Beach Pathogen Forecasting Tools:

Pilot Testing, Outreach, and

Technical Assistance

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Summary: This report describes grant-funded work undertaken by the Wisconsin DNR and its partners between July 2008 and September 2009 to evaluate and pilot test pathogen indicator forecasting tools and models, provide end-user feedback to tool developers, conduct outreach to local beach managers on available tools, and provide training and technical assistance on U.S. EPA's Virtual Beach-Model Builder tool. We document lessons learned and make recommendations to improve future versions of Virtual Beach-Model Builder and foster its dissemination to a broader audience of beach managers. Finally, this document fulfills our reporting requirements for a U.S. EPA Federal Assistance Agreement.

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Cover Photograph: Virtual Beach workshop at the 2009 State of Lake Michigan/Great Lakes Beach Association conference in Milwaukee, WI. Photograph by R. Chris Welch.

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1. Introduction

The U.S. Environmental Protection Agency (U.S. EPA) awarded a research grant to the Wisconsin DNR to evaluate and pilot test pathogen indicator forecasting tools and models, provide end-user feedback to tool developers, conduct outreach to local beach managers on available tools, and provide training and technical assistance on U.S. EPA's Virtual Beach-Model Builder (VBMB) tool. Our work is part of a broader effort to use Internet and geographic information systems (GIS) computer technologies to help identify and solve environmental problems (Watermolen 2009). This report describes the work we undertook with our partners to implement this grant-funded project, documents the deliverables produced, presents lessons learned, and makes recommendations to improve future versions of VBMB and foster its dissemination to a broader audience of beach managers. This document also fulfills final reporting requirements for the U.S. EPA Federal Assistance Agreement.

1.1. Environmental Issue and Need for Project

Over the past 50 years, epidemiological studies and "outbreak" investigations have linked swimming in polluted waters with adverse human health effects. Humans can be exposed to pathogens in recreational waters through ingestion, inhalation, and body contact. Swimming-related diseases can range from less severe gastrointestinal diseases (e.g., sore throats and diarrhea) and non-gastrointestinal diseases (e.g., respiratory, ear, eye, and skin infections) to more serious illnesses, such as meningitis or hepatitis (Rose, et al. 1999; U.S. EPA 2006a). People who swim and recreate in water contaminated with fecal pollution are especially at an increased risk of becoming ill because of pathogens from the fecal matter (Henrickson, et al. 2001; Craun, et al. 2005; Wade, et al. 2006). Bacterial contamination originates from many sources, including coastal and shoreline development, wastewater collection and treatment facilities, poorly maintained or failing septic tanks, urban and agricultural runoff, disposal of human waste from boats, bathers themselves, and natural sources like wildlife and pet wastes and decaying *Cladophora* and dreissenid mussels that wash ashore. Ongoing scientific studies and local monitoring initiatives continue to document the presence of, or the potential for, disease carrying bacteria, viruses, and other pathogens present in local beach water.

State and local public health agencies use beach advisories and closings to communicate to the public that the level of pathogens in the water may be unsafe for swimming or other body contact recreation. These advisories and closings are based on water quality information and typically occur when monitoring results show that fecal bacteria levels exceed an applicable water quality criterion. The Beaches Environmental Assessment and Coastal Health (BEACH) Act of 2000 requires coastal states, including Great Lakes states, to submit to U.S. EPA monitoring, notification, and other information concerning their beaches. The results of the 2005 data collection cycle indicate that 28 percent of beaches had at least one advisory or area closed during the reporting period; states reported a total of 5,540 beach notification actions in 2005 (U.S. EPA 2006b). Comparable levels of beach closings—21 to 27 percent—have occurred every year since 1997 (U.S. EPA 2005), demonstrating an ongoing public health concern.

EPA's *National Beach Guidance and Required Performance Criteria* document (U.S. EPA 2002) requires state, tribal, and local government beach programs to notify the public when coastal recreation waters are not meeting or are not expected to meet applicable water quality standards. Extensive efforts undertaken by these partners have helped reduce human health risks through better monitoring and additional public notification steps. The current guidelines, however, are based on microbiological methods that involve culturing fecal indicator bacteria (*Escherichia coli*) and counting the colony-forming units. The 18- to 24-hour time lag associated with these techniques limits the effectiveness of public notification decisions (i.e. these decisions can result in unnecessary beach closings and swim advisories [Kim and Grant 2004]), as well as the exposure of swimmers to poor-quality water/health risks prior to notification. The inability to make sound beach management decisions raises significant concerns because beach advisories and closings impact a large number of people and can have economic implications (Rabinovici, et al. 2004). For example, U.S. EPA estimates that a third of all Americans visit coastal areas each year, making a total of 910 million trips and spending about $44 billion (U.S. EPA 2000).

