][ ][ ] D R O [ ][ ][ ]

Name of Organization ______

City or Town ______

County ______ Phone ______

Owner/Manager ______

Collected by ______

Sampling Address ______

Which Tap ______

Chlorine Residual (Pools) ______

TYPE OF SAMPLE (Check appropriate space)

____Well Water
____Swimming Pool
____Whirlpool/Spa
____Bathing Beach
____Surface Water
____Swabs
____Other______

DATE: Mo. ____ Day ____ Yr. ____

TIME ______ AM PM

SEND AN ADDITIONAL COPY OF RESULTS TO:

Name ______

Street ______

______ INDIANA ______
City/Town Zip Code

ANALYSIS DATA
(To Be completed By Lab)

TEST PERFORMED:

___Total Coliform___Fecal Coliform___HPC
___Nitrate___Escherichia coli ___ ______

RESULTS VERIFIED

BATHING BEACH, SURFACE WATER:
E. COLI
DRINKING WATER:
TOTAL COLIFORM
FECAL COLIFORM
NITRATE mg/L

POOLS:
HPC cfu/ml
TOTAL COLIFORM
FECAL COLIFORM

(NOTE: Unless specified, Results are cfu/100ml)

REPORT OF SAMPLE:

_____**SATISFACTORY**
___Iron on the filter
___Non-coliform bacteria on the filter

_____**UNSATISFACTORY**
___Chlorinate your well
___Collect samples according to IDEM's regulations

____**NOT VALID BECAUSE:**

___There was too long between collection of sample and receipt for examination.
___The water sample contained Chlorine residual.
___There was an overgrowth on the membrane filter.
___Other______
___WE ADVISE THAT ANOTHER SAMPLE BE SUBMITTED

ANALYZED BY ______

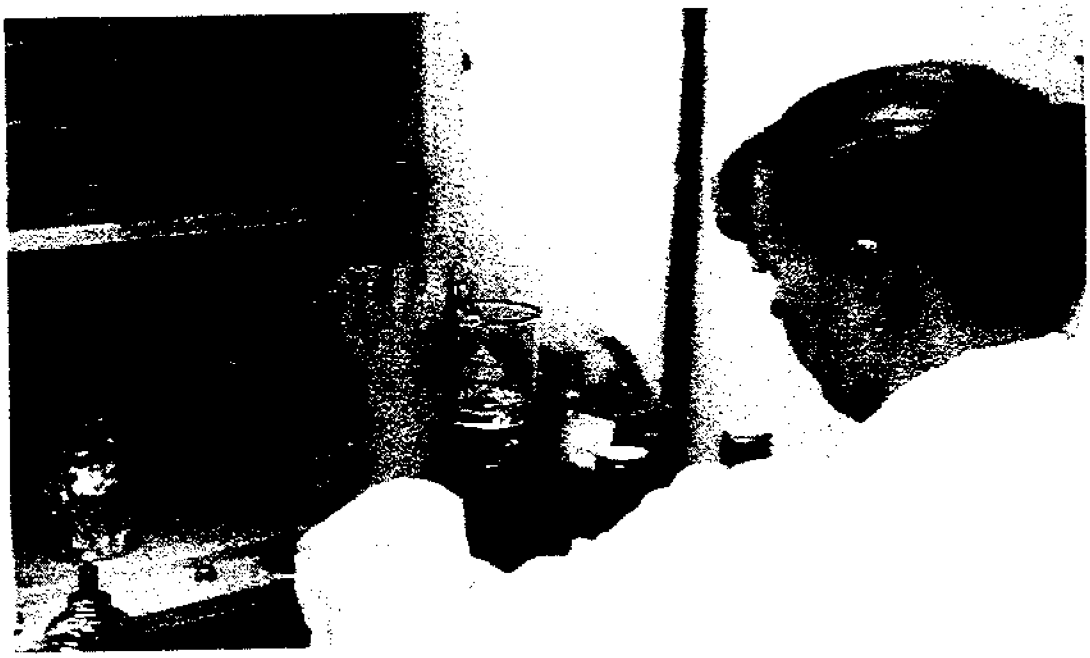
LAB ID
M 4 6 - 3

TIME & DATE ______

DATE REPORTED: ______

Preparation of a dilution of a sample. Sample dilutions may be used to minimize interference of high turbidity or high colony density. Sample plates should ideally produce 20-80 *E.coli* colonies. Reduced sample volumes may also be used.

Shake sample to distribute bacteria uniformly prior to filtering.



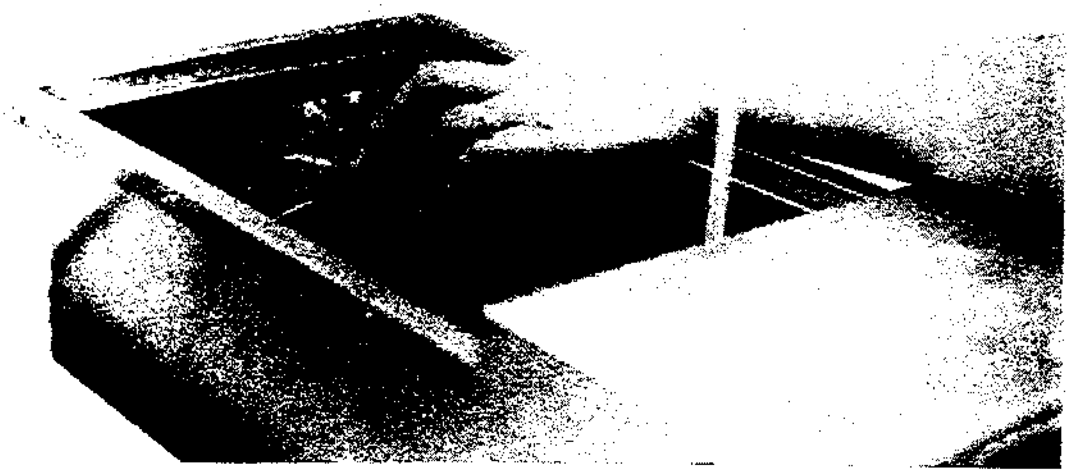
Filtering of sample through .45um sterile membrane filter.

Rinsing of funnel filtering apparatus with sterile buffered rinse water.

Aseptically transfer membrane filter to mTEC media using a rolling motion. The filter should lie flat against the media with no air bubbles. If the filter does not lay flat, reseat the membrane.

Preparation of filtered sample plates for incubation; placement in Whirl-Pak bags, no more than 4 plates deep.

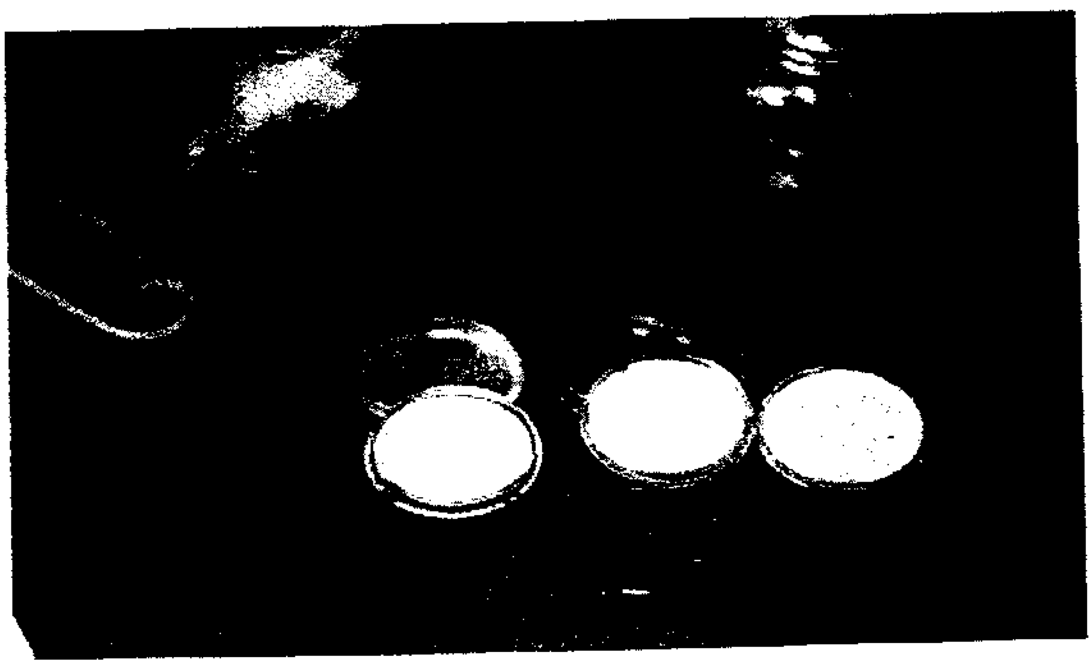
Incubate sample plates inverted for 2 hours at 35°C ± 0.5° to help recover stressed organisms.



After 2 hours incubation at 35°C, transfer plates, inverted and sealed in Whirl-paks, to a 44.5°C ± 0.2° waterbath for 22-24 hours.

After 22-24 hours in the waterbath, remove plates. Place absorbent pads in new petri plates or the lids of the same plates. Saturate pads with the urea broth.

Transfer filter membranes to urea saturated pads. Hold at room temperature for 15-20 minutes.



After 15-20 minutes on the urea substrate, count and record the number of yellow or yellow-brown colonies on those filters ideally containing 20-80 colonies.

Report the Number of verified *E.coli* colonies per 100 ml of sample.

$$\textit{E. coli}/100\text{ mL} = \frac{\text{No. } \textit{E. coli} \text{ colonies counted}}{\text{Volume in mL of sample filtered}} \times 100\text{ mL}$$

Making Sure That What Comes Out of the Ships Doesn't Stink: Marine Sanitation Devices In The Great Lakes[3]

Rhae Giacoma and Eric Reeves

One of the oldest environmental problems in the Great Lakes is contamination of the water by untreated or inadequately treated sewage.[6] Given the fact that millions of people drink out of the lakes and swim in them, outbreaks of high fecal bacteria and other pathogens are always a subject of great concern. In terms of total gallons, the shipping on the Great Lakes is not a significant contributor to that problem. The amount of sewage discharged from ships is orders of magnitude less than what goes into the lakes from sewage treatment systems, combined storm and sewage overflows, agricultural runoff, and home septic tanks.[7] Everyone is expected to clean up their act, however. A ship's crew may be small in comparison to the population of a port city, but each member of the crew presumably creates as much waste as each citizen of the city, and it should all be treated to some comparable standard. Thus, the same legislation which initiated a massive, multibillion dollar, long-term, and far from complete overhaul of United States sewage treatment systems in 1972 also mandated the installation of marine sanitation devices (MSDs) on both commercial and recreational vessels.[8] Marine sanitation [9]devices (MSDs) are required on all vessels with toilets operating on the Great Lakes. They are

[3] Update on an article published as "Working Together to Keep the Great Lakes Clean," *Great Lakes Seaway Review*, vol. 26, no. 1 (July-September 1997), pp. 59.

[4] Lieutenant Commander, US Coast Guard, Assistant Chief, Marine Safety Analysis and Policy Branch, Ninth Coast Guard District, 1240 E. Ninth St., Cleveland, Ohio, 44199, (216) 902-6050, RGiacoma@D9.uscg.mil.

[5] Commander, US Coast Guard, Chief, Marine Safety Analysis and Policy Branch, Ninth Coast Guard District, same address as above, email EReeves@D9.uscg.mil.

[6] "The beginning of environmental concern in the Great Lakes Basin is associated with the problems of human health.... Little or no attempt was originally made...to provide basic services such as water purification of sewage treatment, and the inevitable consequence was repeated outbreaks of waterborne diseases." Theodora E. Colborn, Alex Davidson, Sharon N. Green, R.A. Hodge, C. Ian Jackson, and Richard A. Liroff, *Great Lakes, Great Legacy?* (The Conservation Foundation and The Institute for Research on Public Policy, Washington DC and Ottawa, Ontario, 1990), pp. 52-3. "Historically, the primary reason for water pollution control was prevention of waterborne disease.... Humans can acquire bacterial, viral and parasitic diseases through direct body contact with contaminated water as well as by drinking the water." US EPA and Environment Canada, *The Great Lakes: An Environmental Atlas and Resource Book* (Chicago, Illinois and Toronto, Ontario, 1995), p. 29.

[7] Most outbreaks of bacteria contamination along the lakeshores are attributed to combined storm and sanitary sewer overflows. US EPA and Environment Canada, note 3 above, p. 29. For example, on 3 February 1996 the City of Duluth suffered a break in its water and sewer lines which resulted in the discharge of 500,000 gallons of raw sewage into the harbor. *Duluth News-Tribune* (5 February 1996), p. 6A. Lake Carriers' Association estimates that the 1109 ships entering Duluth-Superior harbor discharged 200,000 gallons of treated sewage throughout 1995. More generally, Lake Carriers' Association has calculated that the total output of treated water from MSDs on commercial vessels of all types in the Duluth-Superior Harbor averages about 772 gallons per day, compared to 44,000,000 gallons per day of treated water from the normally functioning water treatment plants. Rick Harkins, Lake Carriers' Association (Cleveland, Ohio, 11 July 1995).

[8] The Federal Water Pollution Control Act, also known as the Clean Water Act, 33 USC 1251 *et seq.*, discussed in further detail below. In recent decades, in the Great Lakes, "the United States and Canada have committed about $10 billion to improved municipal sewage treatment." Theodora E. Colborn, *et al.*, note 3 above, p. 229.

regulated by both US and Canadian statutes, and also by US state law in some areas.[10] There are three kinds of marine sanitation devices – Type I, II and III. The Type I and II MSDs are designed to treat sewage and discharge the treated effluent overboard. Type III MSDs are holding tanks designed to hold the sewage onboard the vessel until it can be discharged to a reception facility ashore.[11] Operators of vessels in US waters must ensure that marine sanitation devices meet the requirements outlined in US Coast Guard regulations[12] which govern the design, construction and certification of the MSDs. An MSD manufactured in compliance with the regulations will have a plate affixed to it identifying it as such. Most vessels will have either a Type II or Type III MSD onboard, as the Type I devices, which are less efficient than the Type II, are being phased out. The regulations requiring approved marine sanitation devices onboard vessels have been in place since 1975. The US Coast Guard and Transport Canada have the primary responsibility for enforcing requirements for MSDs on commercial vessels, both foreign and domestic, operating on the Great Lakes. The states and provinces take the lead in policing the recreational vessels.

The US law requires that every vessel with installed toilet facilities have an "operable marine sanitation device."[13] The key word here is *operable*. An operable MSD is one that is operating in accordance with the manufacturer's specifications and meeting the standards set forth in the regulations. Ensuring an MSD is operable becomes tricky in the sense that an MSD may be functional and appear to be working, yet may not be meeting the effluent standards established by EPA and outlined in the US Coast Guard MSD regulations. Figure 1 provides a basic schematic of a type I or II treatment system. Type I and II marine sanitation devices work by means of a two stage process for sewage treatment. The first stage consists of the breakdown of raw sewage through the use of aerobic bacteria. The second stage involves disinfecting the effluent, commonly by chlorine or ultraviolet light. Systems in use on United States vessels generally use chlorine disinfection, while Canadian vessels generally use ultraviolet light. Foreign vessels entering the Great Lakes may have either design. The systems can fail when (1) chemicals poured down the toilets kill the aerobic bacteria, (2) the pumps maintaining the proper fluid balance and air mix are not maintained, (3) a system using chlorination in the disinfectant stage runs out of chlorine, or (4) a system using ultraviolet light in the disinfectant stage loses

---

[10] United States rules on ship sewage are in the Federal Water Pollution Control Act, section 312, 33 United States Code section 1322, and Coast Guard regulations at 33 Code of Federal Regulations part 159, "Marine Sanitation Devices." Canadian rules on commercial vessels in the Great Lakes are in the Canada Shipping Act, sections 656-7, and Canada Shipping Act Regulations 26, "The Great Lakes Sewage Pollution Prevention Regulations," Consolidated Regulations of Canada SOR/93-207 (1993), and Canadian rules on recreational vessels are in the Revised Regulations of Ontario, 1990, Regulation 343, "Discharge of Sewage from Pleasure Boats." The US Federal Water Pollution Control Act provides for creation of state no-discharge areas subject to the approval of the US EPA (33 USC 1322(f)), and, as discussed further in the text, two such areas have been created in the Great Lakes. The Ontario regulation prohibits any discharge or system that allows for a discharge from a recreational vessel in Ontario waters of the Great Lakes, but does not apply to commercial vessels. RRO 1990 Reg. 343 §§ 1-4

[11] A type I marine sanitation device is designed to produce an effluent having a fecal coliform bacteria count not greater than 1,000 per 100 milliliters and no visible floating solids. A type II MSD is designed to produce an effluent having a fecal coliform bacteria count not greater than 200 per 100 milliliters and suspended solids not greater than 150 milligrams per liter. A Type III MSD is designed to prevent the overboard discharge of treated or untreated sewage or any waste derived from sewage. These standards were established by both US EPA regulations (40 CFR Part 140) and US Coast Guard regulations (33 CFR 159). Current state and EPA standards for shoreside sewage treatment typically set the same lower limit on fecal coliform (200/100ml, per Minnesota Rules 7050.0211) but set more strigent standards for suspended solids (30mg/l), and address a number of other prarameters such as biochemical oxygen demand and pH (EPA rules at 40 CFR Part 133), although not all systems meet those standards consistently. This is a greatly simplified statement of the standards, which are averages over time.

[12] 33 CFR Part 159.

[13] 33 USC 1322(h)(4).

lamp power or loses light penetration due to excess turbidity. The ultraviolet systems tend to achieve a better kill of the bacteria (and create no undesirable compounds in the final effluent) *if* the system maintains good light penetration. These systems come with a penetration detector and recording device to verify that penetration. The chlorine is a generally reliable disinfectant and chlorine content in the contact chamber can be readily verified by a simple field test. However, chlorine can create undesirable organochloride compounds. In order to reduce some of these undesirable compounds, many of the US lakers have also installed a third dechlorination stage, using sodium sulfate as a neutralizer, on their own initiative. Like any other shipboard system, MSDs need to be properly maintained and inspected in order to insure that they are operating as designed.

The issue of operable MSDs was brought to the attention of the Coast Guard in 1994 when the St. Louis System Remedial Action Plan (RAP) Committee in Duluth, Minnesota expressed concern that commercial vessels were discharging high levels of fecal coliform into the waters of Duluth Harbor. The US and Canadian lakers, represented by the Lake Carriers' Association and the Canadian Shipowners Association, in cooperation with the US Coast Guard, developed a voluntary testing program designed to verify that the MSDs onboard their vessels were operating properly.[14] This program has worked well in helping to alleviate the concerns of the St. Louis River RAP Group. The vessels involved have been very cooperative in carrying out the requirements of this voluntary program. Most vessels have been found to have operable MSDs meeting the regulatory standards. Those whose tests identified systems not meeting the standards have been notified so that appropriate repairs could made to bring them up to snuff. This was a program specifically developed in response to the concerns raised by the local community in Duluth-Superior. But a number of states are battling the same problem, experienced by Duluth-Superior, of high levels of fecal coliform in the water. Although the potential contribution to the problem from shipping is obviously dwarfed by the contribution from other sources, there is a natural expectation that the shipping industry be part of the solution. Also, some states have doubts about the adequacy of the marine systems – which may be based more on problems with recreational boats – and would prefer that no sewage be discharged in their waters, treated or not. As indicated in figure 2, Michigan and Wisconsin have "no-discharge zones" in which it is illegal to dump any sewage or effluent, whether treated or not, into the designated waters. The Michigan zone includes all Michigan waters of the Great Lakes. The Wisconsin zone covers the Wisconsin waters of Lake Michigan. Other states, such as Indiana and Pennsylvania, are looking at establishing no-discharge zones for their waters as well. The State of Wisconsin was involved in the development of the voluntary testing program for commercial vessel MSDs in Duluth Harbor, and this demonstration of the responsibility of the domestic commercial marine industry in addressing the local concerns may well lessen the

[14] The details of the voluntary testing program varied according to whether the MSD used chlorine or ultraviolet light in the second stage of the treatment. (a) *For vessels with aerobic process MSDs and chlorine disinfection:* (1) Each week, vessel personnel conducted tests for dissolved oxygen and residual chlorine, as well as a visual examination for clarity and an odor test. The dissolved oxygen test shows that the bacteria necessary to treat the sewage have enough oxygen to keep them alive and active. The residual chlorine test verifies the amount of chlorine in the system is at the level necessary to effectively treat the effluent. (2) In addition to the weekly tests, vessel personnel sent a sample of the effluent to an on-shore testing facility laboratory twice a year for analysis. This test verifies that the effluent is meeting the regulatory standards. (b) *For vessels with aerobic process MSDs and ultraviolet disinfection:* Vessel personnel continuously monitored the ultraviolet system and performed maintenance as necessary. Each week they logged whether or not the sewage system and monitor were operating properly, and if not, made necessary changes to ensure the system was operating in accordance with manufacturer standards. (c) *For all vessels:* In addition, for both systems, vessel personnel sent a sample of the effluent to an on-shore testing facility laboratory twice a year for analysis and the Coast Guard conducted a random testing program whereby one vessel was boarded each month in the Duluth/Superior harbor and a sample of the sewage system effluent was taken and sent to a laboratory for analysis. Notification was given to the ship or owner of the results of that test.

Wisconsin interest in creating a no discharge zone for that area. More generally, this voluntary testing program developed by the US and Canadian lakers has gone a long way to assuring the Great Lakes states and environmental community that our lakers are not the cause of the high levels of fecal coliform often occurring in or near Great Lakes ports. The specific testing program developed in Duluth-Superior is not necessarily the best model for application throughout the lakes. At this time, the US Lake Carriers' Association is developing more general maintenance and inspection procedures for assuring that all MSDs are operating properly as part of the general "Streamlined Inspection Program" being piloted in the Great Lakes. Under this joint US Coast Guard and Lake Carriers' program, which is based on the concept that a responsible industry can develop better quality control systems than the government can create through direct regulation, we will have continuing, documented assurance that the MSDs are being properly maintained along with all of the other safety and environmental equipment aboard the vessel.

In cooperation with the Seaways and representatives of the foreign vessel operators, such as the Shipping Federation of Canada and the Great Lakes Shipping Association, the US Coast Guard working on the development of a similar program for assuring that all MSDs on the foreign vessels are being maintained and used properly. Although the number of obvious problem vessels are low, we have found in recent years that a number of foreign vessels entering the Great Lakes have inoperable MSDs, thus necessitating some sort of action to address the problem. Moreover, discharge of improperly treated sewage from a vessel in transoceanic trade poses a completely different kind of risk to health – the risk of infection by exotic pathogens which, although small in numbers, may have a significant impact on populations not normally exposed to them. As regulators, we are forced to assume that the relatively small number of vessels detected with obviously nonfunctional MSDs may indicate a larger problem with MSDs that are in operation in some form, but not truly "operable" in the sense of fully functioning in accordance with their design. This leaves us with two responsible choices – to either increase our inspection requirements, or ask the foreign vessel industry for their voluntary participation in an industry quality control program. Based on our good experience with the domestic industry, we think the latter approach is far preferable. Thus, on 15 January 1997, the Coast Guard held an initial meeting in Montreal with members of the maritime community, including the St. Lawrence Seaway Development Corporation, the St. Lawrence Seaway Authority, the Shipping Federation of Canada, Transport Canada Marine Safety, and the Canadian Shipowners Association. The US Great Lakes Shipping Association was is also participating in the process. The purpose of this meeting was to begin the process for developing a program for foreign vessels operating on the Great Lakes to prove the operability of their MSDs. We are looking at different options, including a voluntary testing program such as that which has been used in Duluth. But that is not the only approach. Just as the US lakers have developed their own, industry-specific quality control system within the context of the Streamlined Inspection Program, we would like to see the foreign industry propose what they consider the best, most efficient, and least burdensome method for assuring that their MSDs are being properly maintained and used. This will not be imposing new requirements on the vessels, as they are currently required to have operable MSDs. What this will do is enable them to prove to the regulatory agencies that their MSDs are operating in compliance with the regulations without the creation of new inspection requirements.