While some progress has been made in evaluating the use of more rapid water-quality indicators (e.g., Wade, et al. 2006), additional studies will be required to evaluate the generalizability of the findings, help determine whether the preliminary findings are robust enough from a regulatory perspective, and evaluate the conditions under which such indicators can be applied successfully. Such studies will take several years to complete. In the meantime, other recent studies have shown that predictive models based on real-time observations of measureable beach conditions can provide assessments of water quality that are both more timely and more accurate than standard lab-based monitoring (U.S. EPA 1999; Francy, et al. 2003; Olyphant and Whitman 2004; Nevers and Whitman 2005; Francy and Darner 2007; Frick, et al. 2008; Olyphant and Pfister 2009). Multivariate statistical models can predict concentrations of indicator bacteria based on real-time meteorological (e.g., wind direction and antecedent rainfall), onshore (e.g., algal mats and waterfowl concentrations), and near-shore (e.g., wave height and turbidity) conditions, and can additionally help to provide analyses of sources of fecal indicator bacteria and predictions of how long microbial standards may be exceeded (U.S. EPA 1999).

For most local or regional agencies responsible for beach water quality – typically city or county public health offices – the staff time, software licensing, and/or technical expertise needed to build and run predictive models–including data acquisition and processing, model estimation, and statistical analyses–have proven prohibitive. As such, this type of modeling has been used operationally, that is to inform swim advisory decisions, for only a handful of beaches to date (Francy 2009).

1.2. Project Goals and Objectives

Wisconsin DNR conducted pilot testing, outreach, and technical assistance on a Bacterial Exposure Forecasting Tool as part of a larger U.S. EPA-funded Advanced Monitoring Initiative (AMI) project titled "Developing Water and Land Tools to Forecast Bacterial Exposure in Beach Settings," hereafter referred to as the AMI Beach Forecasting Project. The larger effort was initiated in 2007 by researchers and regulatory staff from the U.S. EPA, U.S. Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), state and local governments, and universities with the goal of developing tools that can provide beach managers and the public with early warnings about pathogen indicator levels. Several approaches linking environmental observations to microbial exposure were investigated, including multivariate statistical models, hydrodynamic/process-based models, and non-point source pollution models. Existing models at 12 beaches[1] were enhanced by incorporating additional data. Software developers at U.S. EPA's Office of Research and Development (ORD) National Exposure Research Laboratory (NERL) worked to integrate modeling methods into a Bacterial Exposure Forecasting Tool known as Virtual Beach.

Wisconsin DNR's work on this project built on recent technology transfer work conducted with U.S. EPA and the Midwest Spatial Decision-Support Systems Partnership[2] as part of our "Internet Tools for Planning, Conservation, and Environmental Protection" effort (see Watermolen 2008, 2009). Among other things, this approach included identifying target user groups and creating tailored hands-on and Web-based training modules, easy-to-follow user instructions, and case studies, as well as providing feedback mechanisms for user suggestions to be incorporated into tools and training modules as they were developed and refined. As outlined in our initial grant application, specific objectives for the Wisconsin DNR's outreach, training, and technical assistance work included:

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[1] These include three *Swimcast* beaches in Lake County Illinois (Forest Park, Rosewood, Waukegan); five *Project S.A.F.E.* beaches in northwestern Indiana (Ogden Dunes, West Beach, Well Street Beach, Lake Street Beach, and Marquette Beach); two *Ohio Nowcast* beaches (Huntington, Edgewater); South Shore Beach in Milwaukee; and Grand Haven, Michigan.

[2] The Midwest Spatial Decision-Support Systems Partnership, founded in 2002, is a U.S. EPA-led federal-state-local government partnership to develop, promote, and disseminate web-based, spatial decision-support tools for watershed management and land-use decision making (see http://www.epa.gov/waterspace/).

- Ensure effective communication regarding the project and resulting products with target audiences, primarily federal, state, county, and local beach managers.

- Instruct federal, state, county, and local beach managers in accessing and using the Bacterial Exposure Forecasting Tool.

- Provide instructional materials and products focused on the Bacterial Exposure Forecasting Tool that can be used throughout the Great Lakes basin.

Wisconsin DNR's initial testing and evaluation of the beta version of the Bacterial Exposure Forecasting Tool during the summer and fall of 2008 indicated that significant modifications were needed in order to conduct outreach and technical assistance outside of the small number of test beaches. It was necessary, therefore, to revise the original work plan to include pilot-testing of the tool. From this came an additional objective:

- Provide practical feedback and recommendations to the developers of the Bacterial Exposure Forecasting Tool and other project partners to lay the groundwork for a successful and widespread transfer of the tool and methods.

We accomplished all of these objectives as outlined in the next chapter ("Project Highlights and Accomplishments") of this report. In addition, we produced several deliverables outside the original scope of work, but necessary to achieve successful technology transfer.

1.3. Relationship of Project to Great Lakes Plans

By helping to evaluate and enhance bacterial forecasting tools, while laying the groundwork for wider technology transfer through outreach and technical assistance, Wisconsin DNR's efforts have addressed high-priority needs identified in a number of overarching plans and initiatives. EPA's *Critical Path Science Plan* calls for field-testing and the development of user guidelines for Virtual Beach in particular. More generally, the *Great Lakes Regional Collaboration Strategy* calls for state, federal, local, and tribal partners to create and improve beach forecasting models, while various *Lakewide Management Plans* call for the dissemination of information and training on predictive models. The multi-agency *Ocean Research Priorities Plan for the Great Lakes* calls for enhancing predictive models, model scope, and application.

Another goal of the *Great Lakes Regional Collaboration Strategy* is to identify the sources of remaining bacterial contamination through standardized sanitary surveys. Predictive models can aid in source identification and remediation processes by estimating the independent relationships between the pathogen indicator response and different contamination sources and/or contributing factors (i.e. model coefficients).

Wisconsin DNR's outreach, training, and technical assistance work additionally helps to meet the goal of the *Wisconsin Great Lakes Strategy* (and similar plans across the Great Lakes) with respect to reducing the number of swim advisories and beach closures: *State of the Lakes Ecosystem* Indicator # 4200. The widespread adoption of real-time and advance forecasting tools like Virtual Beach will likely lead to a reduction in monitoring errors in general, and *Type I* monitoring errors (i.e. false exceedances of water quality standards) in particular. Numerous beach-specific studies indicate that predictive models result in significant reductions in such errors, relative to standard, culture-based monitoring (Olyphant and Whitman 2004; Nevers and Whitman 2005; Francy and Darner 2007; Frick, et al. 2008; Nevers and Whitman 2008; Francy 2009; Mednick, et al. 2009; Olyphant and Pfister 2009).

2. Project Highlights and Accomplishments

During the course of the project, Wisconsin DNR met each of the objectives listed in Section 1.2 ("Project Goals and Objectives") of this report. This included producing several deliverables that were not part of the initial scope of the project, but which were needed in order to accomplish our stated objectives or to lay the groundwork for a more widespread transfer of beach forecasting technology and methods in the future. Findings and recommendations are discussed, respectively, in Chapter 4 ("Lessons Learned") and Chapter 5 ("Recommendations") of this report.

2.1. Initial Communication, Pilot Testing, and Tool Enhancement

Throughout the project period, Wisconsin DNR staff communicated regularly with AMI Beach Forecasting Project partners (EPA, USGS, NOAA, and the Cooperative Institute for Limnology and Ecosystem Research [CILER] at the University of Michigan) through monthly conference calls organized by program staff at U.S. EPA Region 5, as well as semi-annual progress reports posted to the U.S. EPA Science Connector and numerous one-on-one communications. In addition, project staff engaged new local partners to help ensure that the features and functionality of the Bacterial Exposure Forecasting Tool – and its associated instructional materials – were aligned with the needs of the principal user-group (i.e. beach managers and monitoring personnel).

At the outset of the project period, Wisconsin DNR evaluated the two public-domain pathogen indicator forecasting tools developed by U.S. EPA ORD/NERL: the original Virtual Beach - Model Builder (VBMB) and the prototype Virtual Beach "Advisor" (VB-Advisor). At the time, VB-Advisor was considered to be the principal Bacterial Exposure Forecasting Tool, whereas VBMB was effectively a legacy program. VBMB is a spreadsheet-based program that guides users through the process of building and evaluating multiple linear regression models for any beach, including the ability to add, remove, and transform variables and observations on-the-fly, view scatter plots, identify and remove outliers, test for statistical significance, identify best linear unbiased models, and evaluate models according to *Type I* (false exceedance) and *Type II* (false non-exceedance) errors. The prototype VB-Advisor contains pre-estimated models and an automated, Web-based data retrieval system; however, it was only applicable to those beaches for which it is pre-programmed: South Shore Beach in Milwaukee and Huntington Beach in California.

As part of the initial evaluation, project staff communicated extensively with beach water quality monitoring experts at the Racine, Wisconsin Health Department (Dr. Julie Kinzelman), the Lake County, Illinois Public Health Department (Mark Pfister), and the Environmental and Public Health Microbiology Laboratory at the University of Wisconsin-Oshkosh (Dr. Greg Kleinheinz). The purpose of these communications was to help define likely users and to determine what these users' operational needs were likely to be. Based on our evaluation of the VBMB and VB-Advisor tools, on discussions with the engaged local partners, and in consultation with U.S. EPA staff at Region 5 and ORD/NERL, we determined that our outreach and technical assistance should focus on VBMB, rather than VB-Advisor (or any other beach-specific model). Although VB-Advisor preformed favorably at South Shore Beach, it was not easily transferable to other Great Lakes beaches – requiring considerable front-end model-building and computer programming, which would need to be conducted by ORD/NERL personnel on a beach-by-beach basis. This tool also required automated data on beach conditions (i.e. automated data buoys or sondes), which only exist at a few locations.

From our discussions with local partners, we determined that a more flexible tool that could be used with automated and/or non-automated (i.e. routine sanitary survey) data could be applied at many more beaches. The VBMB tool conceptually met these criteria; however, it was not clear that it was functional in an operational (as opposed to a research and development) mode.