In the meantime, the US and Canada will be aggressively enforcing the regulations requiring operable MSDs on commercial vessels entering the Great Lakes through the St. Lawrence Seaway. There are several things the boarding officers look at. First they look for the MSD manufacturer's plate to ensure it meets the specifications in the regulations. Next they look to see if the MSD is functional. If it is obvious that the MSD is not working, the boarding officers will take appropriate action, which may include civil penalty action. The vessel will not be allowed to sail until satisfactory repairs are made. In the past, we have sometimes allowed vessels to take aboard portable toilets as a temporary measure to replace nonfunctional MSDs. In agreement with the Seaways, we are establishing a policy that this option will not be considered after the end of the current, 1997 navigation season. Also, the Saint Lawrence Seaway Authority has taken important action to address the separate issue of the use of the type III holding tanks, which do not always have the capacity to hold the sewage during the whole voyage in and out of the lakes.

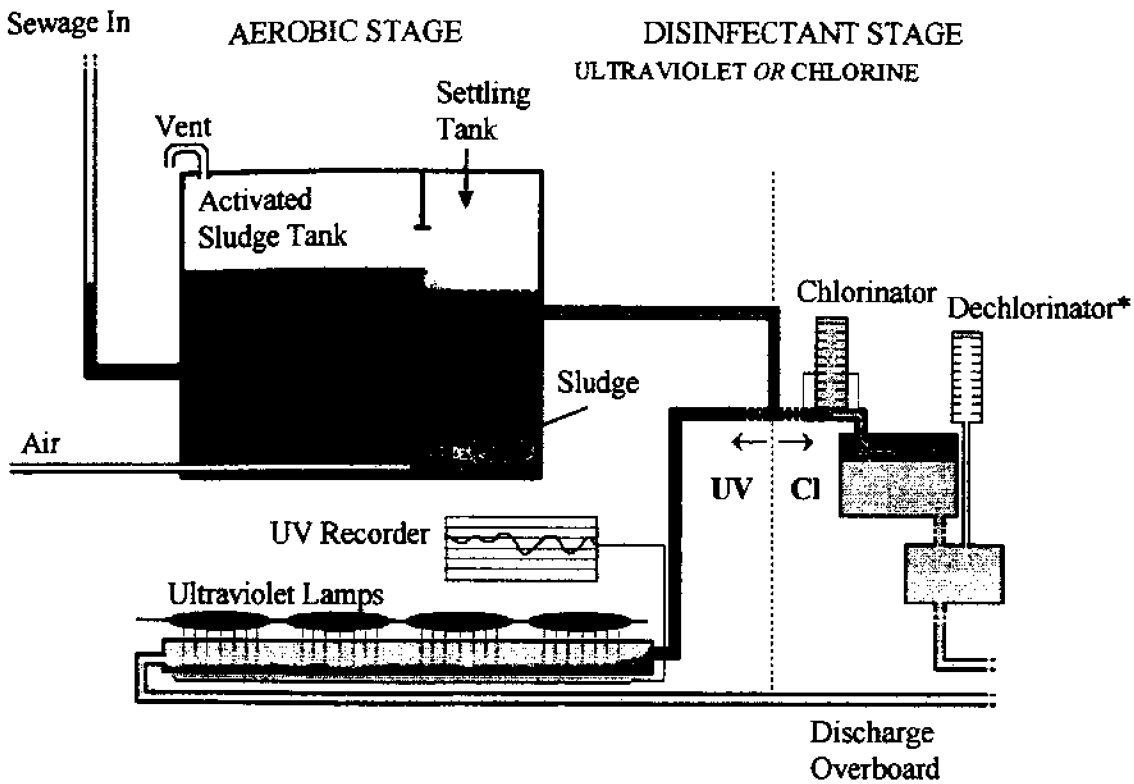
The SLSA has formally advised operators that "Vessels equipped solely with sewage holding tanks shall keep a sewage disposal log or make an entry into the deck log of the date and location where these tanks are pumped out or otherwise voided."[15] The bottom line is simply that all vessels operating on the Great Lakes should be handling their sewage properly.[16] Our MSD voluntary testing program so far has not placed a heavy burden on the shipping industry, and we expect any future programs to not do so either. We are looking for ways to ensure compliance with the MSD regulations without causing undue hardship on the vessels operating on the Great Lakes – and we are looking to the industry to help us do that.

[15] Saint Lawrence Seaway Authority Notice #3 (1997), para. 15, "Sewage Disposal."

[16] In discussions with the Seaways and the foreign marine industry, we have been asked about compliance with the standards by US Navy vessels occasionally visiting the lakes. Since Navy vessels are legally exempt from the US MSD requirements as public vessels, they have been accused of haphazardly discharging sewage into the Great Lakes. That is not the case. According to a US Navy policy which specifically addresses visits to the sensitive fresh waters of the Great Lakes, their vessels only discharge from holding tanks to tank truck reception facilities contracted for at ports of call – thus complying with the same requirement for commercial vessels with type III holding tanks.

Figure 1. Basic Schematic of a Marine Sanitation Device (MSD), Type I or II Treatment System

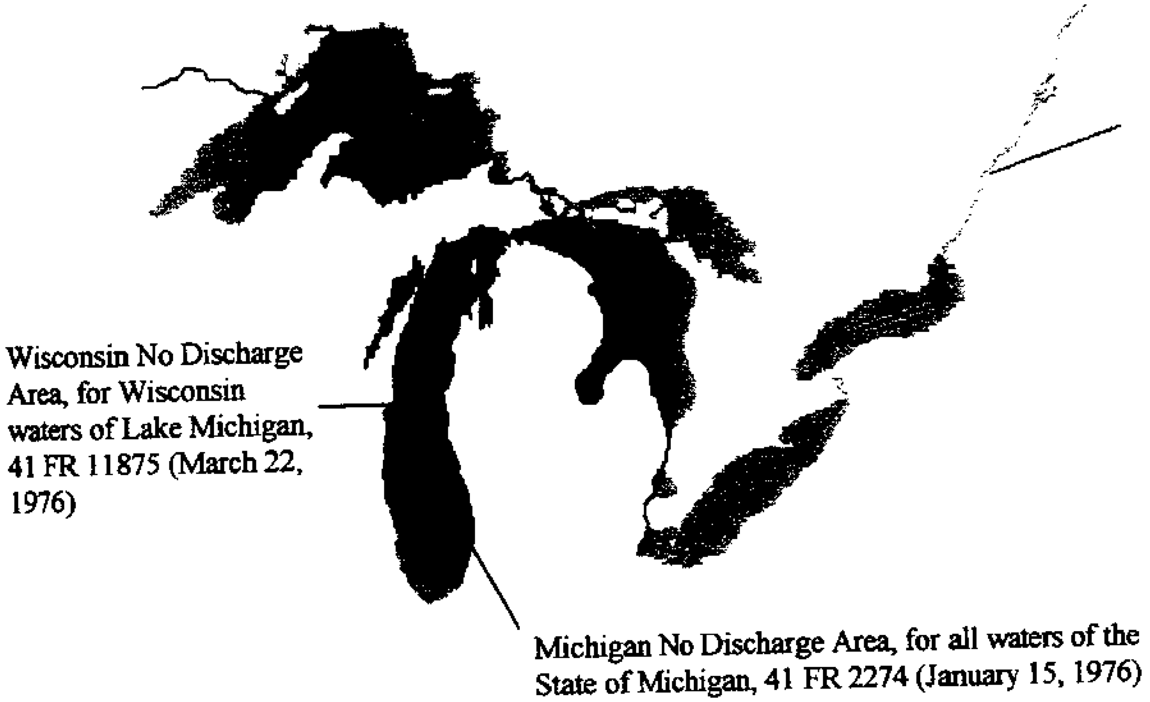
Figure 1. Basic Schematic of a Marine Sanitation Device (MSD), Type I or II Treatment System



*Not included on all chlorination systems

Figure 2. Marine Sanitation Device (MSD) Discharge Areas on the Great Lakes

Figure 2. Marine Sanitation Device (MSD) Discharge Areas on the Great Lakes



Preventing Biological Invasions of the Great Lakes via Shipping

Presentation to the International Association of Great Lakes Researchers

Buffalo, New York, 5 June 1997

M. Eric Reeves

Ballast water is a major vector for biological invasion of the Great Lakes and other aquatic ecosystems. Since 1993, with the active assistance of Transport Canada and the Seaway authorities of both the United States and Canada, the US Coast Guard has enforced a limited regime for the control of ballast water entering the Great Lakes. That regime has provided a significant first step in raising the level of defense against shipborne biological invasions, and has become the model for a nationwide regime now being developed by the US Coast Guard. However, more work is required to (1) scientifically measure the effectiveness of the current regime, (2) develop economically feasible improvements in the Great Lakes and nationwide regimes, and (3) expand the research agenda to address other possible shipping vectors for biological invasions such as sewage and graywater. Of all these research priorities, the most urgent is the need to develop economically feasible improvements to the current exchange regime which can be put in place as soon as possible in order to make exchange practical, safe, and effective for all vessels.

1. Introduction: Ballast Water, Sewage, Graywater, and Exotic Invasions

Some of the researchers have pointed out that a ship can very well be thought of as a "biological island."[19] Just as a foreign vessel entering our waters is in a legal and traditional sense a piece of the territory of its flag nation,[20] it is also a floating community, an unnatural ecology of

[17] Commander, US Coast Guard, MA (Political Science), JD, Chief, US Coast Guard Ninth District Marine Safety Analysis and Policy Branch, Room 2069, 1240 E. Ninth Street, Cleveland, Ohio, 44199-2060, Telephone (216) 902-6049, Telefax (216) 902-6059. The opinions expressed in this paper are those of the author, and should not be considered official policy of the United States Coast Guard.

[19] James T. Carlton, Donald M. Reid, and Henry van Leeuwen, *The Role of Shipping in the Introduction of Nonindigenous Aquatic Organisms to the Coastal Waters of the United States (other than the Great Lakes) and an Analysis of Control Options* (National Sea Grant College Program/Connecticut Sea Grant Project R/ES-6, April 1995), p. 19

[20] Vessels have a unique, ancient, well-recognized, but somewhat confusing and evolving status under international law, as objects subject to the jurisdiction of both the "flag state" and the "port state." See, generally, Louis Henkin, Richard Crawfort Pugh, Oscar Schachter, and Hans Smit, *International Law: Cases and Materials* (West Pub., St. Paul, Minn., 2nd Ed., 1987), chap. 15. "Flag state" jurisdiction, the jurisdiction of the country under which the vessel is registered, literally the flag which the vessel flies, is generally primary when the vessel is operating on the high seas. "Port state" jurisdiction, the jurisdiction of the nation in whose waters the vessel is operating, becomes primary when the vessel enters the ports or other internal waters of another nation. All of the waters of the Great Lakes are the internal waters of either the United States or Canada, and they have plenary jurisdiction to enforce their laws for the protection of safety and the environment over any vessels in the lakes, although the Great Lakes also have something of a dual status under international law. The Great Lakes are "internal waters" as "waters on the landward side of the baseline" under Article 8 of the United Nations Convention of the Law of the Sea, for most purposes. However, the lakes are really *sui generis*. "The customary rules of international

humans and other organisms ranging from rats to viruses which may be living in cargo, stores, ballast water, bilge water, sewage, and graywater aboard the ship, many of which are exotics with the potential to invade the Great Lakes or other aquatic ecosystems. In recent years, with the development of the first regime for controlling ballast water entering the Great Lakes,[21] we have only just begin to understand and deal with this threat. Ballast water remains the primary subject of concern because of the economic impact of zebra mussels and other aquatic nuisance species in the Great Lakes.[22] Human economic systems adapt relatively quickly, however. In economic terms, we long ago adapted to the impact of the lamprey eel on the Great Lakes fisheries, and we are now adapting to the problem of controlling zebra mussels in industrial systems. The long-term loss of ecological integrity and biological diversity, which is really the greater loss to humanity and the planet, is much less well appreciated outside the scientific community. It is too distant. In a similar way, the more insidious threat to human health and ecological integrity from invasions at the microbial level may be just as much a potential threat,[23] but has been of little concern because it is invisible.

What you see may depend on what you look for. Before the invasion of the zebra mussel became noticeable around 1988, ballast water was not of much concern. In 1990, some Canadian researchers conducted what apparently was the first systematic analysis of zooplankton

---

law provide that a state exercises complete jurisdiction over all territory and waters within its boundaries. With the designation of the middle of the Great Lakes as the international boundary, these lakes came under the respective jurisdictions of the United States and Canada. They are thus national waters, and not *territorium nullius*.... Although the lakes are internal waters, they are, nevertheless, considered as high seas by both countries for the purposes of admiralty and criminal jurisdiction.... In this instance the application of the established legal principles of international law provides a legal regime for the Great Lakes that is both necessary and effective." Don Courtney Piper, *The International Law of the Great Lakes: A Study of Canadian-United States Co-operation* (Durham, NC: Duke University Press, 1967) p. 18. In the instance of environmental protection, as well, an international approach has been extremely productive. Recognizing that they share a common ecosystem, the two nations have closely collaborated in environmental regulation under the Great Lakes Water Quality Agreement, done at Ottawa 22 November 1978. That agreement sets general standards which are enforced by the separate but closely parallel laws of the United States and Canada on each side of the line.

21 I provide a detailed review of the Great Lakes regime, and its limitations, in M. Eric Reeves, "Techniques for the Protection of the Great Lakes from Infection by Exotic Organisms in Ballast Water," in Frank M. D'Itri, ed., *Zebra Mussels and Aquatic Nuisance Species*, pp. 283-299 (Ann Arbor Press: Chelsea, Mich., 1997), which is the published version of a presentation to the Sixth Annual Zebra Mussel Conference in Dearborn, Michigan, on 5 March 1996. See also Katherine Weathers and Eric Reeves, "The Defense of the Great Lakes Against the Invasion of Nonindigenous Species in Ballast Water," *Marine Technology* (April 1996), vol. 33, no. 2, pp. 92-100.

22 The damage that exotic organisms have done to the aquatic ecology of the Great Lakes and the economy of the Great Lakes region is now fairly well documented, even if difficult to quantify. See E.L. Mills, J.H. Leach, J.T. Carlton, and C.L. Secor, "Exotic Species and the Integrity of the Great Lakes: Lessons from the Past," *BioScience* (1994) 44: 666-676; W. Ashworth, *The Late, Great Lakes: An Environmental History* (Wayne State Univ., Detroit, 1987); Office of Technology Assessment, *Harmful Non-Indigenous Species in the United States* (US Government Printing Office, Washington DC, 1993); P. Leigh, "Benefits and Costs of the Ruffe Control Program for the Great Lakes Fishery," (National Oceanic and Atmospheric Administration, unpub. paper, 1994).

23 See Laurie Garret, *The Coming Plague: Newly Emerging Diseases in a World Out of Balance* (New York, 1994). She provides an example where it was "theorized that the cholera microbe defecated by a man in Dhaka...got into algae in the Bay of Bengal, lay dormant for months on end, made its way via warm water blooms or ship bilge [or ballast water?] across thousands of miles of ocean, and killed a person who ate ceviche at a food stand in Lima." p. 566.

in ballast water.[24] They of course found a whole range of zooplankton living in the tanks, including potential fresh-water invaders of the Great Lakes. But they did not look for microbes. In 1994, other Canadian researchers conducted what apparently was the first sampling of bacteria in ballast water.[25] We were not really surprised that they found a whole range of interesting strains, including a nasty strain of *E. coli* and something that may or may not have been a form of *V. cholerae*. Mention of "cholera" got a great deal of attention, and prompted a short flurry of high-level political interest while experts at the laboratories had an arcane discussion about testing serums which appears to have been inconclusive. That, unfortunately, diverted attention from the main point of the sampling program. The main point is that ballast water was confirmed as a vector for a whole range of pathogenic bacteria.[26] As far as I know, no one has yet confirmed the presence of pathogenic viruses in ballast water entering the Great Lakes, although the same Canadian group may be looking at that. When someone does that research, we should not be surprised that they find something of interest. Nor should we be surprised to find potential microbial invaders present in other forms of water discharged from vessels, especially sewage and graywater. These "biological islands" we call ships are fertile islands for maintaining and culturing a whole range of life. They are also fertile areas for exploration by ecological researchers.

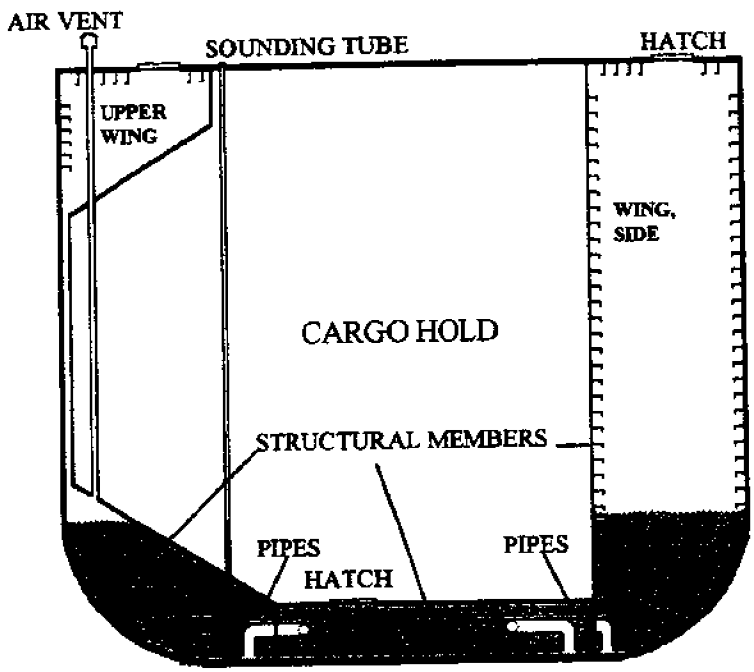
[24] A. Locke, D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen, *Effectiveness of Mid-Ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water* (Canadian technical report of Fisheries and Aquatic Sciences 1822, 1991).

[25] The research was conducted by Aquatic Sciences Inc. for Transport Canada Marine Safety, and the only report is still a draft not releaseable to the public. As this and the previous citation indicate, much of the most interesting work is only available in the form of "gray literature" consisting of papers and reports, sometimes unpublished, and often published as government reports not subject to a peer review by the scientific community. However, there is a published report of *V. cholerae* 01, the nasty strain, confirmed in samples of ballast water and ship sewage from 19 cargo vessels entering US ports on the Gulf of Mexico. Susan A. McCarthy and Farukh M. Khambaty, "International Dissemination of Epidemic *Vibrio cholerae* by Cargo Ship Ballast Water and Other Nonpotable Waters," *Applied and Environmental Microbiology* (July 1994), vol. 60, no. 7, pp. 2597-2601.

[26] The cholerae, if that is what it was, was not necessarily the worst thing found in the samples, and the samples were from a very limited number of vessel (13) taken during the end of the navigation season (November and December 1995) when the coldness of the Atlantic and the Great Lakes would tend to inhibit bacteria. The other bacteria found included *V. alginoliticus*, *V. fluvialis*, *A. hydrophila*, *Pseudemonas sp.*, *Providencia rettgeri*, *Ps. aeruginosa*, and *E. coli* 0111. The main purpose of the sampling was in fact to attempt to measure the overall level of effectiveness of the current ballast water regime in defending against other taxonomic groups, particularly algae and invertebrates. They found a whole range of those as well, including *Copepoda*, *Cladocer* (water fleas), *Polychae* (worms), *Nematoda* (worms), *Mollusca* (mussels), *Rotifera*, *Oligocha* (worms), *Bivalia* (mussels), and *Diptera* (flies).

Figure 1. Ballast Tank Cross Sections (typical designs)

Figure 1. Ballast Tank Cross Sections (typical designs)



2. Ballast Water: The Known Threat

Until recently, serious interest in the problem of ballast water and exotic organisms was largely limited to Canada, the United States, and Australia. (Australia is in a sense the salt water analogue to the Great Lakes region, because the relatively isolated coastal salt waters of Australia have a unique ecosystem which has been severely affected by invasions.) However, the rest of the world is now beginning to realize that infections by ballast water are a more general problem. The United States Congress has now enacted legislation which would apply the current Great Lakes regime to all ports of the United States,[27] and there are limited measures for control being instituted in New Zealand, Israel, Chile, the United Kingdom, Germany, Sweden, and Japan.[28] This increasing world interest is generating a wide variety of proposals for preventative measures.[29] However, these are mostly tentative and almost entirely lacking in any experimental verification at this time. More importantly, very little work has been done to compare the relative costs of implementing these proposals. The report of the US National Research Council Marine Board, one of the most recent general scoping studies, concludes that "there are no off-the-shelf technologies specifically designed for treating ballast water that are suitable for use on board ship without some redesign and modification."[30] On the whole, there is very little real research being done on prevention. A recent survey of research on exotics conducted by the Great Lakes ANS Panel, which requested information on projects being conducted throughout the nation, "indicated that 51 percent of all projects received examined the ecosystem effects of species already present, while only 5 percent of the total expenditure was on prevention of introductions."[31] We have created a whole industry for the study of the zebra mussel. That work is well worth doing, and is of great value to those in the rest of the nation who mush learn to live with the zebra mussel as it advances south and west of the Great Lakes. But where are the scientific and technical conferences, and the funded research projects, on the prevention of new introductions? In the recently published report of the Sixth Annual Conference on Zebra Mussels and Other Aquatic Nuisance Species, only one of the 43 papers directly addressed the subject of preventing new invasions.[32] Even worse, that one paper was mine. I am a government program manager and a political scientist. Where are the papers on prevention from marine biologists and marine engineers?

There are interesting and important things to be done on the basic science of exotic invasions. What exotics are likely to be the next invaders? What is the effectiveness of the

[27] The National Invasive Species Act of 1996, Public Law 104-332 (26 October 1996), which amended the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, Public Law 101-646 (November 29, 1990), codified at 16 United States Code 4701 *et seq.*

[28] See the review of international control measures in Daniel Gauthier and Deborah A. Steel, *A Synopsis of the Situation Regarding the Introduction of Nonindigenous Species by Ship-Transported Ballast Water in Canada and Selected Countries* (Canadian manuscript report of Fisheries and Aquatic Sciences 2380, 1996).

[29] See the detailed review in my background paper for this conference, "An Update and General Survey of Proposals, Studies, and Research on Means to Prevent Infection by Exotic Organisms in Ballast Water" (5 June 1997), which incorporates all the "gray literature" that I have been able to get my hands on to date.

[30] Marine Board Committee on Ships' Ballast Operations, *Stemming the Tide: Controlling Introductions of Nonindigenous Species by Ships' Ballast Water* (National Academy Press: Washington, DC, 1996), p. 86.

[31] Great Lakes Commission ANS Panel, "Policy Position of the Great Lakes Panel on Aquatic Nuisance Species: Research Guidance for the Prevention and Control of Nonindigenous Aquatic Nuisance Species in the Great Lakes" (adopted by the Great Lakes Panel 4 December 1996), p. 2.