Project staff, therefore, set about pilot-testing VBMB for several Great Lakes beaches, including:

- Ogden Dunes in Porter, Indiana (Lake Michigan);
- Huntington Beach in Bay Village, Ohio (Lake Erie);
- North Beach in Racine, Wisconsin (Lake Michigan);
- Maslowski Beach in Ashland, Wisconsin (Lake Superior);
- Red Arrow Park Beach in Manitowoc, Wisconsin (Lake Michigan); and
- Upper Lake Park Beach in Port Washington, Wisconsin (Lake Michigan).

VBMB was used to build models for Red Arrow Park and Upper Lake Park and to effectively re-create existing operational or experimental models for the other beaches. The purpose of this pilot-testing was three-fold: (1) to develop proficiency using the VBMB tool, (2) to identify a suitable case-study for training materials, and (3) to evaluate VBMB's utility (i.e. usefulness) and usability (factors previously shown to affect technology adoption [Davis 1989; Davis, et al. 1989; Bagozzi, et al. 1992]), including whether or not it enabled best modeling practices employed by USGS at Ogden Dunes and Huntington Beach.

Based on this evaluation, project staff made several recommendations to the VBMB software developers, who subsequently made the highest-priority changes in advance of the pilot training workshop discussed in Section 2.2. These modifications included:

- the removal of several extraneous tabs,
- additional variable-transformation options,
- visual enhancements to plots of sensitivity/specificity (i.e. *Type I/II Error*), and
- fixes to the single-day "Make Prediction" function.

It is important to note that at the outset of the project period, the VBMB software was effectively a legacy/prototype program, written in *Delphi*, which made re-programming difficult. Some of our recommended changes, such as providing the ability to predict daily probabilities of water quality exceedances (in place of point estimates), were therefore saved for a comprehensive overhaul of the software – which is underway and will culminate in the release of Virtual Beach version 2.0 in spring 2010. Nevertheless, the software developers at U.S. EPA ORD/NERL were highly accessible and responsive to our requests for enhancements to VBMB–throughout the project period–and deserve special credit for enabling effective training, technical assistance, and field-testing.

2.2. Training Workshops and Instructional Materials

Project staff conducted two hands-on training workshops. The initial pilot workshop was hosted by the Concordia University Center for Environmental Stewardship in Mequon, Wisconsin on April 31 (approximately 4 weeks prior to the opening of the 2009 Great Lakes beach season) and included 16 participants. The second workshop was conducted at the 2009 State of Lake Michigan/Great Lakes Beach Association (SOLM/GLBA) Conference in Milwaukee on October 1 and included 15 participants. The SOLM/GLBA workshop was at capacity with 6 potential participants on a workshop waiting list. VBMB software developers from U.S. EPA ORD/NERL attended both of the workshops.

For the pilot workshop, project staff consulted with Beach Program staff at Wisconsin DNR and U.S. EPA Region 5 and local partners to identify invitees, including all of the Great Lakes beach managers and monitoring personnel in Wisconsin (approximately 20) and other interested parties. For the second workshop, invites were sent to the entire *Beachnet* listserve and were posted on the SOLM/GLBA Conference website and agenda. While open to a much wider audience, the second workshop was similarly weighted toward local beach managers and monitoring personnel. Of the combined 31 participants in the two workshops, 22 are directly involved in managing or monitoring water quality at Great Lakes beaches. These included 15 local public health department personnel (seven from Wisconsin, one each from Pennsylvania, Illinois, and Michigan, and four from Ontario); two sanitary district personnel (one each from northeastern Ohio and northwestern Indiana); four university faculty, staff, or research assistants (three from Wisconsin, one from Michigan); and one scientist from the USGS Ohio Water Science Center. Additional participants included the state beach coordinators for Ohio and Indiana, as well as U.S. EPA staff from Region 5 (Chicago) and Washington, DC, and additional academic personnel and consultants from Michigan, Indiana, and Illinois. In all, participants came from six of the eight Great Lakes states plus Ontario.

Web-based registration enabled us to collect important information on participants' level of technical expertise and other key factors that indicated their ability to conduct predictive modeling for their beaches, including the frequency of routine monitoring and sanitary survey activities which provide the necessary data for model-building and operation. Instructional materials were tailored accordingly. For example, the case study we used (Red Arrow Park Beach) was selected as this beach had not been modeled previously and had a moderate amount of available data from routine monitoring and sanitary survey activities, as well as an automated airport weather station and USGS stream gauge near the beach.

The workshops included morning and afternoon sessions, the core of which entailed step-by-step learning modules on, respectively, *Model-Building* (i.e. data input, evaluation, and variable transformation) and *Model Evaluation* (i.e. fitting, evaluating, and refining models). Both sessions used a real-world case study and data from Red Arrow Park Beach in Manitowoc Wisconsin. The second session in the second workshop also covered "nowcasting" (i.e. predicting current water quality based on the selected best model), reflecting enhancements to VBMB made in response to participant feedback during the pilot workshop.