[32] Frank M. D'Itri, ed., *Zebra Mussels and Aquatic Nuisance Species* (Ann Arbor Press: Chelsea, Mich., 1997).

current Great Lakes regime? What is the likely cost in terms of health and ecosystem diversity as well as direct economic costs in damage to fisheries, tourism, water supplies, and industry? Even more importantly, however, we need to address a more practical, immediate question. What are the costs of possible control measures which could be imposed on marine industry in the near term in order to raise the level of protection before the next invasion? To put it bluntly, we know that we can filter them out, boil them, kill them with biocides, or flush them out much more efficiently and safely on the open ocean. We know that any of those things can be done. What we do not know is how much it would cost to retrofit any of those measures into existing vessels or build them into new vessels under construction. Until we know that -- until we see some serious design work and cost estimates -- we will not be able to take the essential, immediately necessary measures to improve the existing Great Lakes regime and create a workable regime for the larger vessels throughout all of the United States and Canada. The simple fact of the matter (which is something that I can tell you definitively as a government program manager and political scientist) is that it will continue to be politically impossible for us to make any significant improvement in the level of protection for the Great Lakes or the other aquatic ecosystems of North America until either (1) someone presents us with usable cost comparisons of the plausible control options, or (2) another ecological disaster on the level of the lamprey eel or the zebra mussel causes economic dislocation to a significant region of the United States. Please put down your money and make your choices.

At this time, the only method of ballast water management in general use (other than simply retaining the water, which is just as economically painful for a vessel operator as it is for you three hours into a conference without a break to discharge your morning coffee) is open ocean exchange.[33] However, there are significant limitations on the effectiveness and the safety of exchange in ballast tanks as currently designed on most vessels. Figure 1 here provides a crude illustration of the basic problem. Ballast tanks were never designed for being flushed out in the open ocean. Most ballast tanks function like hydras -- they suck in the water and excrete it through the same end. Typically, the end of the one-way pipe sits several inches off the bottom of the tank. Most ballast tanks are lined with longitudinal pieces of steel essential to providing structural support to the hull, creating a whole series of surfaces ideal for trapping sediment and

[33] Contrary to what is often assumed, the main idea is not to salt up the tanks to kill or inhibit the reproduction of fresh water organisms in the ballast. Salting might be a useful attack against some organisms. But that is not an effect that we can rely upon, and is at best a secondary purpose of the exchange requirement. Some organisms can live in a dormant form while exposed to salt water and become active again when exposed to fresh water. "A surprisingly diverse group of [freshwater] taxa, representing protozoans and 11 animal phyla, possess resting stages which may be capable of surviving extended saltwater immersion (although experimental data for most of these taxa are lacking)." James T. Carlton, Donald M. Reid, and Henry van Leeuwen, *The Role of Shipping in the Introduction of Nonindigenous Aquatic Organisms to the Coastal Waters of the United States (other than the Great Lakes) and an Analysis of Control Options* (National Sea Grant College Program/Connecticut Sea Grant Project R/ES-6, April 1995), p. 39. Moreover, the sediments in the ballast tanks give all of the organisms a place in which to shelter from the salinity. A. Locke, D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen, *Effectiveness of Mid-Ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water* (Canadian technical report of Fisheries and Aquatic Sciences 1822, 1991), p. 39. The main purpose of the exchange requirement is to dump the freshwater or coastal saltwater organisms out of the tank and trade them for organisms from the very different ecology of the open ocean (highly oligotrophic, high in salinity and ultraviolet light). Although there can be a good number of organisms in the open ocean, we have been advised that "the probabilities of reciprocal introductions are virtually non-existent." Carlton, Reid, and van Leeuwen, 1995, p. 153. So what we are doing is "contrary ballasting," between two distinct ecological zones, using the fact that we have that distinct zone in the open ocean as a natural barrier to invasion. If it were not a natural barrier, then the aquatic organisms would have already migrated across it, we would have already had natural contamination in the 180 million years since the continents drifted apart, and we would not have a problem to talk about here.

biota.[34] The larger the vessel, the more likely that emptying and refilling the tank while at sea will create dangerous stress on the hull. That does not seem to be a significant problem for vessels small enough to fit through the Seaway into the Great Lakes.[35] However, it is the major difficulty to be overcome in trying to generalize the Great Lakes regime to other areas of North America and the world.

The two logical alternatives are to either alter the current designs of the tanks and piping systems to allow more effective and safe exchange or to treat the water in some fashion, whether ashore, in a specialized vessel, or on the ballasting ship. Most of the attention has focused on some form of treatment aboard the ballasting ship. The many conceivable technologies for treatment aboard ship have in turn sometimes been divided into two general categories, "physical measures" such as filtration, ultraviolet sterilization, heat, and acoustics on one hand, and "chemical measures" or biocides such as chlorine, hydrogen peroxide, sodium metabisulphite, copper and silver ions, ozone, glutaraldehyde-based chemicals or other nonoxidizing biocides, and tank coatings on the other hand. A fairly strong weight of opinion and analysis reported in a number of scoping studies of treatment technologies conducted in Canada, Australia, the United States, and the United Kingdom tends to favor the physical measures over the biocides. Filtering and ultraviolet, each of which are most effective when used in combination with the other, seem to be particularly strong favorites, and there is also a strong interest in heat. However, none of these have yet been demonstrated to be both effective and economical in commercial application. Moreover, they are generally viewed as possibilities for new construction only -- not as viable technologies for retrofitting on existing vessels. Although filtering is being actively pursued as a treatment technology, we are now revisiting biocides, and it is also time for us to take a look at the possibilities for the redesign of ballast tanks in order to make the current reliance on exchange more effective and safe -- an approach which has never been fully examined, but which has the highest potential for doing some real good in the near term.[36]

3. Ship Sewage and Graywater: The Unknown Threats

Now that it is more widely understood that the threat from ballast water includes exotic and pathogenic microbes, it is time to go beyond ballast water and consider what might be in the sewage and the graywater also discharged from foreign vessels entering the Great Lakes and other waters of North America. Figures 2 and 3 illustrate what we are talking about.

All vessels in the Great Lakes are required by United States and Canadian law to either treat their ship-generated sewage in a "marine sanitation device" (MSD) or retain it in a holding

[34] A. Locke, D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen, *Effectiveness of Mid-Ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water* (Canadian technical report of Fisheries and Aquatic Sciences 1822, 1991), p. 39.

[35] See John B. Woodward, Michael G. Parsons, and Armin W. Troesch, "Ship Operational and Safety Aspects of Ballast Water Exchange at Sea," *Marine Technology*, vol. 31., no. 4, pp. 315-326 (October 1994) and Melville Shipping, *Ballast Water Exchange Study: Phase I*, (Melville Shipping Ltd., Ottawa, Ontario, Canada, Transport Canada Contract no. T8080-4-6801, March 1995), which I discuss and compare in M. Eric Reeves, "Techniques for the Protection of the Great Lakes from Infection by Exotic Organisms in Ballast Water," in Frank M. D'Itri, ed., *Zebra Mussels and Aquatic Nuisance Species*, pp. 283-299 (Ann Arbor Press: Chelsea, Mich., 1997) and Katherine Weathers and Eric Reeves, "The Defense of the Great Lakes Against the Invasion of Nonindigenous Species in Ballast Water," *Marine Technology* (April 1996), vol. 33, no. 2, pp. 92-100.

[36] See my background paper for this conference, "An Update and General Survey of Proposals, Studies, and Research on Means to Prevent Infection by Exotic Organisms in Ballast Water" (5 June 1997).

tank to be discharged elsewhere (either ashore to a treatment facility, or three miles out to sea, off the seacoast).37 Treatment in a typical MSD consists of two stages, biological breakdown in a settling tank, followed by either chlorination or ultraviolet treatment. Canadian lakers tend to use the ultraviolet treatment system. United States lakers tend to use the chlorination system, and some of them are also adding a third stage of dechlorination before discharge. The foreign third-party vessels coming into the lakes from across the ocean use all types, including holding tanks as well as the two basic treatment systems. Treatment does not mean complete sterilization. The minimum standards are set by the United States regulations, because the Canadian regulations do not apply to any vessel in compliance with the United States regulations.[38] The most restrictive United States standard, for a "type II MSD," allows "an effluent having a fecal coliform bacteria count not greater than 200 per 100 milliliters and suspended solids not greater than 150 milligrams per liter."[39] We know almost nothing about what exotic strains of *E. coli* or other bacteria and viruses may be present in that effluent, possibly resistant to the chlorine or ultraviolet treatment, or attached to that 150 milligrams of suspended solids per liter. We do know that pathogenic *V. cholerae* 01, has been found in both the ballast water and sewage of ships entering United States ports on the Gulf of Mexico.[40] The report of that one small sampling from 19 cargo vessels does not say whether the cholera was found in the sewage before or after treatment by an MSD. However, the report does point out more generally that "Fecal coliforms were found in two of the eight samples from which *V. cholerae* was isolated.... This result suggests that in these types of samples fecal coliforms are not a reliable indicator of *V. cholerae*."[41] In other words (if this nonbiologist is interpreting the implications correctly) our MSD standards on *E. coli* really tell us very little about how much protection the MSDs provide against exotic and pathogenic microbes.

We know even less about the "graywater." This is the less than precise term for dirty water generated aboard ship by laundries, dishwashers, showers, washing decks, and other general discharge from sinks and drains. As illustrated very crudely and schematically in figure 3 here, graywater may be disposed of in any of three different ways.42 It may be placed in a holding tank, together or separate from a sewage holding tank, for discharge ashore or out to sea. It may be treated with sewage in an MSD. Or it may be discharged directly overboard, into the Great Lakes. A quick survey which the US Coast Guard just conducted on 13 incoming foreign vessels last month indicates that each of the three variations is used on about one third of the vessels.43 There are as yet no regulatory controls on shipborne graywater. But there is as yet no science to tell us whether or not we should be imposing some controls on graywater. What we do not look for, we are not likely to find, and we are certainly not likely to act on.

[37] Canadian rules on ship sewage are in the Canada Shipping Act, sections 656-7, and Canada Shipping Act Regulations 26, "The Great Lakes Sewage Pollution Prevention Regulations," Consolidated Regulations of Canada SOR/93-207 (1993). United States rules are in the Federal Water Pollution Control Act, section 312, 33 United States Code section 1322, and Coast Guard regulations at 33 Code of Federal Regulations part 159, "Marine Sanitation Devices."

[38] The (Canadian) Great Lakes Sewage Pollution Prevention Regulations, section 4(b.1).

[39] 33 Code of (United States) Federal Regulations section 159.3(r).

[40] Susan A. McCarthy and Farukh M. Khambaty, "International Dissemination of Epidemic *Vibrio cholerae* by Cargo Ship Ballast Water and Other Nonpotable Waters," *Applied and Environmental Microbiology* (July 1994), vol. 60, no. 7, pp. 2597-2601.

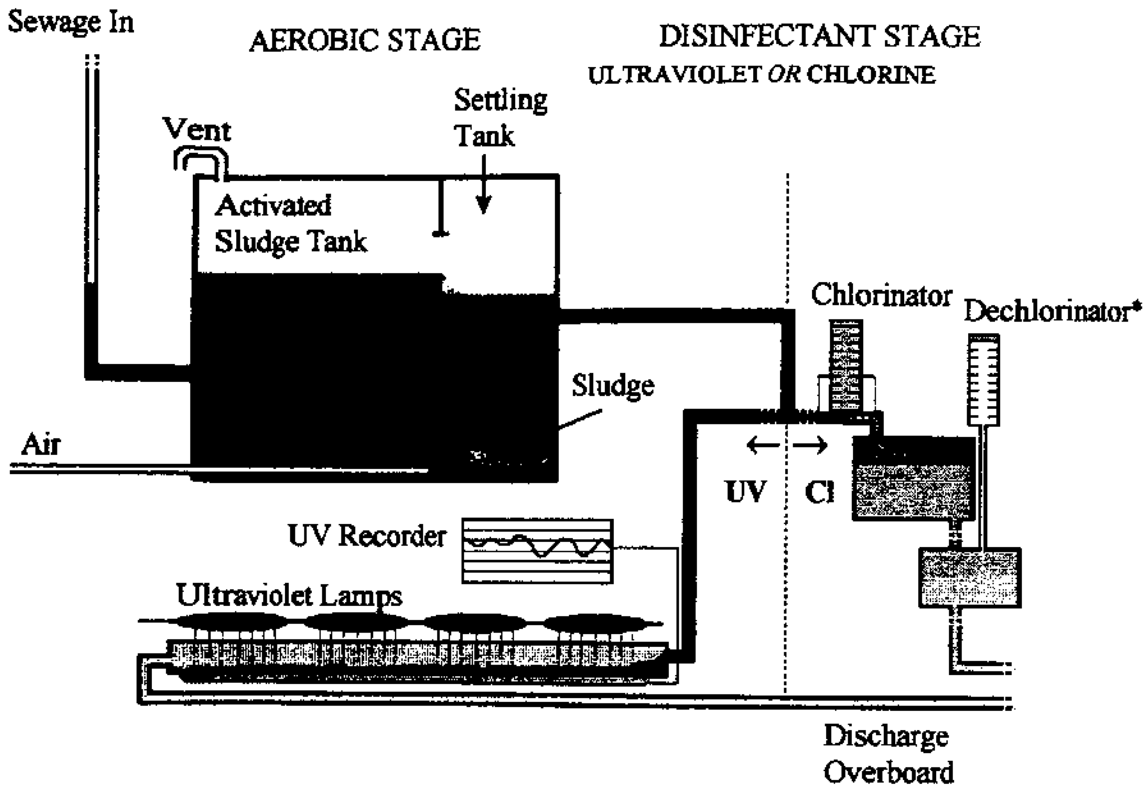
[41] Ibid, p. 2598.

[42] See Melville Shipping Inc. and LGL Limited, *Assessment of Pollution of the Great Lakes from Vessel Sources in Comparison to Other Sources*, Contract T1878-5-0147 for the Canadian Coast Guard, Ship Safety, now Transport Canada Marine Safety (Ottawa, Ontario, March 1995), pp. 36-7. The variety of different systems for handling graywater was also confirmed in a sampling of 13 inbound foreign vessels conducted by US Coast Guard Marine Safety Office Buffalo in May of 1997.

[43] The exact breakdown, on this small and unscientific sample, was as follows: 31% of the vessels put graywater into a holding tank. 38% mixed it with sewage treated in an MSD. 31% discharged it directly overboard

Figure 2. Basic Schematic of a Marine Sanitation Device (MSD), Type I or II Treatment System

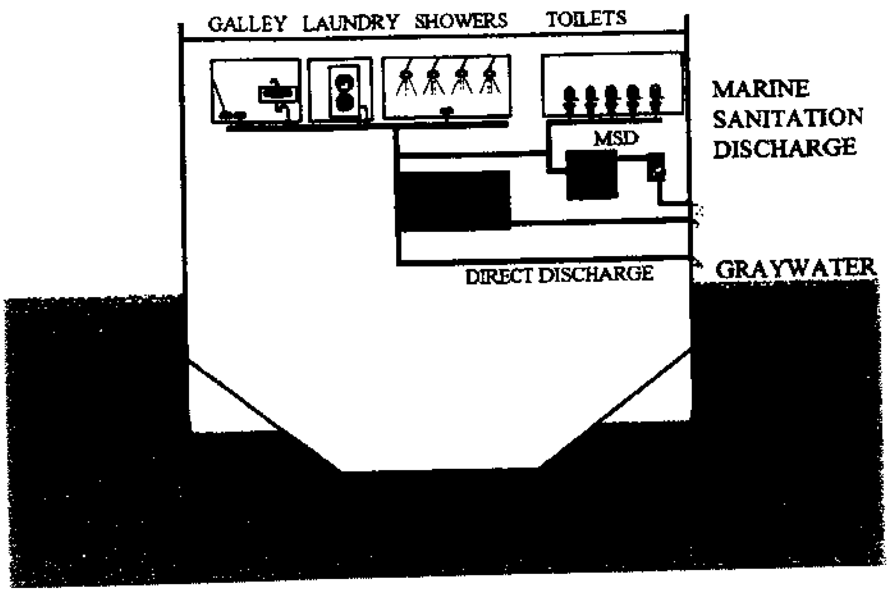
Figure 2. Basic Schematic of a Marine Sanitation Device (MSD), Type I or II Treatment System



*Not included on all chlorination systems

Figure 3. Discharges from Vessels

Figure 3. Discharges from Vessels



A Quick Look into Issues Relating to Discharges of Wastewater, Grey Water, and Ballast Water from Big Vessels and Small Boats into the Indiana Waters of Lake Michigan

Steve Lucas
Natural Resource Commission
Division of Hearings

In searching for sources of bacterial contamination along Indiana's Lake Michigan beaches, the Interagency Task Force on E. coli looked to what was, for many participants, a new direction: Lake Michigan itself. While terrestrial activities are generally thought to provide the primary sources for contamination, the role of lake or "marine" sources is an unknown quantity. The potential for contamination from activities in the lake (and these activities relate primarily to boating) is not well-understood. Even the legal structure governing discharges from vessels, which is straight-forward on Indiana's inland waters, is arcane on the state's portion of Lake Michigan.

In seeking to identify sources of bacterial contamination, the Task Force has reflected that "marine sources of bacterial contamination present a number of complexities, both in terms of legal controls and in terms of the contribution of marine sources to water pollution and beach closings." Contamination sources originate primarily from the four principal types of water found onboard vessels. "Waste water" which may be taken onboard for sanitary systems or as ballast. "Potable water" which may be used for drinking, showers, cooking, and galley washing, and which may be discharged back into the lake as "grey water." Cooling water and boiler make-up water, sometimes collectively referred to as "engine room water." Rainwater, spray from waves on deck, and bilge water and which are sometimes collectively referred to as "incidental water."

The discharge of untreated sewage from any vessel in Lake Michigan or a navigable tributary is generally prohibited both by federal and state law. Acting under 33 USC 1322(b), the U.S. Coast Guard has adopted regulations to "prevent the discharge of untreated or inadequately treated sewage" from vessels, except vessels not equipped with toilet facilities. As provided by Indiana statute, sewage collected in a vessel's holding tank may not be disposed except through an approved disposal facility.

Legal requirements contrast on Indiana's inland waters relative to its portion of Lake Michigan. On the state's inland rivers, streams, and lakes, any discharge of sanitary waste from a vessel's toilet facilities is made unlawful by IC 14-15-2-7. On Lake Michigan and the other Great Lakes, where large interstate and international commercial vessels play an important role, discharges are governed by Coast Guard regulations. For the Indiana waters of Lake Michigan, an operator of a vessel with installed toilets must have an operable Type I, Type II, or Type III marine sanitation device ("MSD"). Type III MSDs are holding tanks, common to many smaller vessels and used in inland waters as well as on Lake Michigan. On the other hand, Type I and Type II MSDs both allow for discharges, albeit under differing environmental standards. Only upon successful petition to the EPA may a state completely prohibit discharges from vessels operating in the Indiana waters of Lake Michigan.

For the untreated wastewater contained in the holding tanks of Type III MSDs, discharge must be to an approved disposal facility. The policy supported by this requirement is also encouraged by other governmental programs. The Indiana Department of Environmental Management participates in the Clean Vessel Act and funds the construction of new, and the rehabilitation of existing, pumpout stations through its Clean Vessel Pumpout Program. By rule, the Indiana

Natural Resources Commission requires any marina, located on Lake Michigan or its navigable tributaries and servicing more than five boats, to provide a pumpout station.

Of course, enforcement of the prohibition on wastewater discharges from holding tanks is not easily accomplished. For example, the Division of Law Enforcement for the Department of Natural Resources regularly inspects toilet facilities on charter boats but typically does not inspect a recreational vessel unless a complaint is received. Enforcement without education may be unfair as well as ineffective. Should there be a renewed emphasis upon communicating to recreational boaters their legal responsibilities for proper disposal of sewage, as well as upon the potential consequences to themselves and their family members for unlawful lake dumping?

Enforcement with respect to Type I and Type II MSDs maintained on Lake Michigan's commercial vessels is the province of the U.S. Coast Guard. Indiana could pursue an EPA petition to prohibit their operation on Indiana waters, as both Wisconsin and Michigan successfully did in the 1970s, but enforcement would continue to be an issue. Other questions are also raised: If Indiana (particularly acting in concert with Illinois) were to successfully ban the operation of Type I and Type II MSDs, what would be the impact on the commercial shipping industry? Is conversion by all ships to Type III MSDs practical and safe? Would the unfortunate effect of a total ban on discharges into Lake Michigan be to encourage "midnight dumping," resulting in disregard for the protective standards now imposed on the operation of Type I and Type II MSDs? Do the environmental standards which must currently be met for discharges already satisfy legitimate concerns for public health, at least for Type II MSDs with their more sophisticated operation processes and criteria? Should the emphasis in Indiana, and in the other Lake Michigan states, be on a prohibition against near-shore discharges?

These questions do not even touch upon other potential sources for bacterial contamination coming from other vessel waters. For example, can grey water or ballast water present significant threats to public health? Can Indiana draw upon research from other jurisdictions to answer these questions, or should new research initiatives be directed to Indiana's portion of Lake Michigan? For now, there are more questions than answers.

1. Potential bacterial contamination sources which originate within Lake Michigan and its navigable tributaries are considered by the Interagency Task Force on E.coli through its "Marine and Other Sources Committee." In this context, "marine" is given the broader definition relating it to all "navigable waters," as opposed to the narrower usage synonymous with "oceanic." Illustrative of the broader definition is the concept of "marine carrier" which applies to vessels operating on the Great Lakes and other navigable waters, as well as the oceans and seas. BLACK'S LAW DICTIONARY, 6th ed. (1990), 967.
2. *The Healthy Beaches Initiative, A Scrapbook of Activities by the Interagency Task Force on E.coli* (August 7, 1997), 20.
3. IC 14-15-2-7.
4. Correspondence to Stephen Lucas from Frank Jennings, Recreational Boating Specialist, U.S. Coast Guard, Ninth Coast Guard District (October 15, 1996). 40 CFR 140.
5. As provided in 312 IAC 6-4-3, a person cannot lawfully operate a marina on Lake Michigan or another navigable waterway "unless the person secures and maintains one (1) of the following: (1) A license under 327 IAC 3-2 for the construction and operation of a wastewater treatment facility or sanitary sewer. (2) A license under 410 IAC 6-10 for the construction of a commercial on-site wastewater disposal facility. (3) An alternative written approval for wastewater disposal from an authorized governmental agency."

Tracking Sources of *Escherichia coli* in Water

W. T. E. Ting*, M. Saluta**, and C. C. Tseng*
Dept. of Biological Sciences, Purdue University Calumet, Hammond, IN* and , Amersham Pharmacia Biotech, Piscataway, NJ**

The safety of water in Lake Michigan is important both to tourism for and regional residents who use the lake as the source of drinking water. In recent years, high fecal coliforms and *Escherichia coli* counts are often detected in beaches, the lake water, and streams that flow into the lake. *E. coli* is a gram negative, facultative anaerobic rod which is commonly found in the intestinal tracts of humans and animals. Since *E. coli* is an obligate intestinal parasite, it can not live freely in nature. The presence of *E. coli* in water indicates recent fecal contamination and possible presence of other enteric pathogens which may post serious health risk to humans. Currently, *E. coli* is the most commonly used fecal indicator for monitoring water pollution (APHA 1989). The beaches in Northwest Indiana are closed when the *E. coli* counts of the water exceed 235 CFU/100ml.

E. coli found in water may come from point sources (e.g. domestic sewage) or non-point sources (e.g. land runoff, septic tank seepage). To understand and control the pollution problem and to analyze the risk of transmission of bacterial diseases to humans, it is necessary to identify both point and nonpoint sources of the contaminant. The water quality of Lake Michigan, the major resource of Norwthwest Indiana, has long been a serious concern. The inability to identify the source of waterborne *E. coli* is one of the major obstacles for improving the water quality.

At present, there is no easy and reliable method to differentiate *E. coli* from various sources. This paper briefly reviews some of the approaches, including our own initiative, that have been proposed for tracking the sources of *E. coli*.

A. Multiple Antibiotic Resistance (MAR)

Patterns of antibiotic resistance of *E. coli* have been used to differentiate between human and animal sources of fecal contamination in natural water. This approach is to study the resistance of *E. coli* isolates to multiple antibiotics. The success of this method is based on the following assumptions: (1) *E. coli* strains from human are likely to be resistant to antibiotics used for clinical treatments; (2) *E. coli* strains isolated form farm animals are likely to be resistant to antibiotics added to animal feeds; and (3) *E. coli* from wild life shows little resistance to antibiotics.