Due to the scheduling constraints of the SOLM/GLBA Conference, the second workshop was approximately 30 minutes shorter than the pilot workshop. Both workshops began with a 45-minute background presentation on multiple linear regression modeling for recreational water quality and an introduction to VBMB, and concluded with a facilitated discussion of participants' perceptions about the usefulness and usability of VBMB (factors that affect technology adoption [Davis 1989; Davis, et al. 1989; Bagozzi, et al. 1992]), suggestions for improving the software, and future directions. Users were additionally asked to complete a detailed evaluation of the VBMB tool and the workshop.

Detailed evaluation forms were filled-out by 21 of the combined 31 participants. Of these, 60% reported that they believed they could use VBMB without assistance following the training (30% unsure). Responses were significantly different among participants in the pilot workshop (88% with 13% unsure) relative to participants in the second workshop (42% with 17% unsure). This appears to have been due in part to a combination of the shorter time available at the SOLM/GLBA workshop, the additional material covered, and a technical issue with the resolution of laptops used at the second workshop (which required participants to scroll up and down in order to see different parts of the VBMB window). Both workshops were rated highly with respect to the following statements (1 = "Disagree" and 5 = "Agree"):

- "The information presented in the workshop was helpful to you" (average response = 4.3);
- "The workshop prepared you to use [VBMB] in your community" (average response = 4.1); and
- "The handouts provided helpful reference material" (average response = 4.6).

Users additionally provided feedback on the usability and usefulness of specific features of VBMB described under Section 2.3.

In response to feedback provided at the pilot workshop, project staff produced a companion user guide titled *Accessing Online Data for Building and Evaluating Real-Time Models to Predict Beach Water Quality* (Mednick 2009b). This report provides an exhaustive list of online sources of data (archived as well as real-time) on meteorological, nearshore, and onshore conditions across the Great Lakes basin, plus detailed instructions on how to access and format these data for use in VBMB or other statistical packages.

All of the training materials provided to workshop participants, including the two step-by-step learning modules and the case study datasets used, a reference list of useful articles and documents on predictive modeling, and links to the USGS techniques and methods report titled *Procedures for Developing Models To Predict Exceedances of Recreational Water-Quality Standards at Coastal Beaches* (Francy and Darner 2006), and other resources are available on Wisconsin DNR's *Beach Water Quality Modeling* website (http://dnr.wi.gov/org/es/science/beachmodeling/). A recording of the second workshop is also posted for viewing from this site as a streaming video.

2.3. Field-Testing, Technical Assistance, and Additional Feedback

As part of the evaluation forms filled-out by workshop participants, respondents rated VBMB on ten features in terms of their operational utility (usefulness) and user-friendliness. These included:

1. Data Formatting/Input,
2. Scatter Plots,
3. Testing for Multicollinearity (VIF),
4. Processing Wind Data into Longshore and Onshore Components,
5. Identifying Outliers,
6. Fitting the Models and Interpreting Results,
7. Evaluating Models Based on "False Negative/False Positive" Plots,
8. Identifying "Best, Unbiased" Models Based on Mallow's Cp,
9. Making Single-day Predictions with 95% Confidence Intervals, and
10. Exporting Model Results to MS Excel for Further Evaluation.

Participants also provided detailed suggestions for enhancements to the tool, both on the evaluation form and during facilitated discussions at the end of each workshop.

Following the pilot workshop, feedback and suggestions were summarized and provided to programmers at U.S. EPA ORD/NERL, who made a second wave of priority enhancements to the software in advance of the 2009 beach season. Two primary enhancements were made:

> First, to make the tool more useful, an "operational nowcasting" function–a separate "Prediction" tab–was created to enable users to more easily make predictions of water quality based on user-entered, real-time or forecast values of the explanatory variables.
>
> Second, to make the tool more user-friendly, the naming- and numbering conventions of the different explanatory variables were standardized across the software's model-building and evaluation tabs, tables, summaries, and plots, and unadjusted R-squared was added as an alternative (more easily-interpreted) model evaluation metric.

As with the initial wave of VBMB modifications following pilot testing, several suggested changes were saved for the comprehensive overall of the software (i.e. Virtual Beach 2.0).

One of our goals for the pilot workshop was to gain the commitment of one or more participants to field-test VBMB during the 2009 beach season. To ensure this outcome and to increase the likelihood of a successful implementation, project staff offered to provide participants with direct technical assistance. Dan Ziegler of the Ozaukee County Public Health Department agreed to test VBMB at Upper Lake Park Beach in Port Washington, for possible use as an operational "nowcast," while Julie Kinzelman committed to continue previously-initiated experimental (i.e. non-operational) modeling at North Beach in Racine (see **Figure 1**).

An operational nowcast model had been developed and deployed at Upper Lake Park in 2008 to guide swim advisory decisions. This "Rainflow" model combined weighted, real-time values on antecedent rainfall, turbidity, and measured flow of Valley Creek, a small stream that outfalls near the beach (see **Figure 2**) to predict whether or not there would be an exceedance. This system was based on iteratively-derived variable weights and multipliers – as opposed to OLS regression – and there was an interest on the part of Mr. Ziegler to see how well VBMB-generated models would perform in comparison, both in terms of accuracy and practical/operational considerations. At the beginning of the beach season project staff met with Ozaukee County staff for a field inspection of the beach and consultation regarding the process of model-building, implementation, and ongoing technical assistance. Local staff provided expertise and guidance based on their long-term experience monitoring the beach, including intensive sanitary surveys conducted over the previous two summers.

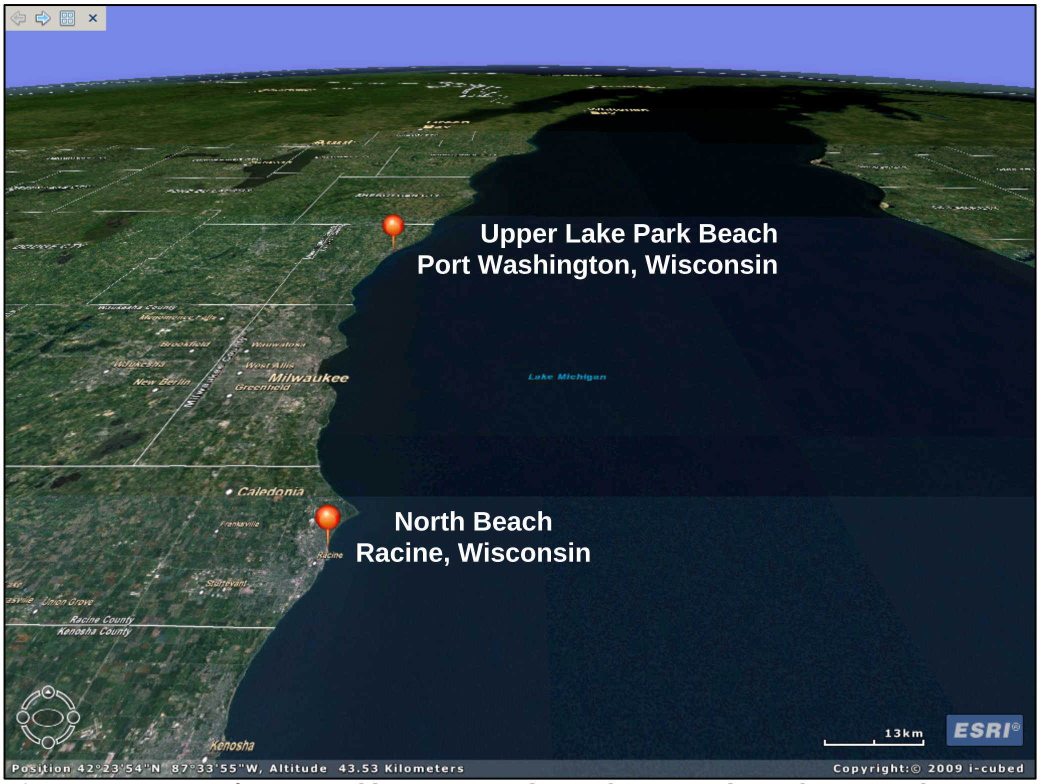

Figure 1. *Location of VBMB Field-testing Sites during the 2009 Lake Michigan Beach Season.*

Figure 2. *Upper Lake Park Beach (U.L.P. Beach), Port Washington, Ozaukee County, Wisconsin.*

Project staff and local partners collaborated on the development, evaluation, and refinement of a nowcast model for Upper Lake Park beach based on data collected in 2007 and 2008 (n = 195). The model-building process took approximately 40 hours of combined staff time (Wisconsin DNR and local partners) including the initial field visit and evaluation. Once built, the model was used to "nowcast" daily water quality conditions, first experimentally and then operationally. During the experimental phase, Wisconsin DNR ran the daily nowcast remotely using data uploaded by county staff as part of their routine monitoring and sanitary survey activities to the Wisconsin *Beach Health* website (www.wibeaches.us) operated by the USGS Wisconsin Water Science Center. Uploaded data included wave height, turbidity, 24 and 48 hour rainfall (from a National Weather Service Cooperative observer Program [COOP] weather station near the mouth of Sauk Creek), Valley Creek flow, water and air temperature, and the previous day's lab results on *E. coli* (MPN/100 mL). Wisconsin DNR project staffers were given password access to the daily data by the USGS database manager, so that they could enter the data into the newly-created "Prediction" tab in VBMB to make real-time predictions, which were then emailed to county staff for comparison to lab results returned the next day.

Even with the addition of the "Prediction" tab and other enhancements made to VBMB, several operational challenges were faced. Chief among these was the inability of the software to save model coefficients to separate files (data had to be re-imported every day). The second was the inability to enter daily data as "native" (i.e. un-transformed) variables and have them automatically transformed and/or combined to match the variables and interaction terms in the model. We provided additional feedback to software developers on these issues for the development of Virtual Beach 2.0. For the purpose of the 2009 field-testing, project staff developed a series of Excel spreadsheets to transform and combine the data as needed, after which the local monitoring personnel could enter them into the VBMB "Prediction" tab. After one month of experimental nowcasting, in which the VBMB model had zero *Type I* errors versus one *Type I* error by the original "Rainflow" model, Ozaukee County staff took over the operation of the VBMB-based nowcast and used it in place of the Rainflow model for the last four weeks of the 2009 season. Project staff provided training and illustrated, step-by-step directions on the nowcasting process, including data entry/transformation using the custom spreadsheets. Local staff members were thereafter able to run the nowcast in approximately 5 minutes per day, on top of routine monitoring and sanitary survey activities.