Kaspar *et al.* (1990) tested 202 *E. coli* isolates from urban and rural water with 11 antibiotics. They found more antibiotic resistant *E. coli* from urban than from rural water samples. Parveen *et al.* (1997) studied multiple antibiotic resistance profiles of 765 *E. coli* isolates from point and nonpoint sources collected from Apalachicola National Estuarine Research Reserve. They reported that *E. coli* from point sources displayed higher resistance, higher MAR indices (# of antibiotics to which the isolate shows resistance / # of antibiotics tested), and more diverse MAR profiles than those from nonpoint sources.

Although the *E. coli* isolates from different sources showed some differences in their antibiotic resistance patterns, there are some major drawbacks of MAR studies. For examples, no specific MAR profile can be associated with either point source or nonpoint source only (Parveen *et al.* 1997). Furthermore, antibiotic resistance is not a stable character of a bacterium. It may change after a plasmid transfer among enteric bacteria in intestines or in sewage systems (Parveen *et al.* 1997, Trevorset *et al.* 1987). It may change over time, and it may be different in different geographic areas (Wiggins 1996).

B. Detection of Sth Gene

The Sth gene of *E. coli* encodes the heat stable toxin. According to Oshireo and Olson (1996), this gene is found almost exclusively in human *E. coli* isolates. Therefore, it is possible to use the gene as a marker for *E. coli* of human origin. Of the 110 fecal samples from animals tested, none was found positive for the gene. The report also revealed that sewage samples greater than 1 l sample size yielded positives results.

Although the Sth gene is exclusively found in human *E. coli* isolates, not all human isolates carry this particular gene. It is not possible to determine whether an sth gene negative *E. coli* isolate is from human or animal sources.

C. Subspecies Typing

Most bacterial species can be further classified into different strains. Traditionally, bacteria are typed with phenotyping methods such as biotyping ,serotyping, and phage typing. Biotyping is to differentiate bacteria according to the differences in their biochemical reactions. Serotyping is to type bacteria based on differences in surface antigenic structures, such as O, H, and K antigens. Phagetyping is to characterize bacteria based on susceptibility to infection by various phages. There are several problems of using these methods to type *E. coli*. For instance, biotyping has low discriminating power. Serotyping requires a complete set of antisera against all the serotypes and phagetyping needs a complete collection of coliphages. Antisera are difficult and expensive to prepare. Neither the antisera nor the phage collection are commercially available.

In recent years, genomic typing has been used for more accurate identification of bacterial strains and for discriminating bacterial subtypes which can not be differentiated by traditional phenotyping methods. Genomic typing differentiates bacterial strains based on DNA polymorphism which may be due to deletions, insertions, rearrangements or point mutations. DNA typing is highly discriminative and has been used for various epidemiology studies (Bingen *et al.* 1994). It has a great potential for investigating the source of bacterial contaminants in environmental studies. The success of using a genomic typing method to identify the source of *E. coli* is based upon the following assumptions: (1) different strains of *E. coli* are associated with different animal hosts; (2) different strains of *E. coli* can be separated from each other by their unique DNA fingerprints; and (3) the origin of an unknown *E. coli* from a water sample can be identified by comparing its DNA fingerprints with a comprehensive *E. coli* DNA fingerprint database.

Several popular methods have been used to generate bacterial DNA fingerprints. They are ribotyping, restriction fragment length polymorphism (RFLP), pulsed-field gel electrophoresis (PFGE), and random amplified polymorphic DNA fingerprinting (RAPD).

a. Ribotyping

Ribotyping is to determine rRNA gene restriction fragment polymorphisms. The DNA of the bacterium is isolated and then digested by different restriction enzymes into fragments. The fragments generated by each restriction enzyme are first separated on a gel by electrophoresis and then transferred to a positive charged nylon membrane. The DNA fragments on the membrane are hybridized with labeled cDNA probes. The cDNA probes only bind to the fragments containing certain rRNA genes (such as 16s and 23s RNA genes) and yield distinct bands (Bingen *et al.* 1994).

This method has been used to study epidemiology of a number of pathogens, such as *Salmonella enterica, Enterobacter cloacae, Streptococcus agalactiae, Staphylococcus aureus, Yersinia enterocolitica, Vibrio cholerae* O1 and non-O1, *V. vulnificus* (Bingen *et al.* 1994, and Dalsgaard *et al.* 1995).

b. Restriction Fragment Length Polymorphism (RFLP)

Restriction fragment length polymorphism (RFLP) was initially developed for medical and forensic investigation. In past dozen years, this technique has been widely applied to genetic analysis and identification of both prokaroyotes and eukaroyotes. The procedure for RFLP is similar to ribotyping but the technique depends on the knowledge of the intrinsic properties of DNA and the selecting of probes for Southern blot visualization. Banding patterns generated with multilocus probes could be very complex and difficult for comparison. Single locus patterns are simple but less informative (Reynold and Sensabaugh 1991).

c. Pulsed-Field Gel Electrophoresis (PFGE)

This technique is to separate high molecular weight DNA fragments using pulsed field gel electrophoresis. Genomic DNA is embedded in agarose plugs and digested with restriction enzymes that have rare restriction sites. Slices containing the digested DNA are loaded into the agarose gel wells, and the large DNA fragments are separated by PFGE using an alternating field.

Herbein *et al.* (1996) used PFGE to investigate non-point fecal coliform sources to tidal inlets on the eastern shore of the Chesapeak Bay. In their study, DNA fingerprints of *E. coli* from raccoons (4 patterns) , goose (14 patterns) and otter (4 patterns) were compared and found to be significantly different from each other. However, the DNA fingerprints from muskrat (3 patterns), humans (3 patterns) and water (10 samples) were not significantly distinguishable from those of raccoons.

d. Random amplified polymorphic DNA fingerprinting (RAPD).

This method utilizes simple short (10-mer) arbitrary primers and relatively low annealing temperatures to randomly amplify distinct sequences between two fortuitous primer binding sites on the isolated DNA by polymerase chain reaction (PCR). The amplified DNA fragments are separated into bands on a gel by electrophoresis. The major advantages of RAPD over other molecular techniques are simplicity, sensitivity, and reliability. Information of DNA sequence is not needed. Unlimited numbers of arbitrary primers can be used to generated different sets of DNA fingerprints from a single sample. This technique has been used to study genetic diversity of *E. coli* strains previously considered to be homogeneous (Brikun *et al.* 1994 and Pacheco *et al.* 1997). It has also been successfully used for epidemiological investigation of many pathogens, including *Enterobacter aerogenes* (Darvin-Regli *et al.* 1996), *Nocardia asteroides* (Louie *et al.* 1997), and *Legionella pneumophila* (Whitney *et al.* 1997).

To explore the feasibility of using RAPD for identifying and tracing *E. coli* sources, we have conducted a preliminary study on 40 isolates from human, several animal species and ground water samples from a Lake Michigan beach. Total DNA from each isolate was purified, and RAPD analysis was carried out using RAPD Analysis Beads (READY-To-Go^{TM}, Pharmacia). Eight arbitrary 10-mer primers were evaluated for their ability to generate distinct genomic profiles from different sources. Primers which yielded few bands (less than 4) were less informative due to the lack of polymorphic fragments, while those which produced many (greater than 15) bands were less desirable for our purposes (Tseng *et al.* 1997). Most suitable primers were those which generated about 4 to 12 bands; these provided sufficient information for meaningful analysis. Among the 8 primers tested, Primer 2, 1283, and 1247 generated very distinct bands (Fig.1). They were chosen for our study. To facilitate the comparison of DNA profiles, a RFLP and fingerprinting software system was used for cluster analysis (Bio-Red, Hercules, CA).

To test our hyposthes, we compared the DNA profiles of three *E. coli* isolates from beach ground water with those from human and nonhuman sources. The RAPD pattern of ground water isolate GW002 was very similar to that from seagull isolate SG001 (Fig. 2). It appeared that seagull was one of the sources of *E. coli* in beach ground water.

Our study showed that RAPD is a useful and effective technique to generate multiple sets of *E. coli* DNA fingerprints and differentiate *E. coli* strains. An extensive database is needed to identify the environmental isolates. In conclusion, RAPD is a promising new approach to trace the source of *E. coli* in natural water.

Reference

1. American Public Health Association. 1989. Standard methods for the examination of water and wastewater. 17th ed. American Public Health Association, Washington, DC.

2. Bingen, E. H., E. Denamur, and J. Elion. 1994. Use of ribotyping in epidemiological surveillance of nosocomial outbreaks. Clin. Microbiol. Rev. 7:311-327.

3. Brikun I., K. Suziedelis, and D. E. Berg. 1994. DNA sequence divergence among derivatives of *Escherichia coli* K-12 detected by arbitrary primer PCR (random amplified polymorphic DNA) fingerprinting. J. Bacteriol. 176:1673-1682.

4. Dalsgaard, A., P. Echeverria, J. L. Larsen, R. Siebeling, O. Serichantalergs, and H. H. Huss. 1995. Application of ribotyping for differentiating *Vibrio cholerae* Non-O1 isolated from shrimp farms in Thailand. Appl. Environ. Microbiol. 61: 245-251.

5. Davin-Regil, A., D. Monnet, P. Saux, C. Bosi, R. Charrel, A. Barthelemy and C. Bollet. 1996. Molecular epidemiology of *Enterobacter aerogenes* acquistion: one-year prospective study in two intensive care units. J. Clin. Microbiol. 34:1471-1480.

6. Herbein, S. A., G. M. Simmons, JR, and S. L. Myers. 1996. Use of pulsed field gel electrophoresis (PFGE) to investigate nonpoint fecal coliform sources to tidal inlets on eastern shore of the Chesapeak Bay. Abstr 96th Gen. Meeting, Am. Soc. Microbiol. p. 467.

7. Kaspar, C. W., J. L. Burgess, I. T. Knight and R. R. Colwell. 1990. Antibiotic resistance indexing of *Escherichia coli* to identify sources of fecal contamination in water. Can. J. Microbiol. 36:891-894.

8. Louie, L., M. Louie, and A. E. Simor. 1997. Investigation of a pseudo-outbreak of *Nocardia asteroides* infection by pulsed-field gel electrophoresis and randomly amplified polymorphic DNA PCR. J. Clin. Microbiol. 35-1582-1584.

9. Oshiro, R. K., and B. H. Olson. 1996. Occurrence of the Sth toxin gene of *Escherichia coli* influent and final chlorinated effluent. Abstr. 96th Gen. Meeting, Am. Soc. Microbiol., p.467.

10. Pacheco, A. B. F., B. C. Guth, K. C. C. Soares, L. Nishimura, D. F. De Almeida and L. C. S. Ferreira. 1997. Random amplification of polymorphic DNA reveals serotype-specific clonal clusters among enterotoxigenic *Escherichia coli* strains isolated from humans. J. Clin. Microbiol. 35: 1521-1525.

11. Parveen, S., R. L. Murphree, L. Edmiston, C. W. Kaspar, K. M. Portier and M. L. Tamplin. 1997. Association of multiple-antibiotic- resistance profiles with point and nonpoint sources of *Escherichia coli* in Apalachicola Bay. Appl. Environ. Microbiol. 63:2607-2612.

12. Reynold R., and G. Sensabaugh. 1991. Analysis of genetic markers in foresenic DNA sampling using the polymerase chain reaction. Anal. Chem. 63:2-15.

13. Trevors, J. T., T. Barkay, and A. W. Bourquin. 1987. Gene transfer among bacteria in soil and aquatic environments: a review. Can. J. Microbiol. 33: 191-198.

14. Tseng , C. C., W. T. E. Ting., M. Saluta. 1997. Random amplified polymorphic DNA (RAPD) analysis of dynamic human *Escherichia coli* genome. Abstr. 97th Gen. Meeting, Am. Soc. Microbiol. p.303.

15. Whitney, C. G., J. Hofmann, J. M. Pruckler, R. F. Benson, B. S. Fields, U. Bandyopadhyay, E. F. Donnally, C. Giorgio-Almonte, L. A. Mermel, S. Boland, B. T. Matyas and R. F. Breiman. 1997. The role of arbitrarily primed PCR in identifying the source of an outbreak of Legionnaires' disease. J. Clin. Microbiol. 35:1800-1804.

16. Wiggins 1996. Discriminant analysis of antibiotic resistance patterns in fecal streptococci, a method to differentiate human and animal sources of fecal pollution in natural w aters. Appl. Environ. Microbiol. 62: 3997-4002.

Primer Analysis

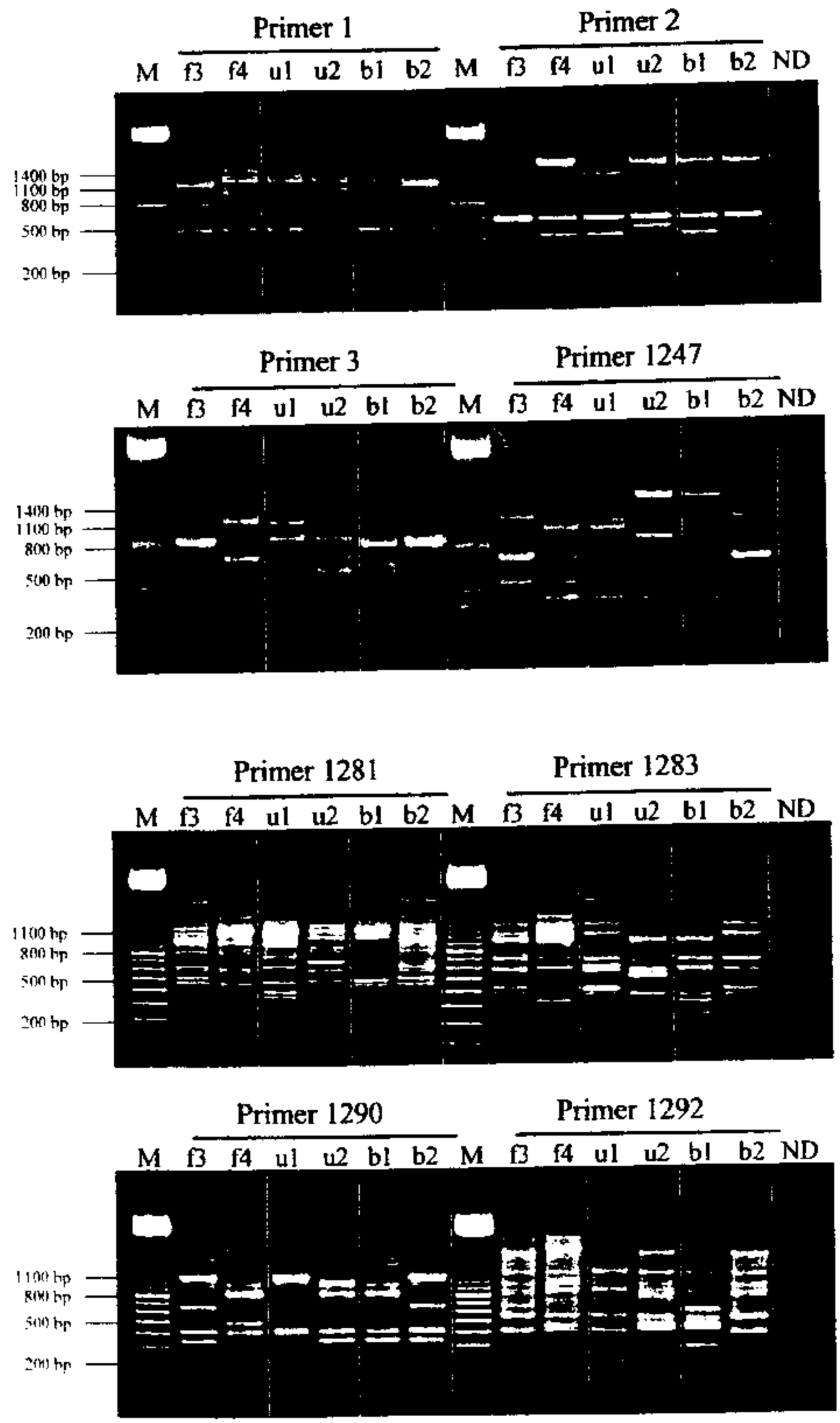


Figure 1 . RAPD fingerprints of 6 human *E. coli* isolates with 8 different primers.

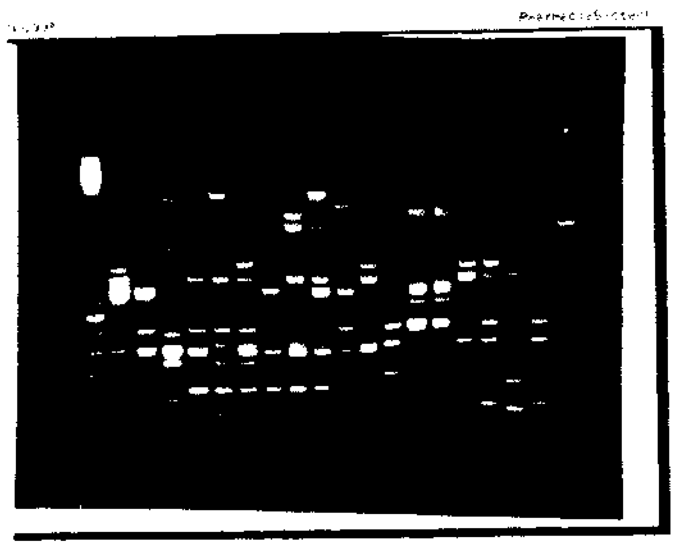


Figure 2. RAPD fingerprints of E. coli isolates from humans (HM), ground water samples (GW), chicken (CK), seagull (SG) and turkeys (TK) with primer 1283.

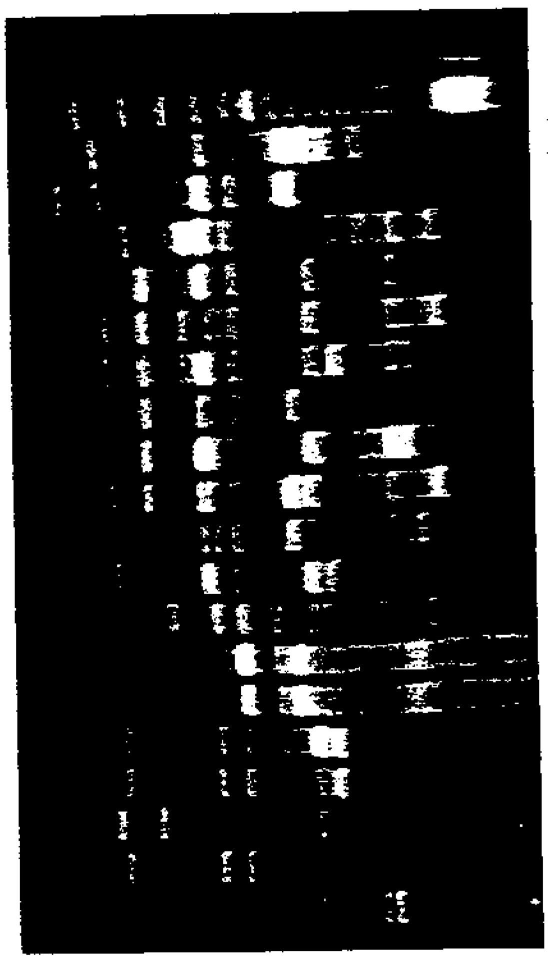


Figure 3. Primer 1283.

INDIANA STATE DEPARTMENT OF HEALTH RESIDENTIAL SEWAGE DISPOSAL PROGRAM

Alan M. Dunn, R.E.H.S., Supervisor
Indiana State of Department of Health

On-site sewage disposal (septic) systems are commonly used for the disposal of domestic wastewater from individual residences and small businesses. On-site sewage disposal systems are those which do not result in an off-lot discharge of effluent. On-site sewage disposal systems in Indiana are not just for rural families. A majority of the existing systems are in suburban areas (such as subdivisions and the fringes of urban areas), and lake areas. The typical on-site sewage disposal system is composed of a septic tank and an absorption field for disposal of the wastewater by soil absorption. The primary goals of proper on-site sewage disposal are to protect public health and prevent deterioration of environmental quality. Failing systems are those in which the system is installed. In areas such as the Lake Michigan dunes, rapidly permeable soil conditions significantly increase the potential for contamination of our water resources by wastewater from on-site sewage disposal systems. These soil conditions, combined with a significant number of old systems utilizing antiquated technologies, means that we must have an increased awareness of the potential for problems in these areas. Homeowner education, proper system operation and maintenance, and performance monitoring are all essential to the continued use of on-site sewage disposal systems while protecting our water resources.

CHEMISTRY AND MOVEMENT OF SEPTIC-TANK ABSORPTION-FIELD EFFLUENT IN THE DUNES AREA, LAKE AND PORTER COUNTIES, INDIANA

By GREG A. OLYPHANT AND DENVER HARPER

Final Report to Indiana Department of Environmental Management
FFY 1993 Section 319 Grant No. C9995008-93-0

From the Indiana Geological Survey
Indiana Geological Survey Open-File Report 95-8
October 7, 1995

Principal Investigators: Greg Olyphant, Denver Harper, Edwin Hartke, and Tracy Branam

Cooperating Investigators (Indiana State Dept. of Health): Alan Dunn, Tim Decker
Field Assistants: John Haddan, Christopher Dintaman, Christopher Carlson

Contents

Illustrations

Tables

Appendices

Appendix 2. Results of Quarterly Sampling
Appendix 3A. Daily Measurements at Jensen Site (Site 23); June 27, 1993, to May 2, 1994
Appendix 3B. Daily Measurements at Jensen Site (Site 23); May 5, 1994, to Sept. 5, 1995
Appendix 3C. Daily Measurements at Fulghum Site (Site 34)
Appendix 4. Neutron Counts; Jensen and Fulghum Sites

CHEMISTRY AND MOVEMENT OF SEPTIC-TANK ABSORPTION-FIELD EFFLUENT IN THE DUNES AREA, LAKE AND PORTER COUNTIES, INDIANA

By GREG A. OLYPHANT AND DENVER HARPER

Summary

Chemical analyses of water sampled from domestic water wells of 70 residences in the town of Beverly Shores, Indiana, indicate that the only evidence of contamination at depth in the water-table aquifer is elevated concentrations of chloride and nitrate+nitrite at a few locations. More detailed investigations of soil and groundwater chemistry in the immediate vicinity of septic-tank absorption fields indicated that the unsaturated zone and shallow part of the water-table aquifer are being locally degraded by septic effluent. Evidence of contamination includes elevated concentrations of chloride (>1,000 mg/L), nitrate+nitrite (>30 mg/L), and periodic occurrences of fecal coliforms (>20 CFU/100 mL). Bacteria have never been detected in the water wells of the residences, however, and the concentrations of chloride and nitrate+nitrite in samples from the domestic wells are much lower than those in the shallow water table. Continuous measurements of physical and chemical parameters, including measurements made in conjunction with an injection test, clearly demonstrate that septic effluent periodically enters the water table, as a result of rainfall infiltration and gravity drainage. The findings of this study indicate that, while no widespread contaminant plumes currently exist within the water-table aquifer of the area, degradation of water quality is occurring, and the degradation is greatest in low-lying areas on the edge of the Great Marsh, where the water table lies very close to the ground surface.

Introduction

As a continuation of our initial investigations of hydrologic and aqueous chemical conditions in the vicinity of septic-tank absorption fields in Beverly Shores, Indiana (Section 319 Grant No. 9995008-02-0), we undertook the present project in cooperation with personnel of the Division of Sanitary Engineering, Indiana State Department of Health (ISDH). The two principal objectives of the project were: (1) to conduct large-scale reconnaissance investigations, involving sampling of domestic water wells throughout the city, and (2) to increase the number of sites at which intensive monitoring is being conducted from two to four residences. As part of the intensive studies, we also initiated continuous monitoring of field-chemical parameters at two of the sites.