Results of at Upper Lake Park were encouraging. In addition to the fact that local staff were able to run the model without interfering with their normal activities, the model proved to be highly accurate, with an R-square value of 0.63 during the 2009 nowcast, a significant reduction in *Type I* and *Type II* errors relative to the "persistence model" during the 2007-2008 model-building period (see **Figure 3**), no *Type I* errors during the 2009 nowcast, and a mean absolute error of just 19 MSU/100 mL (untransformed) in 2009. The absolute error is low in part because observed and predicted values were low (i.e. no actual exceedances); however, a visual inspection of the nowcast performance confirms that the model was extremely sensitive to small-scale fluctuations in *E. coli* (see **Figure 4**).

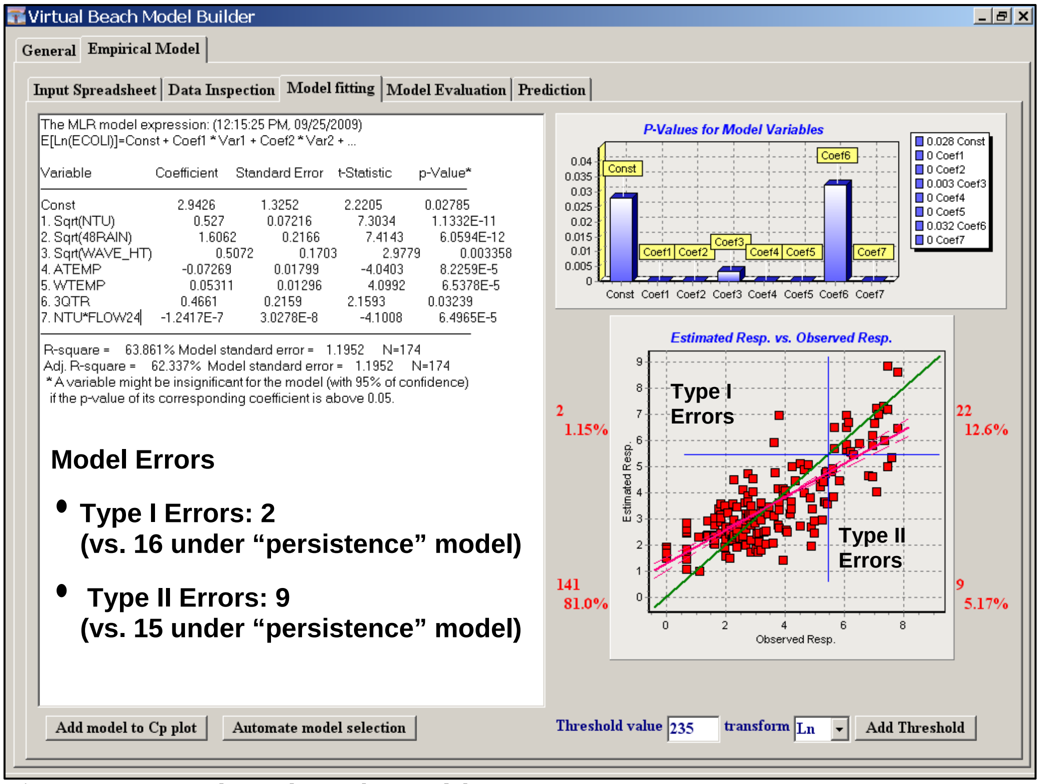

Figure 3. *Upper Lake Park Beach – Model Accuracy 2007-2008.*

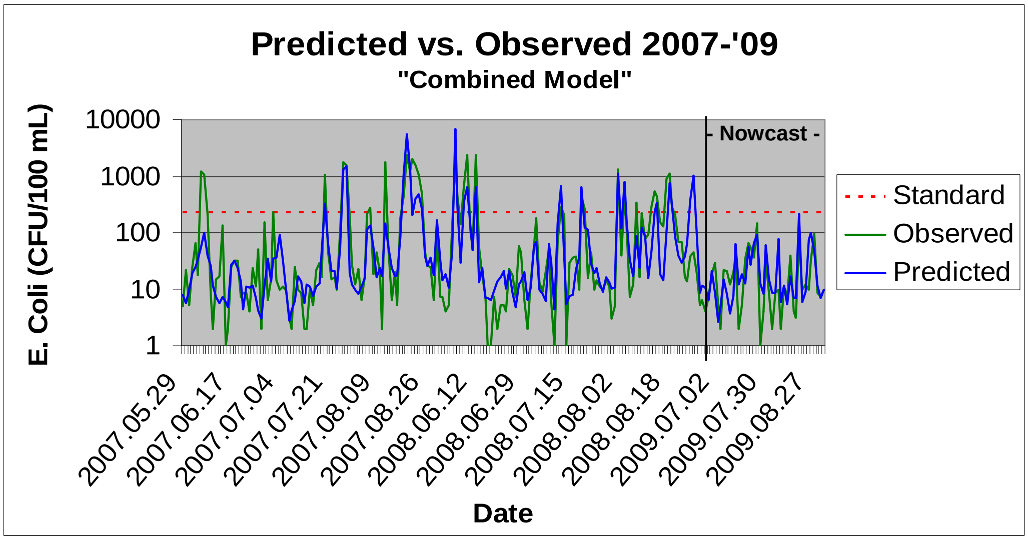

Figure 4. *Upper Lake Park Beach – Nowcast Accuracy 2009 (Note the log scale.).*

2.4. Basin-wide Communication and Outreach

Initial interviews with local beach monitoring experts at the Racine Health Department (Julie Kinzelman), Lake County Public Health Department (Mark Pfister), and Environmental and Public Health Microbiology Laboratory at the University of Wisconsin at Oshkosh (Greg Kleinheinz) served as source material, along with background research, for an article titled "Reducing Bacterial Contamination at Great Lakes Beaches" which was published in the American Planning Association's online *Environmental Planning Journal* (Mednick 2009a).

Following the pilot workshop and enhancements to VBMB, Wisconsin DNR sent a 1,200-word project summary to the roughly 650 subscribers to the *Beachnet* listserve. This posting included the following sections: *I. Background and Objectives*, *II. Progress to Date*, and *III. Upcoming Events*, including the Virtual Beach training workshop that would take place at the SOLM/GLBA conference in Milwaukee. A follow-up email to the listserve invited conference registrants to sign-up for the workshop.

Project staff prepared and delivered a presentation titled "A Predictive modeling tool for local beach managers: Virtual Beach-Model Builder" at the SOLM/GLBA conference with AMI Beach Forecasting Project partners from U.S. EPA ORD/NERL, as well as local partners from the Racine Health Department and Ozaukee County Public Health Department (Mednick, et al. 2009) to an estimated audience of 80+ attendees in the "Rapid Assessment Methods and Predictive Models for Beach Management" session. That presentation described Wisconsin DNR's pilot-testing, outreach, and technical assistance efforts, including the results and practical lessons of local field-testing in the summer of 2009.