The reconnaissance studies were intended to evaluate chemical conditions of the water-table aquifer, which was considered to be vulnerable to contamination by septic effluent from the many dry wells[44] in the area. In particular, the ISDH had concerns about the possible existence of wide-spread contaminant plumes in the portion of the water-table aquifer containing domestic wells. The program of intensive monitoring was aimed at quantifying the transient effects of rainfall infiltration and evaporation on soil-water and shallow water-table chemistry in the immediate vicinity of septic-tank absorption fields.

Reconnaissance Investigations

Most of the residences in Beverly Shores are constructed on dune sands that overlie lacustrine sands and gravels; many of the residences obtain their domestic water from wells installed in the latter units. The sands and gravels rest upon glacial tills and lacustrine silts and clays (Fig. 1). The homeowners of Beverly Shores were

[44] A drywell is a concrete tank, perforated on the sides and bottom. Spillover from a septic tank drains directly into the shallowly buried drywell, from which effluent seeps readily into the surrounding material.

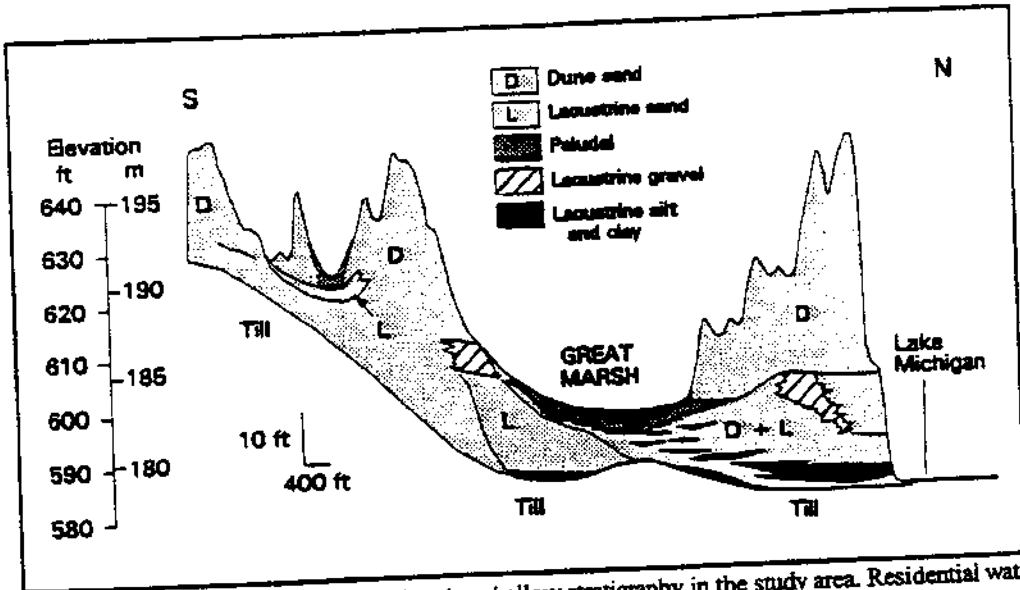


Figure 1. Geologic cross section showing shallow stratigraphy in the study area. Residential water wells of Beverly Shores are in the dune and lacustrine sands that overlie impermeable tills and lacustrine clays. Modified from a cross section by Todd A. Thompson, Indiana Geological Survey.

solicited to participate by allowing access to their domestic water wells. All of the residences in Beverly Shores are identified in Figure 2A, and those that were included in the study are indicated.

Separate samplings were conducted during a period of low water-table (discharge season) and a period of high water-table (recharge season). The first sampling was conducted between October 23 and November 14, 1993, when the water table was low, and the second sampling was conducted between March 26 and April 17, 1994, when the water table was high. Water-filtration systems were bypassed in every instance and field measurements of water temperature, dissolved oxygen (DO), pH, Eh, and specific conductance (SpC) were made on each sample before delivering them to the laboratories of the ISDH in Indianapolis. Laboratory analyses included determination of the concentrations of chloride, sulfate, nitrate+nitrite, ammonium, and surfactants, as well as total bacteria counts and fecal coliforms.

Appendix 1 provides a complete tabulation of all chemical and bacterial analyses for both sampling periods, and Figure 3 shows the frequency distributions of the major ions. The frequency distributions have a typical log-normal shape, wherein most of the samples contained very low concentrations of dissolved solids but a few samples have relatively high concentrations. Cross-plots of data collected during the two sampling periods (Fig. 4) show that, although there were some deviations at individual sites, most of the data are clustered around a line of 1:1 correspondence, which indicates that there was no significant difference in water-table chemistry between the two seasons.

As shown in Figure 5, chloride has a strong correlation with SpC (an indicator of total dissolved solids) during both seasons. Indeed, chloride has the strongest correlation of the ions measured and is used in this report as an indicator of salinity.

No elevated levels of *E. coli* or total bacteria were observed in the domestic well samples. Three sites had concentrations of nitrate+nitrite that exceeded the U.S. EPA's maximum contaminant level of 10 mg/L. The site with the highest concentration of nitrate+nitrite had a value of 19 mg/L in both samplings, but each of the other two sites exceeded the maximum level only during one season. A total of thirteen samples had concentrations of chloride that exceeded 250 mg/L, which is a secondary U.S. EPA drinking-water standard. Five residences exceeded the standard on both samplings. As shown in Figure 6, the locations where chloride and nitrate+nitrite exceed EPA standards are scattered across Beverly Shores, so that there is

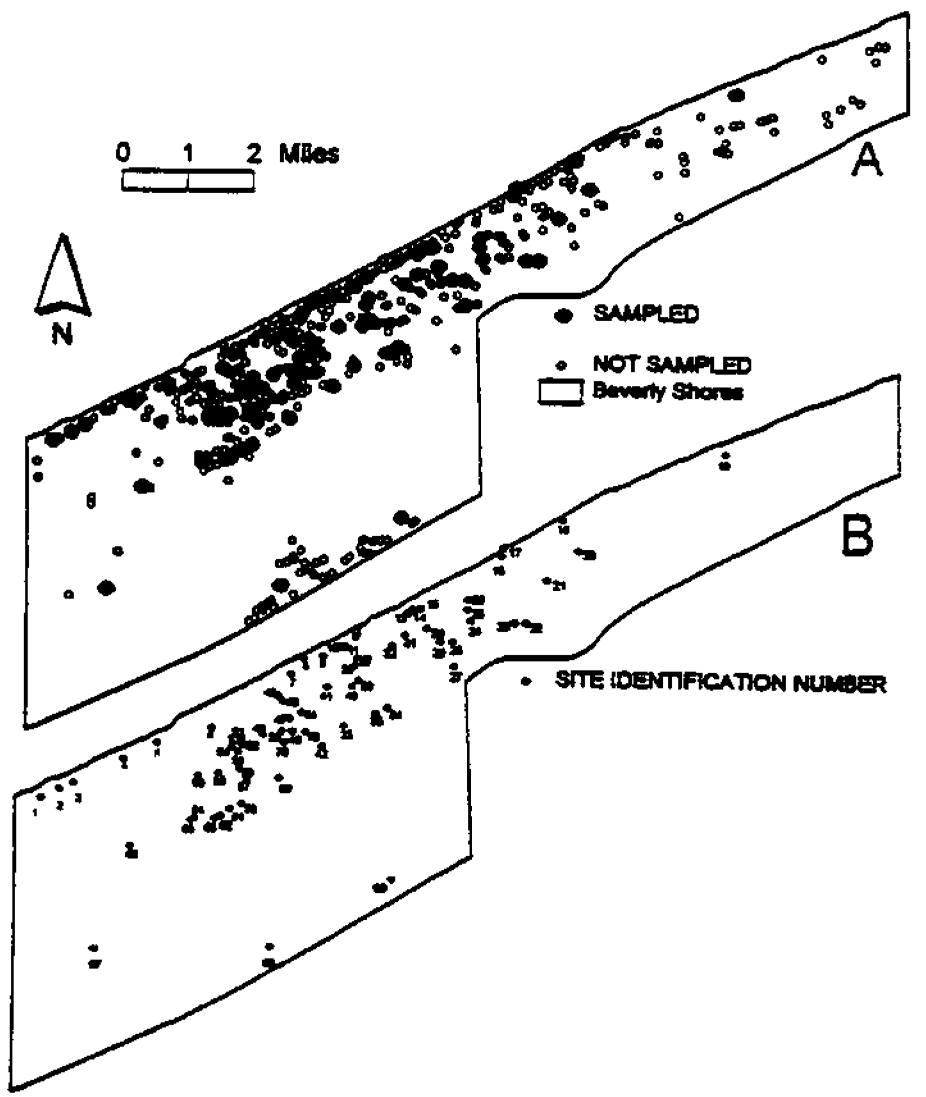


Figure 2. Maps of Beverly Shores showing (A) locations of all residences and whether or not they were sampled, and (B) identification numbers of houses where domestic water wells were sampled.

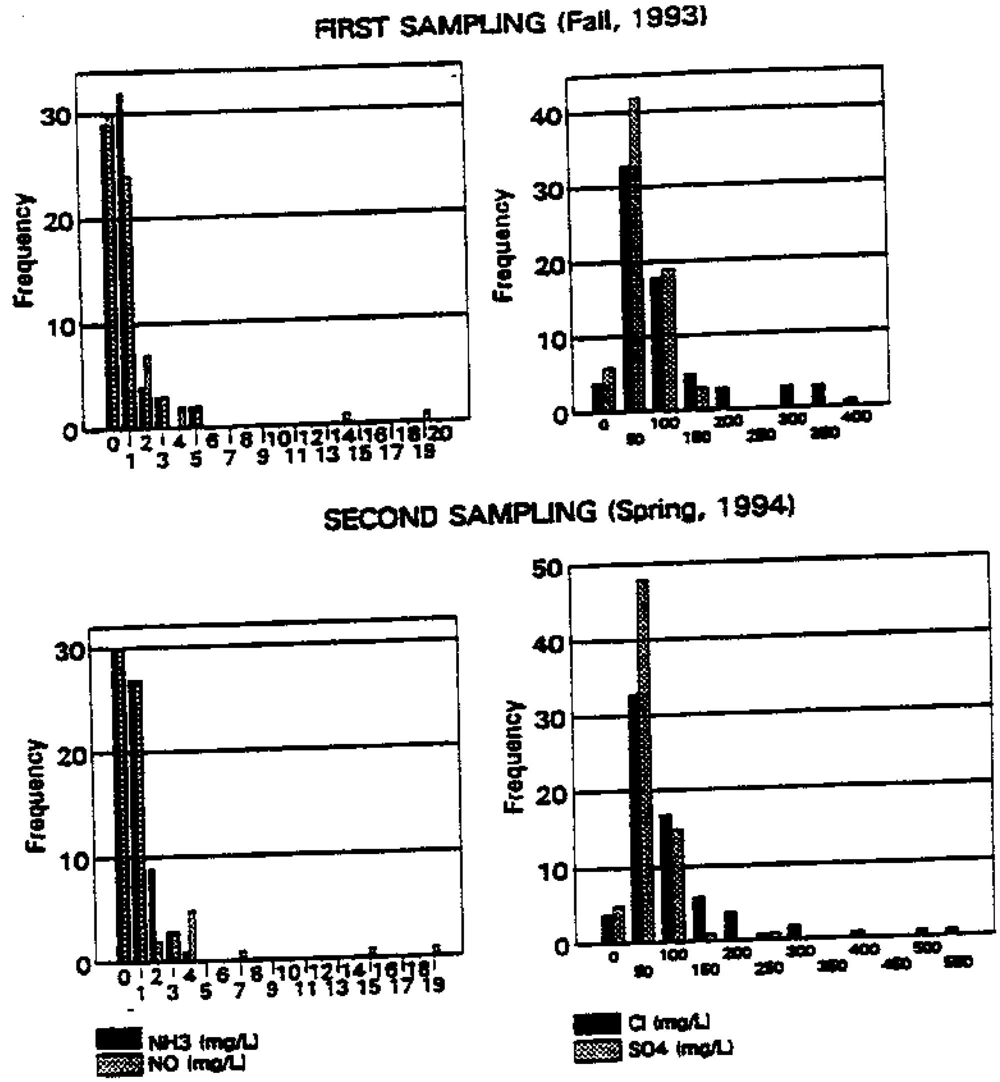


Figure 3. Histograms of selected chemical species in water samples collected during reconnaissance investigations.

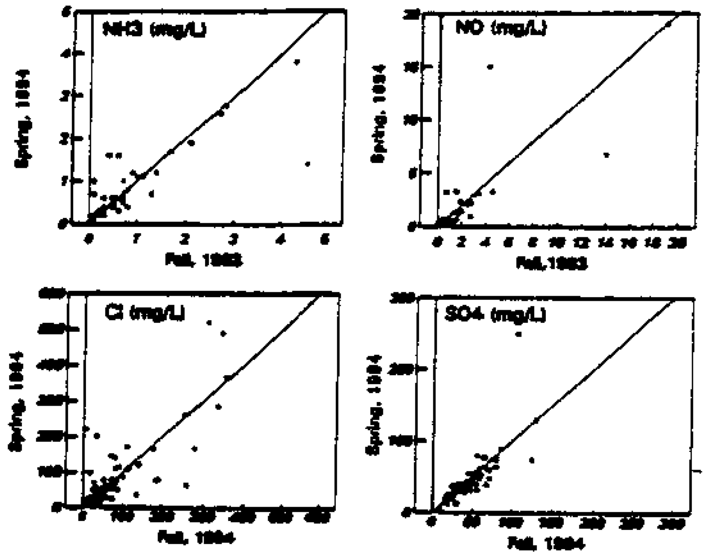


Figure 4. Cross-plots of ion concentrations in groundwater collected from domestic wells during first and second reconnaissance samplings.

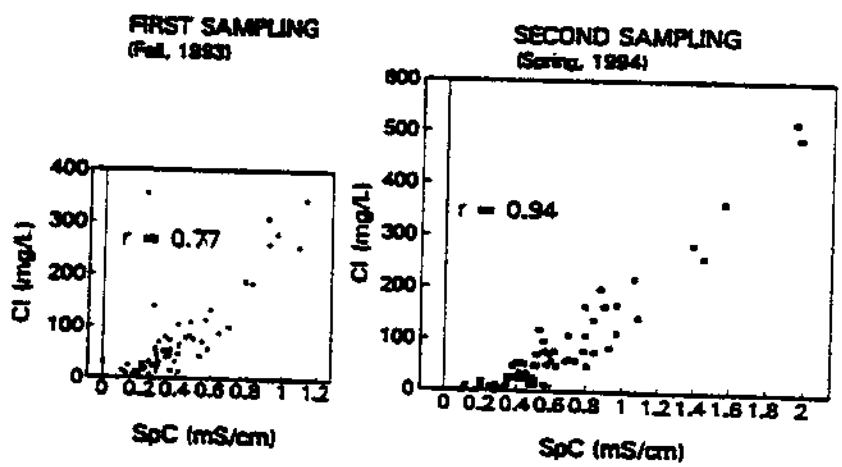


Figure 5. Correlation between chloride concentration and SpC in samples collected from domestic water wells during reconnaissance investigations.

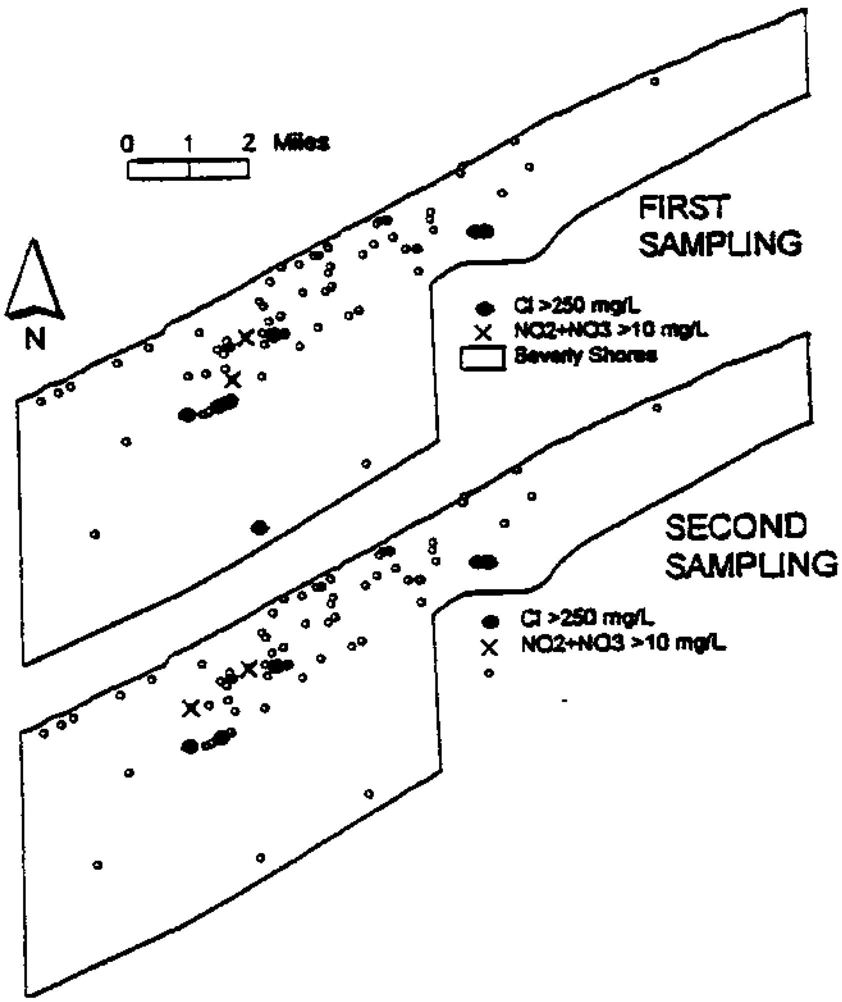


Figure 6. Maps of Beverly Shores showing locations where chloride and nitrate+nitrite exceeded U.S. EPA levels.

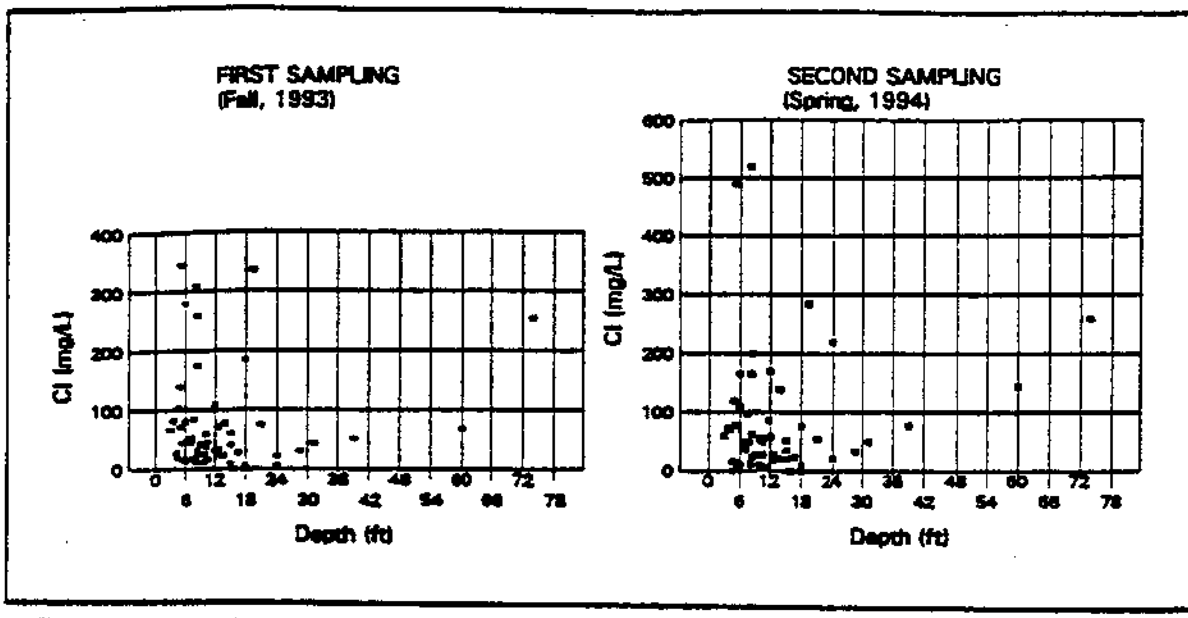


Figure 7. Plots showing variation of chloride concentrations with depths of domestic well-screen intervals.

no evidence of any widespread contaminant plume in the aquifer.

As shown in Figure 7, there appears to be no correlation between water chemistry and depth within the aquifer. The highest chloride concentrations were observed at residences in low-lying areas, where the vertical distance between septic outflow and the water table is smallest. As a result of these observations, we subsequently concentrated our intensive studies in such low-lying settings.

Intensive Investigations

Monitoring wells and pressure-vacuum soil-water samplers were installed at two new sites in October, 1993. The two new sites, referred to as the Miller and Fulghum Sites, are identified in Figure 2B as Sites 4 and 34, respectively. The installations at these two new sites were initially sampled for water chemistry, along with the installations at the original intensive sites (referred to as the Jensen and Carstedt Sites, identified on Figure 2B as Sites 23 and 28), in February, 1994. Descriptive information on all of the intensive monitoring installations is presented in Table 1.

The Jensen and Fulghum Sites are located in low-lying areas where the water table is within five meters of the land surface, so that the potential for septic effluent to enter the water table is high. At the Jensen Site, effluent discharges from two drywells, whereas the Fulghum Site utilizes a tile-finger distribution system. Sampling at the Carstedt Site, which is situated on a high dune, was discontinued after February, 1995, because of the absence of any septic impacts on the groundwater there. Sampling at the Miller Site, which is located on the foredune ridge, was discontinued after November, 1994, because the water table there was so low that physical and chemical monitoring could not be reliably conducted.

A total of 54 samples of saturated-zone water and 57 samples of unsaturated-zone water were collected during the seven quarterly samplings that we conducted at intervals of every three months throughout the study. Most of the data are from the Jensen and Fulghum Sites. All of the quarterly water samples were submitted to the laboratories of the ISDH in Indianapolis for chemical analysis. The laboratory analyses included determinations of SpC, pH, and alkalinity, as well as concentrations of nitrogen as ammonia, nitrogen as nitrite + nitrate, nitrate, aluminum, barium, calcium, chloride, fluoride, copper, iron, magnesium, manganese, nickel, total phosphorous, potassium, silica, sodium, strontium, sulfate, sulfide, and zinc. Bacterial analyses included determinations of *E. coli*, fecal coliforms, and total bacteria.

TABLE 1. DESCRIPTIVE INFORMATION ABOUT MONITORING-SITE INSTALLATIONS

ID	Installation type	Instrumentation	Function	Depth (m)
JENSEN SITE (Site 23, Fig. 2B)				
JWU	Monitoring well		Quarterly chemical sampling	14.3
JWM1		Pressure transducer	Continuous water-level measurement	4
JWM2		Chemical probe	Continuous field chemistry/ Quarterly chemical sampling	4.9
JWM3				5.3
JWM4			Quarterly chemical sampling/ Monitoring well for injection test	5.5
JWL			Quarterly chemical sampling	2.7
JLE5	Pressure-vacuum soil-water sampler		Quarterly chemical sampling	1.5
JLE8				2.4
JLE12				3.7
JLW8				2.4
JLW11				3.4
FULGHUM SITE (Site 34, Fig. 2B)				
FW1	Monitoring well	Pressure transducer	Continuous water-level measurement	3.2
FW2		Chemical probe	Continuous field chemistry/ Quarterly chemical sampling	3.8
FL4	Pressure-vacuum soil-water sampler		Quarterly chemical sampling	1.2
MILLER SITE (Site 4, Fig. 2B)				
MW	Monitoring well	Pressure transducer	Quarterly chemical sampling	15.5
ML3.5	Pressure-vacuum soil-water sampler			1.1
ML10.5				3.2
CARSTEDT SITE (Site 28, Fig. 2B)				
CW	Monitoring well		Quarterly chemical sampling	30
CL5	Pressure-vacuum soil-water sampler			1.5
CL8				2.4
CL13				4
CL20				6.1

A complete tabulation of the data collected during the first six quarterly sampling periods[45] is provided in Appendix 2, along with data collected during our previous investigation. A general summary of the results is presented in Table 2. The highest chloride concentrations were consistently found at the Jensen Site. Concentrations exceeding 1,000 mg/L occurred in the unsaturated zone, especially below the drywells, and in the monitoring wells immediately below the drywells. The chloride values were much lower (<100 mg/L) at the Fulghum and Miller Sites.

High concentrations of nitrate+nitrite (>10 mg/L) were observed in the wells at the Fulghum Site on every sampling. At the Jensen Site, nitrate+nitrite exceeded 10 mg/L on two occasions in those unsaturated-zone monitoring installations that are situated adjacent to the eastern drywell. However, elevated concentrations of nitrate+nitrite were never observed in the saturated zone at the Jensen Site.

High bacteria counts were observed in numerous samples collected on November 20 and 21, 1994 (Appendix 2); in consultation with personnel of the ISDH, it was decided that these results are probably spurious because such high levels were never again observed at many of the ites. Among the other samples, fecal bacteria counts greater than 10 CFU/100 mL were detected on two occasions in samples collected in JWM2, JWM4, and FW2 and on one occasion in a sample from JWM3. Only one of these samples (from JWM4) exceeded 100 CFU/100 mL.

On April 4, 1995, sediment cores were collected from the Jensen and Fulghum Sites using a vibracorer. About 2.4 meters of core was obtained at the Jensen Site and 1.8 meters of core was obtained at the Fulghum Site. Both cores were collected immediately adjacent to the septic-distribution systems. The cores were cut into 30 cm intervals and delivered to the

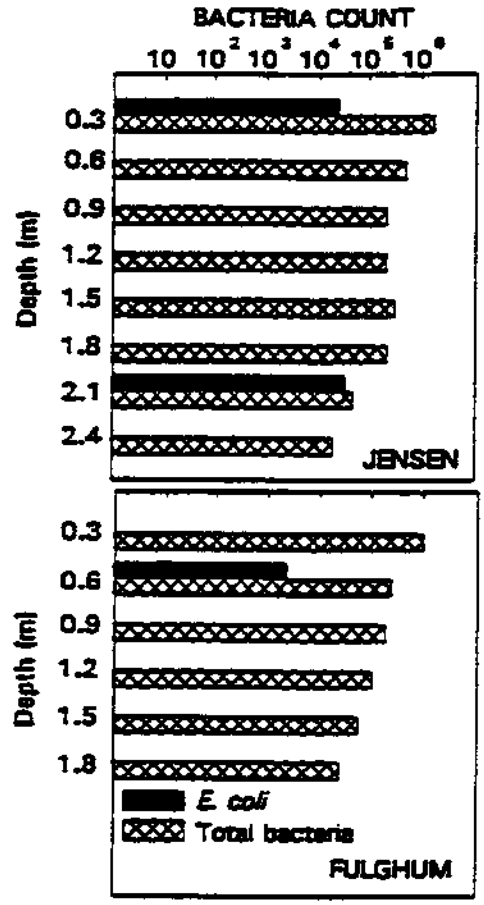


Figure 8. Depth profiles of bacteria counts in sediment cores from Jensen and Fulghum Sites. The cores were taken adjacent to existing septic-tank absorption fields.

Biological Laboratory at Indiana University-Northwest for bacterial analyses. The results of the analyses are shown graphically in Figure 8. *E. coli* were detected in the uppermost 1 foot and at a depth of 7 feet at the Jensen site. At the Fulghum site, *E. coli* were detected at a depth of 2 feet. All other samples indicated no *E. coli* were present. Total bacteria were abundant in the cores from both sites. The total bacteria counts exhibit a classical profile, with the highest counts at, or near, the surface, where the greatest amount of biological activity and contamination exists. The counts gradually decline in number with depth.

[45] Data from the seventh sampling period have not been received from ISDH as of the project's termination date.

TABLE 2. STATISTICAL SUMMARY OF WATER CHEMISTRY ASSOCIATED WITH INTENSIVE STUDY SITES

SITE ID	FECAL COLIFORM (CFU/100 mL)					CHLORIDE (mg/L)				NITRATE + NITRITE (mg/L)				
	N	ND	MEAN	MAX	MIN	N	MEAN	MAX	MIN	N	ND	MEAN	MAX	MIN
JENSEN SITE (Site 23, Fig. 2B)														
JWM1	1	0	NO DATA			1		850		1	1		8.6	
JWM2	6	2	55	80	30	6	328	855	26	6	6	3.8	9.8	0.6
JWM3	5	2	84	150	17	6	791	1100	515	6	6	3.1	4.1	1.9
JWM4	3	3	54	110	23	3	902	1000	750	3	3	4.9	6.4	3.2
JLE5	1	0	<1.1			4	282	620	49	7	7	9.0	20	2.1
JLE8	1	0	<1.1			5	905	1000	900	7	7	8.9	13	4.6
JLE12	1	0	<1.1			2	1020	1040	1000	6	5	4.7	14	<0.1
JLW4	0	0	NO DATA			4	68	210	13	4	1		0.4	<0.1
JLW11.5	1	0	<1.1			2	1080	1210	950	3	3	3.7	6.2	1.5
JWL	4	1	1.1			11	10.4	17	5	11	2	1.1	1.7	0.5
JWU	5	1		23		12	17	39	13	12	1	0.1		
JPW	1	0	<1.1			1		610		1	1	1.9		
FULGHUM SITE (Site 34, Fig. 2B)														
FW1	1	0	<3			1		36		1	1		32	
FW2	5	3	46	93	23	6	47	70	30	6	6	46	56	31
CARLSTEDT SITE (Site 28, Fig. 2B)														
CW	4	1	43			14	34	157	6	10	1		0.2	
CL5			NO DATA			8	6	7	3	5	1		0.4	<0.1
CL8			NO DATA			7	15	34	7	4	1		0.2	<0.1
CL13			NO DATA			3	21	28	10	2	0	<0.1		
CL20			NO DATA			7	6	15	4	4	0	<0.1		
MILLER SITE (Site 4, Fig. 2B)														
MW			75	75	4.1	2		11		2	1		0.2	<0.1
ML105			NO DATA			1		40		1		<0.1		

The Jensen and Fulghum Sites were instrumented for continuous monitoring of hydrologic and field-chemical conditions. The deployment of pressure transducers (for water-table monitoring) and chemical probes (for monitoring of SpC, pH, temperature and DO) is indicated in Table 1. In addition, precipitation was measured with tipping-bucket rain gauges at both sites. Both sites also contained neutron-probe access tubes that allowed periodic measurements of soil-moisture profiles in the unsaturated zone. A weighing lysimeter for measuring infiltration and evaporation was deployed at the Jensen Site throughout the study and a vertical array of soil-tension sensors was deployed during part of the first year. All together more than 19,000 hours of monitoring data were recorded at the Jensen Site and more than 10,000 hours of monitoring data were recorded at the Fulghum Site as part of this study. A complete tabulation of these data are given as daily averages and totals in Appendices 3A, 3B, and 3C.

Figure 9 shows the variation of the water table at the Jensen Site over a period of monitoring that began in June, 1993,and continued into September, 1995. Data on daily net infiltration and evaporation for the same period of monitoring are also presented in the figure. The summer and fall of 1993 were much wetter than the same periods of 1994 and 1995. The total range of water-table variation during the study period was about one meter. By the end of the study in September, 1995, the water table was again approaching the low level observed in 1994 (about 183.5 m above sea level). The highest water tables (about 184.4 m) occurred in late spring of 1994 and again in 1995. Total evaporation for the warm season of 1994 (April through October) was 23 cm as determined from the weighing lysimeter, and for the months of April through August of 1995 was 19 cm. Total infiltration for the same periods was 34 cm and 38 cm. In both cases the infiltration totals are much larger than the evaporation totals indicating the importance of rainfall infiltration in the hydrology of the area.

The data on groundwater pH and specific conductance (SpC) are shown, along with precipitation data for the same period, in Figure 10. Groundwater pH varies in a cyclical manner, reaching a maximum of about 6.4 in late winter and a minimum of about 5.8 during midsummer. SpC exhibits a more irregular pattern of rising and falling values, although there is some tendency for SpC to be lower in spring (high water table) than in summer. The short-term variations correspond to rainy periods, and, as discussed below, can be associated with infiltration of leachate from septic systems into the shallow water table.

Soil-moisture profiles were measured with a neutron probe approximately bi-weekly at the Jensen and Fulghum Sites. A total of 34 moisture profiles were determined for the Jensen Site and 25 moisture profiles were determined for the Fulghum Site. The raw data were used to determine the soil moisture profiles is presented in Appendix 4 along with a brief description of how moisture-content values were computed. Figure 11 shows the wettest and driest soil-moisture profiles observed during the period of monitoring at the Jensen Site. The greatest differences occurred between two and four meters below the surface, whereas the near-surface portion of the profile was consistently dry due to gravity drainage in the reworked dune sands. Total moisture storage of the unsaturated zone ranged from a minimum of about 40 cm of water (September, 1994) to a maximum of more than 70 cm of water (early April, 1995) (Figure 12). The large range of variation in soil-moisture conditions is consistent with a medium having a large hydraulic conductivity and flow.

At the Jensen Site, we conducted an injection test (using bromide and elevated SpC as tracers) in June, 1995, to evaluate solute transport in the immediate vicinity of the drywell, and a pump test to determine saturated-zone conductivity was conducted in September, 1995. *In situ* hydraulic conductivity of unsaturated-zone sand was also determined using a Guelph permeameter. The pump-test data yielded an hydraulic conductivity of 1.5 x

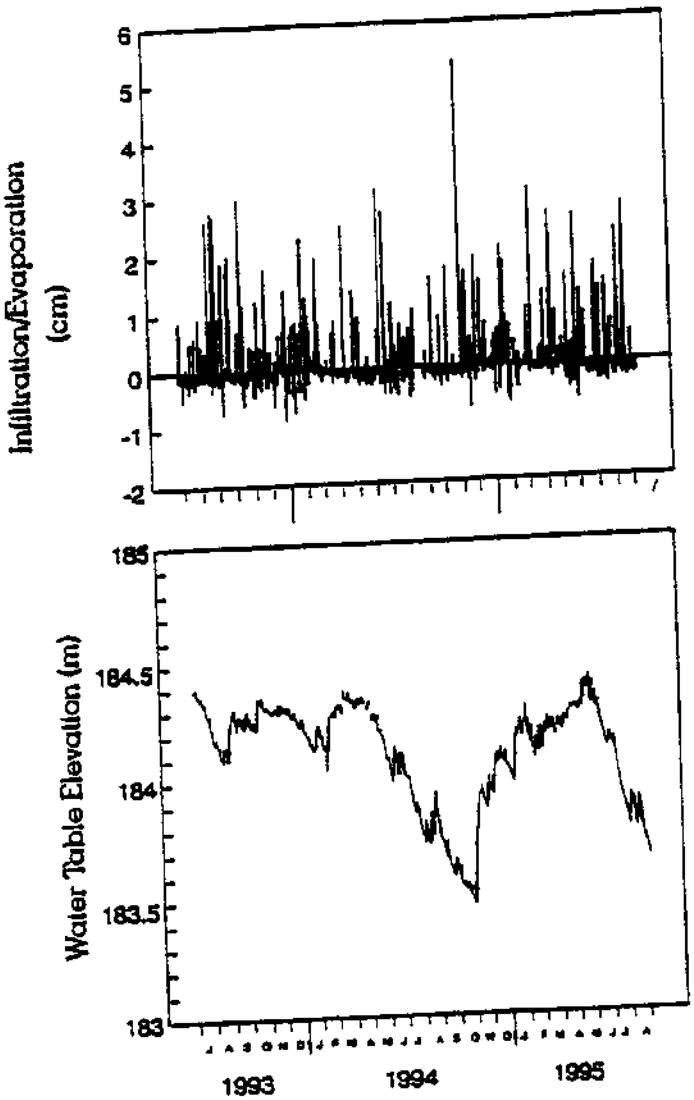


Figure 9. Temporal variation of infiltration and evaporation (from weighing lysimeter), and water-table elevation (from pressure transducer) at the Jensen Site during the entire period of monitoring. In the upper figure, positive numbers indicate net daily infiltration, and negative numbers represent net daily evaporation.

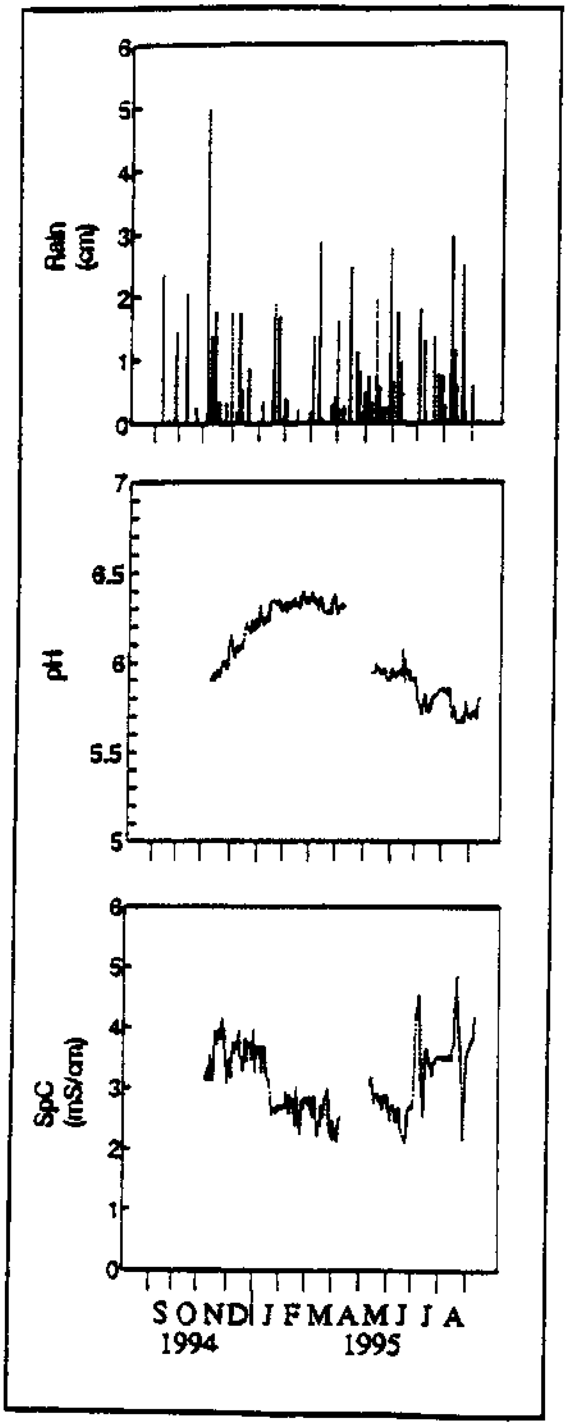


Figure 10. Temporal variation of groundwater pH and SpC at Jensen Site during 1994 - 1995 water year. Short-term fluctuations are a response to rainfall infiltration and gravity drainage.

conductive (saturated conductivity of 1.4×10^{-2} cm/s).

On June 9, 1995, 1,500 liters of water containing a bromide concentration of 1,800 mg/L and a SpC of 800 mS/cm were injected, by gravity drainage, directly into a drywell at the Jensen Site. Continuous monitoring of water levels and SpC were made in the following wells: JMW2, JMW3, JMW4, and JLW. Samples of water were also collected from the wells and from the unsaturated zone adjacent to the dry well (from JLE5, JLE8, and JLE12) and were submitted for determination of bromide concentration to the Geochemistry Laboratory of the Indiana Geological Survey. The water samples were collected on the day of the injection (June 9), and on June 10, 12, and 16. Bromide, which does not naturally occur in the groundwater of the area was eventually detected in all of the soil-water samples and all of the well samples except those from JLW. The largest concentrations (exceeding 200 mg/L) were observed in the shallow soil-water samples, but a concentration of 74 mg/L was also observed in the sample from JMW4 (adjacent to the drywell) on June 16.

The effect of the injection was also manifested in a rise of SpC at the monitoring points. Figure 13 shows the results of monitoring associated with the injection. An immediate rise of the water table was observed at each well, and, as expected, a total rise was greatest in wells closest to the drywell. However, the response of SpC to the injection was greatly delayed, even in the closest wells, and no response was ever recorded at the lower well (JLW). The rise in SpC was observed first at JMW2, which is located immediately adjacent to the drywell at its southeast edge. However, the largest rise occurred in JMW4, which is on the northwest edge of the drywell. As noted in our previous report, the water table slopes away from the drywell in both directions. These data indicate that the flow to the northwest (toward the domestic well) is somewhat greater than the flow toward the wetland on the southeast side of

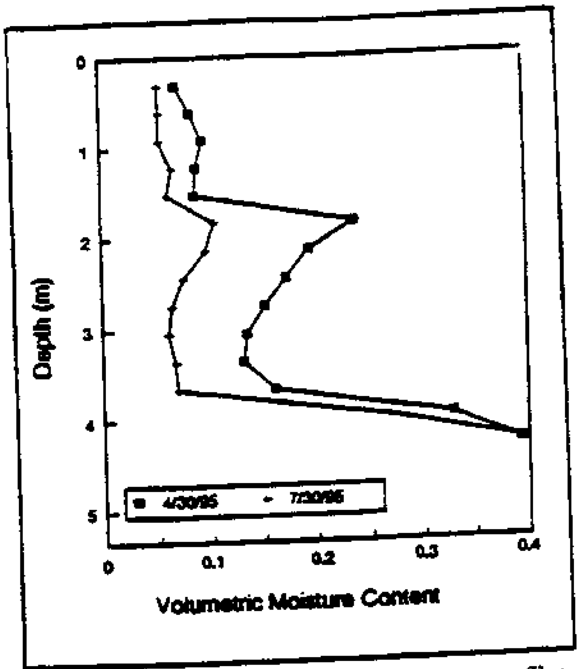


Figure 11. Wettest and driest soil-moisture profiles, measured at the Jensen Site during 1995.

the site. The largest rises of SpC actually occurred two weeks after the initial injection, when 4.3 cm of rainfall caused large quantities of original injection water to be flushed from the unsaturated zone into the water table. This flushing effect was observed in all three of the wells surrounding the drywell.

Another rainstorm that occurred a week later also produced rises of SpC in the monitoring wells.

Conclusions

The lacustrine and dune sands of the Beverly Shores area are highly permeable, and in many areas the water table lies very close to the ground surface. Because of the general use of drywells by the residents of the community, personnel of the ISDH were concerned that widespread contamination of the water-table aquifer was occurring. At the same time, others were suggesting that septic effluent from Beverly Shores was contributing to bacterial

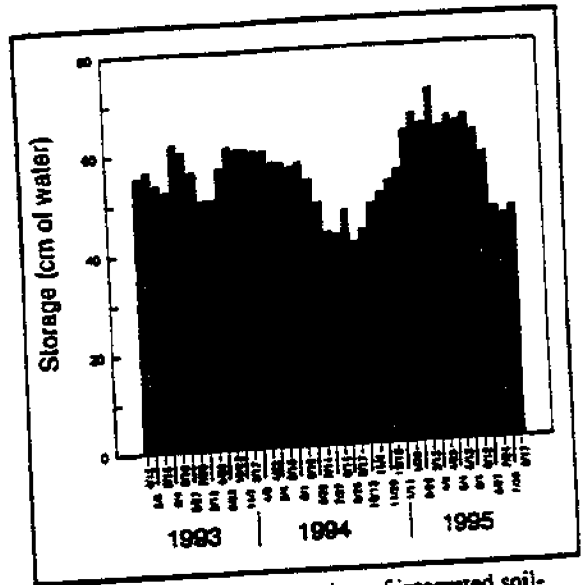


Figure 12. Temporal variation of integrated soil-moisture profiles at the Jensen Site during the entire period of monitoring. Note higher values in summer of 1993, which correlated with higher water-table elevations in Fig. 9.

contamination of streams that drain into Lake Michigan and causing periodic beach closures

Our investigations, which have included sampling of residential wells throughout the community of Beverly Shores, as well as intensive monitoring of residences in particularly vulnerable areas, have provided no evidence of widespread aquifer contamination. This absence of contamination in the soil and groundwater – particularly the absence of *E. coli* – would seem to refute the hypothesis that septic effluent from Beverly Shores represents a major source of the outbreaks of *E. coli* that have occurred along the local shoreline of Lake Michigan.

Although there is no evidence of widespread aquifer contamination, there is some evidence of local groundwater degradation in the form of elevated levels of chloride and nitrate+nitrite. At one of our intensive monitoring sites (Jensen Site), elevated chloride concentrations occur in the immediate vicinity of the drywell. The chloride concentration is greatest in the unsaturated sand below the

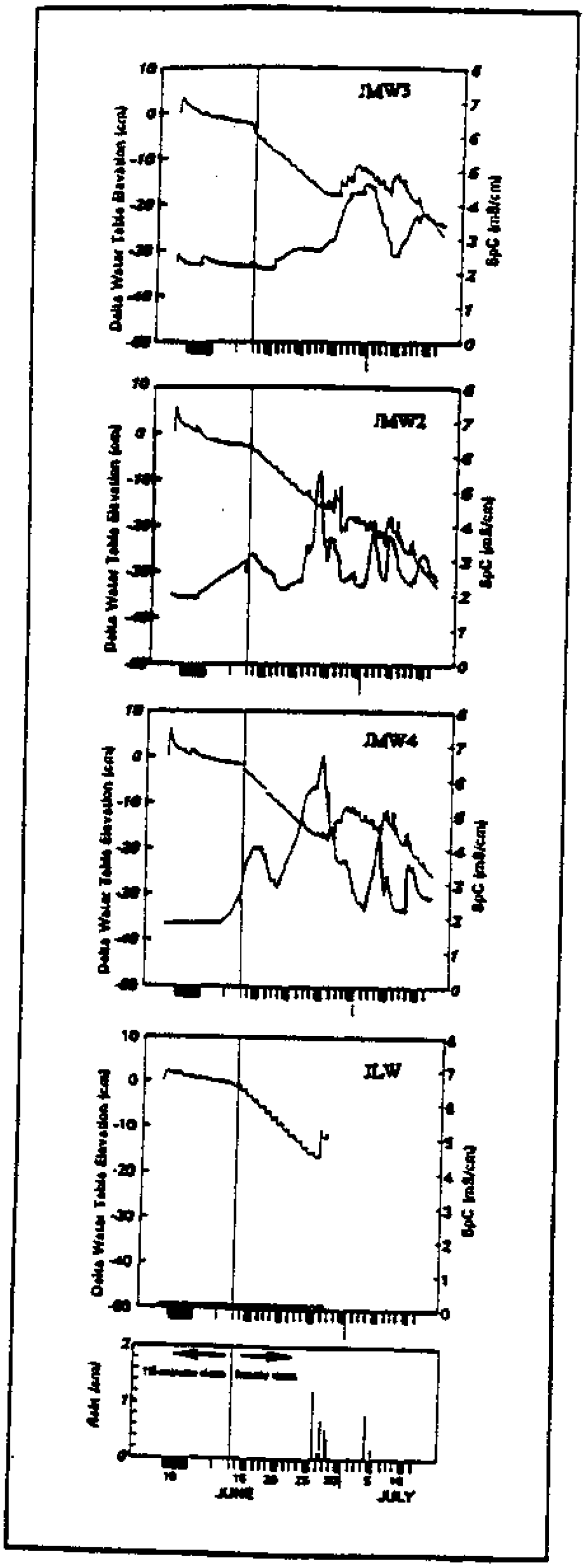


Figure 13. Responses of water-level (upper curves) and field chemistry (lower curves) to injection of high TDS water (15-minute data), and to subsequent rainfall (hourly data), at the Jensen Site.

mg/L), but it decreases to less than 20 mg/L on the edge of the Great Marsh which is only 20 meters north of the drywell. The hydraulic gradient between the drywell and the domestic well is greater than the gradient between the drywell and the marsh, and this may explain the consistently high values of chloride (> 250 mg/L) observed in the domestic well. The high concentrations of chloride in the domestic well are probably due to recycling of domestic wastewater and should serve as a caution against the widespread use of drywells in such bhighly conductive soils. Long term use of drywells in these permeable dune sands, especially in low-lying areas where the water table is very near the ground surface, may indeed lead to widespread contamination of the water table aquifer of the area.□

APPENDIX 1

Results of First and Second Reconnaissance Investigations

(See Fig. 2B for locations of sites)

Abbreviations:

- **Bact.: total bacteria**
- **FC: fecal coliform**
- **G.W. Temp.: groundwater temperature**
- **NH_3/N: ammonia, as nitrogen**
- **NO_2NO_3N: nitrite plus nitrate, as nitrogen (referred to as *nitrate+nitrite* in the text)**
- **Surf.: total surfactants**

APPENDIX 2

Results of Quarterly Sampling

(See Fig. 2B for locations and Table 1 for description of installations:
Sites beginning with the letter "J": Jensen Site (Site 23)
Sites beginning with the letter "F": Fulghum Site (Site 34)
Sites beginning with the letter "M": Miller Site (Site 4)
Sites beginning with the letter "C": Carstedt Site (Site 28))

Abbreviations:

Alk: alkalinity, reported as calcium-carbonate ($CaCO_3$) equivalent Bact.: total bacteria
FC: fecal coliform
NH_3/N: ammonia, as nitrogen
NO_3/N: nitrate, as nitrogen
NO_2NO_3N: nitrite plus nitrate, as nitrogen (referred to as *nitrate+nitrite* in the text)
Tot. P.: total phosphorous

Explanation: Silica reported as mg/L is dissolved reactive silica. Silica reported as µg/L is silica.

APPENDIX 3A

Daily Measurements at Jensen Site (Site 23)
June 27, 1993, to May 2, 1994

Abbreviations:

- **D.T.W.:** depth to water
- **G.W. Temp.:** groundwater temperature
- **Infil./Evap.:** net infiltration (if positive) and net evaporation (if negative)
- **W.T. Elev.:** water-table elevation

APPENDIX 3B

Daily Measurements at Jensen Site (Site 23)
May 5, 1994, to September 5, 1995

Abbreviations:

- **D.T.W.: depth to water**
- **G.W. Temp.: groundwater temperature**
- **Infil./Evap.: net infiltration (if positive) and net evaporation (if negative)**
- **W.T. Elev.: water-table elevation**

APPENDIX 3C

Daily Measurements at Fulghum Site (Site 34)

Abbreviations:

- **D.T.W.: depth to water**
- **G.W. Temp.: groundwater temperature**
- **W.T. Elev.: water-table elevation**

APPENDIX 3B

Daily Measurements at Jensen Site (Site 23)
May 5, 1994, to September 5, 1995

Abbreviations:

- **D.T.W.: depth to water**
- **G.W. Temp.: groundwater temperature**
- **Infil./Evap.: net infiltration (if positive) and net evaporation (if negative)**
- **W.T. Elev.: water-table elevation**

APPENDIX 4

Neutron Counts
Jensen and Fulghum Sites

Abbreviations:

Std. Count: neutron-probe standard count

Explanation: Volumetric soil-moisture content (SM) is calculated as a function of the count ratio (CR), which is determined by dividing neutron counts by the standard count. The factory calibration function that was used is SM = 0.412 x (CR - 0.028). On each measurement day, neutron counts were made at depth intervals of 30 cm (1 foot) throughout the unsaturated zone.

MAUMEE BAY BACTERIA TASK FORCE

Chris Cutler
Division of Environmental Services
Toledo, OH

The crown jewel in Ohio's State Park system is Maumee State Park. It is located in Lucas County, just outside the Toledo metropolitan area. Maumee Bay State Park opened in 1991, and is the newest state park in Ohio. In the short time that the park has been open, it brought to the area more tourist dollars which have enhanced the economics of the region.

Therefore when we started to have beach postings in 1994 well it became a hot political issue. Just to clarify, Ohio does not officially close a beach, instead, the beach is posted. Posted means that a sign is placed on the beach warning swimmers that the water may be harmful to their health and that they swim at their own risk. This is done when geometric means averages of either fecal coliforms exceed 200 colonies/100 mL or E. Coli. exceeds 126 colonies / 100 mL.

The beaches at Maumee State Park were posted for over half the swimming season in 1994. In 1995, when the E. coli counts began to rise again, it was decided that some form of action needed to be taken. Based on the assumption that the E.coli counts might rise for the 1995 swimming season, preliminary ground work was started in the winter of 1994 and 1995. I met with my supervisors, the manager of the State Park and the director of the sampling program for Lucas County in order to develop a strategy. In this case, Lucas County runs the sampling program and the state of Ohio's Department of Health pays for the analyses.

Therefore, the first meeting consisted of the Lucas County Health Department, Division of Environmental Services and the State Park officials. Environmental Services became involved because we had the expertise in tracking down spills and sources. By involving Environmental Services, it was hoped that we would be able to identify the culprit causing the contamination. The groundwork was laid for future meetings.

The original organization grew to include other agencies. As I mentioned at the beginning of my presentation, this is a political issue, so the following individual agencies became involved: State Environmental Protection Agency; the Department of Health; Department of Natural Resources; and personnel from the state beach. Membership also included county agencies such as the Lucas County Commissioners, the Lucas County Health Department and the Ottawa County Health Department. The Ottawa County Health Department became involved because the county is adjacent to the state park. Also included in the membership are the local agencies. Maumee Bay State Park is actually just outside the city limits of Oregon, Ohio so this city has a very strong interest in the Task Force and its results. Also, several different divisions of the city government from the City of Toledo are involved.

From the initial meeting, it was decided that a few initial tasks definitely needed to be accomplished. The first task was to convince the State Department of Health for Ohio to change the standard monitoring protocol from fecal coliform to E.coli. Both standards were on the books, but no lab was capable at the time of analyzing consistently for E.coli. The City of Toledo purchased new instrumentation which finally provided consistent E.coli analyzes. This was important because the City of Toledo was the contract lab for the analysis of the swimming beach samples.

In order to get the state to change the standards, a lot of steps needed to be taken to have the change take place. There was representation on the Task Force from the state health department. However, the representative was not upper level management but mid level management. He was able to make a recommendation to his supervisors concerning the change from fecal coliform to E. coli standards. A recommendation would only take us so far in our quest. We still needed outside political assistance. The form of assistance finally came in the form of letters from the Ottawa County Health Department and the City of Toledo. Also, the wishes of the Task Force were further expressed at a meeting of the Lake Erie Protection Commission.

At the meeting, the Task Force also identified two separate problems. We have the beach along Lake Erie and then an inland lake beach a short distance away. In both cases, the swimming waters had been contaminated. The water inflow to the inland lake from Lake Erie is controlled and in fact was opened only once in 1995. Therefore we felt that we had a good grasp of what was happening to the water at the inland lake. The only influx of water to the inland lake system was rainwater. The natural conclusion was that the rainwater runoff was probably bringing in some form of contaminants from wildlife in the area.

Based on this conclusion, it was decided that we needed to do some type of bird control. In order to do this we tried several methods, the first of these being harassment. Loud noises were used to get rid of the birds. The next was a strong public relations campaign to stop people from feeding the birds. In fact if people were caught feeding the birds then they would be issued a citation.

Another thing that the Task Force did was dye testing on some of the septic systems. Lucas County hired another person who was responsible for dye testing. The suspect septic systems were identified in western Lucas County. Of the 150 septic systems tested, 45% were found to be faulty and another 15% had inconclusive results. The inconclusive results were due to rainfall happening at the time of the testing. It must be pointed out that this does not mean 45% of the septic systems in western Lucas County are faulty. The systems tested were those already suspected of being faulty.

Other accomplishments of the Task Force are the support and funding of projects through Ohio Sea Grant and the Lake Erie Protection Fund. The Task Force approached professors from the University of Toledo to do a study pertaining to the contamination problems at Maumee Bay State Park. The researchers from the University of Toledo received a small amount of funding from the Lake Erie Protection Fund, The Lucas County Commissioners and in kind services from the City of Toledo. The money was used to sample five days a week at the beaches in the State Park as well as sampling multiple locations on the beaches in the summer of 1996. The sampling protocol overrode the State Department of Health's sampling time frame which occurred on Monday's during the summer season. The funding has been extended for two more years from the Lake Erie Protection Fund to the University of Toledo Research Foundation.

Therefore, currently the Task Force is analyzing the data collected from the intensive sampling that occurred in the summer of 1996. The researchers sampled approximately 600 isolates from five to eight locations in the area. Samples were collected from both the beaches and ditches near the beaches. Also included were both bird droppings and sediment samples. The beach and ditch samples were identified as hypothetical positive and the bird droppings and sediment samples were hypothetically identified as sources. Analysis methods include membrane specificity with MIDI/FAME system and RFLP of plasmid samples. The researchers have found that the two techniques complement each other.

The current analyses indicate that we have no single source for the pollution to the State Park. We do have a lot of weather related impact. We have been able to determine that northeastern winds or strong rains will force the ditch water up against the Lake Erie beach. This provides a near shore effect on the swimming water. The Ohio Environmental Protection Agency samples the water from 100 to 200 yards, from the swimming beach. This was done three times during the summer. The E.coli counts averaged 2 colonies/100 mL at the distance from shore. This provides further support to the idea of the contamination as being a near shore effect. Levels near the shore were averaging 100 colonies/100 mL.

Future plans for the Task Force include the publications coming from the University of Toledo's research efforts in this area. The Task Force has also asked the researchers to extend their sampling efforts to local drainage ditches to further determine sources. The researchers are also building a database which includes the identification of the bacteria as well as it's potential source.

Finally, in the summer of 1996, we did sampling for both fecal coliform and E.coli and found no consistent relationship. We had 11 single sampling days that would have been posted based on fecal and six days that would have been posted based on E.coli. None of the days for either standard caused the geometric mean average to exceed Ohio Health Department standards.

The Healthy Beaches Initiative in Indiana

Dawn Deady
Coastal Coordination program
Indiana Department of Natural Resources

The Healthy Beaches Initiative involves a collaborative effort among 17 agencies and various organizations interested in protecting public health, the health of the Lake Michigan shoreline, and the quality of life in northwest Indiana. In this effort, experts from various fields have joined together to resolve an issue of the Indiana shoreline that is also occurring nationwide in other coastal states. It is not frequent or long lasting, but one that periodically hampers the full enjoyment of one of the most sought after resources in the nation, and the State of Indiana. The issue is sporadic, unpredictable high levels of bacteria in the swimming waters of our beaches.

The process and products resulting from this collaborative effort, the Interagency Task Force on E. coli, will be outlined as well as the Task Force's future direction. Before explaining how the Task Force is working, it is important to explain why the Task Force is working.

Recreation

The southern Lake Michigan shoreline is a source of pride for Indiana. Since the turn of the century, when northwest Indiana entered the industrial revolution, the dunes have been a place to relax and enjoy. The south shore railroad allowed millions of people from Chicago to enjoy this Indiana treasure as well.

The Indiana Dunes State Park has enchanted visitors since 1925 and receives about 900,000 visitors annually. The Indiana Dunes National Lake Shore was established by Congress in 1966 to preserve a portion of the natural landscape for educational, inspirational, and recreational use. The National Lakeshore receives approximately 1.6 million visitors annually

In addition to the state and federal park, several municipal parks such as Marquette Park in Gary, and Washington Park in Michigan City, and county parks such as Whihala Beach in Whiting provide access to the spectacular beaches along Lake Michigan. Beaches in Beverly Shores, Long Beach, and Dune Acres are popular with community residents. Over 20 beaches along Indiana's coast are used for swimming and other recreational activities.

Southern Lake Michigan is the warmest and sandiest portion of the lake, naturally providing wide beaches which offer tremendous opportunities for recreational and leisure activities. Both Indiana residents and visitors deserve beaches which can be enjoyed, safely, and without risk, at all times.

Economy

A healthy coast is important to the regional and state economy. In 1996, visitors to Indiana coastal counties spent over $500 million. Lake County, the western most county on Indiana's coast, ranked third in tourism dollars received among the 92 counties in the state. Statistics show that the Indiana Dunes National Lakeshore generates approximately $26 million for the regional economy. The Dunes State Park collected $259,000 in admissions last year.

In addition to tourism, industries such as commercial fishing and sport fishing are dependent on a healthy lake. Trout and salmon fishing alone had an annual economic impact of $2.8 million.

Although an analysis has not be conducted of the regional economic losses due to beaches being closed, it is conceivable thousands of dollars are lost each day when residents and visitors who expect to enjoy a day at the beach are warned swimming here could be hazardous to their health. Park admissions, hotels, gas, and food are some of the related revenues that are lost. For those states which face the challenge of maintaining healthy beaches, they must also face the challenge of publicly working toward a solution without incurring a negative image of their beaches. The negative image of periodic beach closures in northwest Indiana potentially threatens the highest success of these and future industries.

Current Monitoring Efforts

Because of the extensive use of the Indiana shoreline, great effort is made to ensure the water is clean, and the beaches healthy. The Indiana Dunes National Lakeshore and several other county and municipal health departments routinely monitor many of Indiana's Lake Michigan beaches roughly between Memorial Day and Labor Day. When samples show that E. coli counts are too high, beaches are closed to swimming.

Indiana was recognized in a report released this summer by the Natural Resources Defense Council as one of only six states out of the 35 coastal states in the nation that consistently use the EPA recommended standard or something stricter to monitor beaches, and close beaches when standards are violated.

Although much research has been conducted by different agencies and great efforts have been made toward determining a cause and solution to this concern, the reality is the nature of the problem is difficult to understand, much less develop effective solutions, in a piece meal fashion. It has become obvious no single agency currently has the resources to address this concern. However, if several agencies were to pool their resources, a more comprehensive approach could be taken to resolve the issue.

What has become apparent is that an integrated scientific investigation of southern Lake Michigan would be more likely to produce information toward solving the E. coli induced beach closure problem. Public work groups conducted in 1995, as well as individuals, have echoed the perspective beach closings should be eliminated. Researchers familiar with the issue reiterated that this goal would require several agencies to cooperate on a common strategy.

Interagency Task Force on E. coli

A little over a year and a half ago, the Lake Michigan Coastal Coordination Program contacted several agencies, upon receipt of a federal grant solicitation notice, to learn if there was interest among the technical experts to conduct a joint study of the issue. The group that met to consider a joint study decided a productive effort would need to include a broader range of local, state and federal agencies. They also decided the amount of the grant was insufficient to conduct the study needed. The decision was made to develop a comprehensive strategy to help unify the efforts of the agencies.

The formation of the Interagency Task Force on E. coli has been, and continues to be, an evolutionary process. The task force is a group of technical experts joined by the common goal of seeking the causes and solutions to the periodic high levels of bacteria along Indiana's coast. The task force is not funded or given any special authority. Participation of agencies has been sanctioned through written endorsement by the participating agencies. Participation is diverse, including a wide range of experts on various issues. Functions of the group are carried out on a voluntary basis by the participants.

The task force has identified a common vision to direct their efforts. The vision emphasizes the task force's consensus to develop a comprehensive approach that is consistent in method, includes a system which provides data as current as possible, identifies the sources and fate of bacteria, and suggests actions for remediation.

The Inter-Agency Technical Task Force on E. coli consists of technical experts from local, state, and federal agencies who have banded together in an effort to solve northwest Indiana s bacteria induced beach closure problem. A comprehensive approach to the problem will include consistent methods of data collection for the development of a real-time forecasting system, identification of the sources and fate of the bacteria, and a systematic program of remediation. These measures are necessary to ensure for the State of Indiana the safety of public health and the economic vitality of the recreational use of the Lake Michigan shoreline.

Task Force Initiatives

The task force has met roughly 14 times since February 1996. Generally the task force has provided the opportunity for researchers to communicate. The task force has even brought together researchers from different agencies, who have worked on similar projects, but never previously met.

The task force meetings are a forum for new research proposals. Presentations have been made by several researchers currently conducting studies associated with bacteria and the Indiana coastline.

Several specific activities have been undertaken by the task force since its inception:

(1) The task force has agreed that it will by letter, informally endorse a research proposal when the proposal is presented to the task force and is consistent with the goals and objectives of the task force.

(2) The group has developed a Scoping Document which outlines the issue of bacteria beach closings for Indiana on Lake Michigan and establishes general parameters and standards for planning and research that the task force addresses.

(3) A committee has prepared Standard Operating Procedures for Recreational Water Collection and Analysis through a committee which includes agency representatives who conduct monitoring in the Indiana Lake Michigan coastal area. The procedures will provide an increased level of consistency of the
sampling and analysis across multiple agencies.

(4) The task force has posted a web site including general information about the task force and its meetings, as well as sampling data for some of the beaches.

This past winter, the task force developed a list of potential sources of bacterial contamination and possible actions to further define or otherwise address these sources. Recently, the task force established four committees to provide greater concentration of expertise in these areas.

Interagency Task Force on E. coli Committees

Point Sources, Sewerage Overflows and By-passes
Nonpoint Sources and Septic Systems
Marine and Other Sources
Monitoring Methods, Data Acquisition, and Information Dissemination

Future Directions

Future efforts that are envisioned by the task force include pursuing the development of an implementation strategy with interested citizens, organizations, and local officials to eliminate bacterial contamination of swimming waters. A priorities of the strategy is the development of a geographic information system to help target source areas potentially contributing to the contamination. A second priority is the establishment of a monitoring network to define the contribution of bacteria from possible sources.

Additional efforts will include:

Centralizing existing data and future data collected, ultimately to be accessible on the Internet.

Continuing to integrate agency efforts and reduce duplication of efforts to support cost efficiency.

Increasing the effectiveness and efficacy of the present monitoring programs.

Forming partnerships to maximize funding opportunities.

Conclusion

The problem of bacterial induced beach closures is infrequent, yet it has plagued the Indiana shoreline for 30 years. The Task Force has accomplished much in a short time through improved communications and cooperation and has provided much needed direction for a coordinated solution to maintain the health of Indiana's spectacular beaches.

Notes

Safe Swimming in Santa Monica Bay - Reducing the Risk

John H. Dorsey
City of Los Angeles, Stormwater Management Division

A. Santa Monica Bay

1. Semi-enclosed bay, 266 sq mi, 50 mi of coastline.
2. Home to vast array of marine life.
3. Vital to many commercial and recreational uses.
4. Bordered by rural and urban watersheds.

B. Safe swimming problem

1. Frequent beach closures, warnings.
2. Human enteric virus found in storm drain discharges.
3. Anecdotal information on illnesses among swimmers and surfers.

C. Santa Monica Bay Restoration Project

1. Formed in 1988 – National Estuary Program.
2. State and Federal (EPA) funded.
3. 1994 – Adopted its comprehensive Bay Restoration Plan listing 73 action items to manage and improve the Bay's resources and beneficial uses.
4. Nine actions directly deal with protecting the public from potential health risks due to swimming and surfing.

D. Epidemiological Study

1. Cooperative effort to examine whether there are adverse health effects associated with swimming in marine waters contaminated by urban runoff.
2. Study conducted during summer 1995 where 15,492 swimmers participated.
3. Increased risk of the following illnesses when swimming in runoff contaminated water: fever, nausea, and gastroenteritis, cold and flu-like symptoms such as nasal congestion, sore throat, fever and/or cough.
4. Ratio of total to fecal coliforms informative – ratios of <8 significantly correlated with increased risk of illness when total coliforms exceeded 5000 cfu/100 ml.

E. Shoreline monitoring program

1. Needed to coordinate various beach monitoring efforts for greater efficiency.
2. New program – cooperative sampling on daily or weekly basis among three agencies (City of Los Angeles, Los Angeles County Sanitation, Los Angeles County Department of Health Services)
3. Sixty shoreline and 17 inshore stations along 50 mi of coastline.
4. Water samples tested for concentrations of Total and Fecal Coliforms, Enterococcus using membrane filtration (City and County Sanitation) or Multiple Tube Fermentation (County Health).
5. All results electronically sent to County Health.

F. Data use

1. County Health personnel assess all data according to their Ocean Water Regulatory & Monitoring Protocol (1997):

- Guidelines in protocols based on water quality objectives from the California Ocean Plan, bay epidemiological study (ratios of Total: Fecal coliforms).
- Beaches closed if sewage or chemical spill evident.
- Warnings posted next to flowing storm drains, or if bacterial levels exceeded guidelines in protocol.
- County lifeguards close beaches or post warning signs.

2. Beach Report Cards distributed by the local environmental group, Heal the Bay:

   - Grades based on levels of bacteria, ratios of Total Fecal coliforms.
   - Distributed monthly to dive, surf shops.
   - Annual summary report distributed to wider audience, media.

G. Reducing risk

1. Focusing on storm water, urban runoff discharges.

2. Public education increasing:

   - School outreach programs.
   - Catch basin stenciling.
   - General public outreach (stormwater pollution prevention)

3. Diversion projects in progress to connect low flow drains to sanitary sewer system.

Combined Sewer Overflows (CSO): A Discussion of IDEM's CSO Program

Reginald Baker[1] and Leslie E. Dorworth[2]

Wastewater History

Testaments to the ancient plumber echo in the ruins of rudimentary drains, grandiose palaces and bath houses, and in vast aqueducts and lesser water systems of empires long buried. Close to 4,000 years ago, about 1700 BC, the Minoan Palace of Knossos on the isle of Crete featured four separate drainage systems that emptied into the great sewers constructed of stone.

But it's to the plumbing engineers of the Old Roman Empire that the Western world owes its allegiance. The glory of the Roman legions lay not only in the roads they built and their system of law and order but also in their engineering genius. The skill of their craftsmen enabled them to erect great baths and recreation centers, the water supplied by aqueducts from sources miles away.

Now, to the present, environmental engineering, or sanitary engineering as it was called before 1970, began in the United States in the 1830's with the design of water supply systems. Following the Civil War, industrialization and urbanization created life threatening water and air quality problems that primarily occupied the sanitary engineer's profession in the late 1800s and into the 20th century. By the early 1900s, indoor plumbing was becoming the norm in most households. Most household and commercial plumbing was tied directly into the storm water system and conveyed directly to the receiving surface waters.

By the onset of World War II, safe drinking water was expected throughout the United States. By the 1950s, wastewater treatment facilities were being constructed across the country. After the Clean Water Act was passed in 1972, federal construction grants for new construction or expansion of Publicly Owned Treatment Works (POTW) was passed.

Background: CSO

Combined sewer overflows (CSO) are structural devices on combined sewer systems that divert sanitary sewage (consisting of domestic, commercial, and industrial wastewater) mixed with stormwater (surface drainage from rainfall and snowmelt) in a single pipe to a treatment facility. There are approximately 1,100 municipalities in the United States connected to CSO. In terms of population, this represents approximately 43 million people. Most of the CSOs in the country are located in the Northeast and in the Great Lakes. In Indiana, there are 114 CSO municipalities (900 outfalls). Indiana alone represents approximately 10% of the nation's total CSOs and of this total, 70% of the municipalities have a population less than 10,000.

EPA estimates that combined sewer overflows (CSOs) annually discharge 1.2 trillion gallons of raw sewage and stormwater directly into streams, lakes, and estuaries across the country during major storm events. CSOs occur when older-design sewer systems, which collect both rainwater runoff and wastewater in the same sewer, are flooded during some storm events. In these

1 IDEM, Office of Water Management
2 Illinois-Indiana Sea Grant College Program

situations, the combined wastewater overflows untreated into the nearest body of water. Beach and shellfish bed closures, human health problems, fish kills, and high drinking water treatment costs have been linked to CSOs.

History of National CSO Policy

CSOs are a major problem throughout the country and especially a concern during heavy rain events when the discharges could affect human health. The impacts, usually adverse, are difficult to quantify due to site specific variability in volume being carried, the frequency of events and general characteristics of the CSO. Nationally, it was estimated that it would take $41.2 billion to correct the problems.

In 1989, the EPA came up with a National CSO Strategy. They reaffirmed that CSOs were point source dischargers and that the CSOs were subject to the requirements of both the National Pollution Discharge Elimination System (NPDES) Program and the Clean Water Act (CWA). The Clean Water Act requires that all discharges from any point source into the waters of the United States must obtain a NPDES permit.

The National CSO Strategy objectives are three: (1) to ensure that CSOs only result during wet weather; (2) bring all wet weather CSO discharges into compliance with the technology-based and water quality based requirements of the CWA.; and (3) minimize the impacts that CSOs have on water quality, aquatic biota and human health. To accomplish the three objectives nationally, the states are charged with developing state-wide permitting strategies which are designed to reduce, eliminate or control CSOs.

1994 EPA National CSO Policy

By 1991, the EPA had concluded that their 1989 state implementation strategy was not proceeding rapidly enough. In the Federal Register, the EPA announced a new draft CSO Policy. This occurred in January 1993. The Final CSO Control Policy was published April 19, 1994 in the Federal Register. In the 1994 policy, two additions were made which the states would need to implement: (1) the need for 3 additional minimum technology based controls and (2) the development of a Long Term Control Plan.

How Indiana's CSO Strategy Evolved

This will be a step-by-step compilation of how the new policy was implemented in Indiana presented in bullet statements.

- September 1994, the CSO staff from Indiana Department of Environmental Management (IDEM) attended a CSO forum in Chicago.
- October 1994, The National Policy and existing CSO Strategy were reviewed internally at IDEM
- January 1995, the CSO Municipal Workgroup was selected
- February 1995, the first meeting of the Workgroup
- September 1995, the Draft Strategy for Indiana was published in the Indiana Register for Public comment
- May 1996, Final CSO Strategy was published in Indiana Register

Indiana's CSO Strategy clearly outlines four specific objectives. The first objective states that there should be clear levels of control that are presumed to meet appropriate health and environmental objectives. The second objective of the strategy requires that there be sufficient flexibility provided to municipalities, particularly those communities that are financially disadvantaged. Also, consideration must be given to site-specific nature of CSOs and determine the most cost effective means for reducing pollutants as well as meeting CWA objectives and requirements. The third objective states that there should be a phased approach to the implementation of CSO controls. This is based primarily on the community's financial capability. Finally, the fourth objective is to review and revise, when appropriate, the water quality standard (WQS) and implementation procedures when developing control plans to reflect the site specific nature of wet weather impacts of CSOs.

In order to accomplish the objectives, a CSO strategy was needed. Phase I of the strategy first deals with the Combined Sewer Operational Plan (CSOP) which is typically submitted by the municipality 12 months after effective new, renewed or modified permit was in place. The next stage of the implementation plan requires that there be either a review or revisions made to the Sewer Use Ordinance prior to implementation. Under the Sewer Use Ordinance, the following must be included: (1) prohibit the introduction of inflow sources to any sanitary sewer; (2) prohibit the construction of any new combined sewers; and (3) require any new construction tributary to be designed so as to either minimize or delay the inflow contribution to the existing sewers. Also, any new construction is required to have the inflow/clear water connection be separate from any sanitary connection.

Next, the municipality must submit a Stream Reach Characterization and Evaluation (SRCER) protocol to IDEM. This is normally done 6 months after the effective date of the permit. The permittee must address the methods being used for characterizing instream impacts as well as the collection system characterization, precipitation dose and reponse relationship.

Approximately 18 months after the approval of the CSOP, the SRCER report is submitted. In this report, the instream impacts are summarized. Also discussed in the report is the effectiveness of the nine minimum controls. The report also provides a baseline for conditions necessary for the determination of long term controls required to attain WQS.

As indicated in the 1994 Policy, technology based controls need to be addressed by the states. The following is a list of minimum technology based controls required in the 1989 National CSO Policy. The controls are as follows: proper operation and regular maintenance of the CSO; the maximum use of the collection system for storage; review the pretreatment programs and do any necessary modifications; maximize the flow to the POTW for treatment; prohibit CSO discharges during dry weather ; control solid and floatable materials in CSO discharges (not a requirement in the 1991 Indiana CSO Strategy). Three additional technology based controls were added to meet the qualifications of the 1994 Policy, in Indiana. The additional three include pollution prevention programs based on the federal definition, the need for public notification to ensure that the public receives adequate notification of CSO occurrences as well as CSO impacts, and a monitoring protocol that effectively characterizes the CSO impacts and the efficacy of CSO controls. Indiana is also required to create a plan that documents the implementation of the nine minimum controls. The 1994 Federal Policy also requires that the states implement a Long Term Control Plan to deal with CSOs. Indiana has addressed this in a plan for water quality based CSO controls.

Phase II is a finalization and implementation of the Long Term Control Plan (LTCP). The plan is to be submitted 12 months after the SRCER. The municipality must address in the plan the development of water quality based CSO control measures: sewer separation; deep tunnel storage; retention basins; end-of-pipe controls (primary treatment); public participation; and financial capability analysis. Instituted in the LTCP are the nine elements of the plan. The nine elements are as follows: (1) characterization, monitoring, and modeling activities as the basis for the selection and design of effective CSO controls; (2) a public participation process that actively involves the affected public in the decision-making to select long term CSO controls; (3)

consideration of sensitive areas as the highest priority for controlling overflows; (4) evaluation of alternatives that will enable the permittee, in consultation with the NPDES authority, and the public, to select CSO controls that will meet CWA requirements; (5) cost/performance considerations to demonstrate the relationships among a comprehensive set of reasonable control alternatives; (6) operational plan revisions to include agreed upon long term CSO controls; (7) maximization of treatment at the existing POTW for wet weather flows; (8) an implementation schedule for CSO controls; and (9) a post-construction compliance monitoring program adequate to verify compliance with water quality based requirements and ascertain the effectiveness of CSO controls.

The long term control approach towards attainment of WQS in Indiana may take two directions. The first is a demonstration approach. In this case the planned control program is adequate to meet WQS as well as protect the designated uses i.e. fishing and swimming. There are times when WQS cannot be met because of the natural conditions or pollution sources other than the CSOs. When this occurs, total maximum daily loads (TMDL), including a waste load allocation, should be used to apportion the pollutant loads. The planned control program will provide the maximum pollution reduction benefits that are reasonably attainable as well as allowing for a cost effective expansion or retrofitting if additional controls are subsequently determined to be necessary to meet WQS or the designated uses.

The second approach is the presumption approach. Under the presumption approach, controls adopted in the LTCP should be required to meet one of the following:

1. No more than an average of four (4) system-wide overflow events per year, with a possible exemption by the NPDES authority of two (2) additional overflows. An overflow event is one of more overflows resulting from a precipitation event, that does not receive ***minimum treatment***. Minimum treatment refers to primary clarification, solids and floatables disposal, and disinfection of effluent to meet WQS.

2. The elimination or the capture for treatment of no less than 85% by volume of the combined sewage collected in the combined sewer system during precipitation events on a system wide annual average basis.

3. The elimination or removal of no less than the mass of pollutants identified as causing water quality impairment through the system characterization, monitoring, and modeling effort for the volumes that would be eliminated or captured fro treatment under the first paragraph.

What should a municipality do when applying for a CSO permit?

There are four common sense points that should be used to obtain the permit from IDEM. First, communicate openly and often with the permitting authority. The CSO Strategy is actually a dynamic and flexible document that recognizes that there is no single solution equally applicable to all 114 CSO municipalities. The staff at IDEM will work closely with the permittees in order to increase rate of the permitting process. Second, coordinate across the municipal departments. What this means is that a commitment must be obtained from the highest elected official down. Most NPDES permits are issued to a municipality. The mayor has the authority to make CSO Operational Plans work. Third, get the public involved (rate payers) now. Make sure you inform them of what it means to be served by a combined sewer system. In this case "An ounce of **(public education)** prevention, will yield a pound of (**rate increase**) cure. Fourth, concentrate on keeping the problems out of the collection system. Community based programs such as anti-litter pickup, recycled motor oil/antifreeze center identification and "toxaway" household hazardous waste collection days will keep contaminants out of the sewer.

APPENDIX A

A National Healthy Beaches Symposium
August 7, 1997
Attendee List

Beth Admire
Office of Legal Counsel
IN Dept. of Environmental Mgmt.
100 N. Senate Ave.
P.O. Box 6015
Indianapolis, IN 46202-6015
Phone: 317-232-8755
Fax: 317-233-5517

Tom Anderson
Save the Dunes Council
444 Barter Road
Michigan City, IN 46360
Phone: 219-879-3937
Fax: 219-872-4875

Anita Arends
National Park Service
Resource Management
1100 N. Mineral Springs Rd.
Porter, IN 46304
Phone: 219-926-7561 x335
E-Mail: anita_arends@nps.gov

Robert C. Bagley
City of Racine Health Dept.
730 Washington Ave.
Racine, WI 53405
Phone: 414-636-9493
Fax: 414-636-9576

Kathy Baird
Dept. of Environmental Mgmt.
Northwest IN Regional Office
504 N. Broadway - Suite 418
Gary, IN 46402
Phone: 219-881-6730
Fax: 219-881-6745

Reggie Baker
IN Dept. of Environmental Mgmt.
Office of Water Mgmt.
100 N. Senate Ave.
P.O. Box 6015
Indianapolis, IN 46206-6015
Phone: 317-233-0473

Meredith Becker
Lake Michigan Ecological Station
National Biological Service
1100 N. Mineral Springs Rd.
Porter, IN 46304
Phone: 219-926-8336
Fax: 219-926-5792

Mark A. Breederland
Michigan State University Extension
21885 Dunham Road - Suite 12
Clinton Township, MI 48036
Phone: 810-469-6085
Fax: 810-469-6948
E-Mail: breederm@msue.msu.edu

Beth Burnett
Illinois-Indiana Sea Grant
Purdue University
1159 Forestry Building
West Lafayette, IN 47907-1159
Phone: 765-496-3722
Fax: 765-496-2422

Susan Claussen
Michigan City Sanitary District WWTC
1100 E. Eighth St.
P.O. Box 888
Michigan City, IN 46360
Phone: 219-874-7799
Fax: 219-874-8053

Terry Coleman
State Parks & Reservoir
IN Dept. of Natural Resources
4570 N. 100th East
Fremont, IN 46737
Phone: 317-233-6132
Fax: 317-232-4132

Christopher Cutler
Division of Environmental Service
26 Main St., International Park
Toledo, OH 43605
Phone: 419-697-5109

Stephen Davis
Lake Michigan Specialist
IN Dept. of Natural Resources
100 W. Water St.
Michigan City, IN 46360
Phone: 219-874-8316
Fax: 219-879-2499

Dawn Deady
Coastal Coordination Program
Indiana Dept. of Natural Resources
402 W. Washington St.-RoomW264
Indianapolis, IN 46204-2748
Phone: 317-233-0132
Fax: 317-233-4579
E-Mail: dawn_deady_at_dnrwater
@ima.isd.state.in.us

Chris Dintaman
IN Geological Survey
611 N. Walnut Grove
Bloomington, IN 47405
Phone: 812-855-1356
Fax: 812-855-2862

Erich Ditschman
Hubbell, Roth & Clark, Inc.
P.O. Box 824
Bloomfield Hills, MI 48303-0824
Phone: 248-338-9241
Fax: 248-338-2592 or 248-333-4312
E-Mail: www.hrc-engr.com

John Dorsey
Stormwater Mgmt. Division
Dept. of Public Works
650 S. Spring St. - Suite 700
Los Angeles, CA 90014
Phone: 213-847-6347
Fax: 213-847-5443
E-Mail: jdorsey@eng.ci.la.ca.us

Leslie Dorworth
Illinois-Indiana Sea Grant
Department of Biology
Purdue University
Hammond, IN 46323-2094
Phone: 219-989-2726
Fax: 219-989-2771
E-Mail: dorworth@calumet.purdue.edu

Alan Dunn
Resid. Sewage Disposal San. Eng.
Indiana State Dept. of Health
2 N. Meridian, 5th Floor
Indianapolis, IN 46204
Phone: 317-233-7177
Fax: 317-233-7047
E-Mail: adunn@iquest.netZip

Chuck Dykstra
City of Racine - Environmental Health
730 Washington Ave.
Racine, WI 53403
Phone: 414-636-9203
Fax: 414-636-9165

Tom Eaton
Miller Citizen Corp.
8540 Oak Ave.
Gary, IN 46403
Phone/Fax: 219-938-8831

Veronica Erwin
IN Dept. of Environmental Mgmt.
100 N. Senate Ave. (Shadeland Office)
P.O. Box 6015
Indianapolis, IN 46208-6015
Phone: 317-308-3203
Fax: 317-308-3219

Greg Ester
City of St. Clair Shores
20000 Stephens Drive
S. Clair, MI 48080
Phone: 810-445-5350
Fax: 810-445-5324

Mary Fulhum
US EPA
77 W. Jackson Blvd.
Chicago, IL 60604
Phone: 312-886-4683

LT CMDR Rhae A. Giacoma, USCG
Commander (M)
Ninth Coast Guard District
1240 E. Nineth Street
Cleveland, OH 44199
Phone: 216-902-6050
Fax: 216-902-6059
E-Mail: rgiacoma@D9.uscg.mil

Steve Gradus
City of Milwaukee Health Dept.
841 N. Broadway - Room 308
Milwaukee, WI 53202-3653
Phone: 414-286-3526
Fax: 414-286-5098

Richard Grey
Lake County Parks & Recreation
2293 N. Main St.
Crown Point, IN 46307
Phone: 219-755-3696
Fax: 219-755-3693

Russ Grunden
IN Dept. of Environmental Mgmt.
1301, IGC-N
100 N. Senate Ave.
Indianapolis, IN 46204
Phone: 317-232-8499
Fax: 317-234-8560

Robert C. Haas
Michigan Dept. of Natural Resource
33135 S. River Road
Mt. Clemens, MI 48045
Phone: 810-465-4771
Fax: 810-465-5704

Denver Harper
Indiana Geological Survey
611 N. Walnut Grove
Bloomington, IN 47405
Phone: 812-855-1369
E-Mail: dharper@iu-gismo.igs.
indiana.edu

Robert Hendrickson
U.S. Coast Guard Auxiliary
7625 Indian Lake Road
Indianapolis, IN 46236
Phone: 317-823-1075
Fax: 317-823-2916

Rick Hoffman
Beach Health Protection Team Leader
U.S. EPA
401 M Street, SW
Washington, D.C. 20460
Phone: 202-260-0642
Fax: 202-260-9830

Mark Holdeman
IN Dept. of Environmental Mgmt.
100 N. Senate Ave. (Shadeland Office)
P.O. Box 6015
Indianapolis, IN 46208-6015
Phone: 317-308-3198
Fax: 317-308-3219

Wade Jacobson
Great Lakes National Program Office
U.S. Environmental Protection Agency
77 W. Jackson Blvd. - Mail Code G-17J
Chicago, IL 60604
Phone: 312-886-2844
Fax: 312-353-2018
E-Mail: jacobson.wade@
opamail.epa.gov

Nysa James
Engineer- Dept. of Natural Resources
402 W. Washington St.
Indianapolis, IN 46204
Phone: 317-232-4155
Fax: 317-233-1205

Burton Jones
Dept. of Biological Sciences
University of Southern California
Los Angeles, CA 90089-0371
Phone: 213-740-5765
Fax: 213-740-8123
E-Mail: bjones@usc.edu

Jennifer Kane
Natural Resources Commission
Division of Hearings
402 W. Washington St. - Rm. W272
Indianapolis, IN 46204-2748
Phone: 317-232-0156
Fax: 317-233-2977

Caren Kanic
Water Reclamation Facility
5500 Old Porter Rd.
Portage, IN 46368-1136
Phone: 219-762-2909
Fax: 219-762-1301

Lori Kaplain
Deputy Director
IN Dept. of Natural Resources
IN Government of Natural Resources
IN Government Center South
402 W. Washington St.
Indianapolis, IN 46204
Phone: 317-232-4020
Fax: 317-233-6811

Karen Lagerberg
Michigan Sea Grant
333 Clinton St.
Grand Haven, MI 49456
Phone: 616-846-8250
Fax: 616-846-0655

Laurel Last
Lake Michigan Ecological Station
National Biological Service
1100 N. Mineral Springs Road
Porter, IN 46304
Phone: 219-926-8336 x425
Fax: 219-926-5792

Sue Lehman
Michigan City Sanitary District
532 Franklin St.
P.O. Box 888
Michigan City, IN 46361
Phone: 219-874-7799
Fax: 219-874-8053

Angela Lewis
Purdue University North Central
E. Coli Team
1401 South US 421
Westville, IN 46391
Phone: 219-785-5201
Fax: 219-785-5483

Danielle A. Livinghouse
Environmental Planner
LaPorte County Health Dept.
4th Floor - County Complex
Courthouse Square
LaPorte, IN 46350
Phone: 219-326-6808
Fax: 219-326-6808 x203

Amira Looney
Office of Water Management
Indiana Dept. of Environmental Mgmt.
P.O. Box 6015
Indianapolis, IN 46206-6015
Phone: 317-308-3188
Fax: 317-308-3219
E-Mail: alone@opn.dem.state.in.us

Steve Lucas
Natural Resources Commission
Division of Hearings
402 W. Washington St., Room W272
Indianapolis, IN 46204
Phone: 317-233-3322
Fax: 317-233-2977

Peter McCarthy, Port Director
IN International Port at Burns Harbor
Indiana Port Commission
6600 US Highway 12
Portage, IN 46368
Phone: 219-787-8636
Fax: 219-787-8842

Matt Mehnert
City of Racine Health Dept.
730 Washington Ave.
Racine, IN 53405
Phone: 414-636-9493
Fax: 414-636-9576

Brian Miller
Illinois-Indiana Sea Grant Program
Purdue University
1159 Forestry Building
West Lafayette, IN 47907
Phone: 765-494-3586
Fax: 765-496-2422

Keri Morris
Purdue University North Central
1401 South US 421
Westville, IN 46391
Phone: 219-785-5201
Fax: 219-785-5483

Paul Muelle
Huron-Clinton Metro Parks
13000 High Ridge Drive
P.O. Box 2001
Brighton, MI 48116-8001
Phone: 810-227-2757
Fax: 810-227-8610

Steven Newhouse
IN Dept. of Environmental Mgmt.
100 N. Senate Ave.
P.O. Box 6015 (Shadeland Office)
Indianapolis, IN 46208-6015
Phone: 317-308-3203
Fax: 317-308-3219
E-Mail: san@opn.dem.state.in.us

William W. Pippenger
DNR Advisory Council
23 Fleet Parkway
Culver, IN 46511
Phone: 219-842-3405

Phillip Pope
Illinois-Indiana Sea Grant Program
Purdue University
1159 Forestry Building
West Lafayette, IN 47907-1159
Phone: 765-494-3593
Fax: 765-496-2422
E-Mail: phil_pope@acn.purdue.edu

CDR M. Eric Reeves, USCG
Chief, Marine Safety Analysis & Policy
Ninth Coast Guard District
1240 East 9th Street - Room 2069
Cleveland, OH 44199-2060
Phone: 216-522-3994
Fax: 216-522-3261
E-Mail: ereeves@d9.uscg.mil

Maj. Larry Rhinehart
IN State Boating Law Administrator
Indiana Government Center South
402 West Washington, Room W255 D
Indianapolis, IN 45204
Phone: 317-232-0614
Fax: 317-232-8035

Eleanor K. Roemer
Friends of the Parks
407 S. Dearborn - Suite 1590
Chicago, IL 60605
Phone: 312-922-3307
Fax: 312-922-7481

Steve Schaub
U.S. EPA - Office of H20
401 M Street, SW
Washington, D.C. 20460
Phone: 202-260-7591

Rob Scheffer
Hammond Health Department
Hammond, IN 46324
Phone: 219-853-6358
Fax: 219-852-6403

Cheryl Scully
Water Reclamation Facility
5500 Old Porter Rd.
Portage, IN 46368-1136
Phone: 219-762-1301
Fax: 219-762-1301

John Solenberg
U.S. Coast Guard Auxiliary
7605 Indian Lake Road
Indianapolis, IN 46236
Phone: 317-823-6627
Fax: 317-823-9398

Wendy Smith
Indiana Dunes State Park
1600 North 25 East
Chesterton, IN 46304
Phone: 219-926-1390

Greg Steele
Director Epidemiology Resource Center
Indiana State Dept. of Health
2 North Meridian, Sec 3-D
Indianapolis, IN 46204
Phone: 317-233-7416
Fax: 317-233-7770

Teresa Stoner
Lake Dalecarlia Regional Waste Dept.
15901 Briargate Place
Lowell, IN 46356
Phone/Fax: 219-696-4035

Andrew S. Teets
IN Dept. of Environmental Mgmt.
Nonpoint Source Section
100 N. Senate Ave.
P.O. Box 6015 (Shadeland Office)
Indianapolis, IN 46208-6015
Phone: 317-308-3212
Fax: 317-308-3219

Steve Thorp
Great Lakes Commission
400 Fourth St.
Ann Arbor, MI 48103
Phone: 313-665-9135
Fax: 313-665-4370

W.T. Evert Ting
Dept. of Biological Sciences
Purdue University Calumet
Hammond, IN 46323-2094
Phone: 219-989-2490
Fax: 219-989-2130

Leslie P. Toth
Ottawa County Environ. Services Div.
12251 James St. - Suite 200
Holland, MI 49424
Phone: 616-393-5645
Fax: 616-393-5643

Lt. Ed Troche
IN Dept. of Natural Resources
Law Enforcement Division
100 W. Water St.
Michigan City, IN 46360
Phone: 219-879-5710
Fax: 219-874-2196

Janet H. Vail
Grand Valley State University
1 Campus Drive
Allendale, MI 49401
Phone: 616-895-3048
Fax: 616-895-3864

Curtis Vosti
Hammond Parks
c/o Vostron
224 Humpfer St.
Hammond, IN 46324
Phone: 219-933-6986
Fax: 219-933-7163

Gary R. White
Environmental Health Specialist
Macomb County Health Dept.
42535 Elizabeth Road
Mt. Clemons, MI 48043
Phone: 810-469-5236

Richard Whitman
Lake Michigan Ecological Station
National Biological Service
1100 N. Mineral Springs Road
Porter, IN 46304
Phone: 219-926-8336 x424
Fax: 219-926-5792
E-Mail: richard.whitman@nps.gov

Doug Wickersham
State Parks & Reservoir
IN Dept. of Natural Resources
402 W. Washington St.-Room W298
Indianapolis, IN 46204
Phone: 317-232-4124
Fax: 317-232-4132

Sandy Wilonore
Save the Dunes Conservation Fund.
444 Barter Road
Michigan City, IN 46360
Phone: 219-879-3937
Fax: 219-872-4875

Steven M. Yagelski
Chesterton WWTP
300 League Lane
Porter, IN 46304
Phone: 219-926-1032
Fax: 219-929-5350

Alex Zlotin
IN Geological Survey
611 N. Walnut Grove
Bloomington, IN 47405
Phone: 812-855-1356
Fax: 812-855-2862