Through these communications interest in bacterial exposure modeling – and VBMB in particular – notably increased, as indicated by the excess demand for the training workshop at the SOLM/GLBA conference and a number of inquires about the tool from conference attendees, potential attendees, and listserve subscribers. We have responded to several requests for the VBMB software and training materials from beach managers, consultants, and educators throughout the Great Lakes basin. In response, Wisconsin DNR developed a *Beach Water Quality Modeling* project website (http://dnr.wi.gov/org/es/science/beachmodeling/), including background information on recreational water quality predictive modeling, a summary of this project, and the training materials and data, as well as streaming video of the VBMB training workshop at the SOLM/GLBA conference.

3. Project Administration

This chapter provides an overview of project administration, including information on the Federal Assistance Agreement, project staffing, key collaborators, and communications with U.S. EPA.

3.1. Grant Period

U.S. EPA Federal Assistance Agreement (No X700E54401-0) was awarded for the period July 1, 2008 through September 30, 2009 in the amount of $21,000.

The project work plan was modified through a no-cost extension submitted in January 2009 and approved in July 2009 to refocus efforts from outreach, promotion, and technical assistance towards pilot testing, training, and technical assistance.

3.2 Project Staffing

Dreux Watermolen, Wisconsin DNR's Chief of Science Information Services, served as the project manager for the entire project period and was responsible for oversight of the Wisconsin DNR efforts.

The Federal Assistance Agreement provided funding for one limited-term employee during the grant period. Adam Mednick, a Senior Natural Resources Educator and Research Scientist, carried out the day-to-day work of the program.

Several permanent Wisconsin DNR staff members contributed to program implementation. Science communications manager R. Chris Welch assisted with the development of the Internet website, managed online registration for our workshops, and captured training sessions with streaming video.

In addition, we coordinated our efforts closely with Wisconsin DNR's Beach Program. Bob Masnado, Wisconsin DNR's Chief of Water Evaluation, served as our primary contact. Additional assistance was provided by Toni Glymph and Shauna Chase, the agency's former Beach Program Coordinators, and Dr. Greg Kleinheinz, University of Wisconsin-Oshkosh, the State's current contract Beach Coordinator.

3.3. Key Collaborators

As described in Chapter 2 ("Project Highlights and Accomplishment") of this report, we worked with collaborators from various local, state, and federal agencies, as well as several academic scientists in carrying out this project.

Principal collaborators from the U.S. EPA included Richard Zdanowicz and Holiday (Holly) Wirick (Region 5, Chicago) and Richard Zepp, Kurt Wolfe, Rajbir Parmar, and Jon Wong (ORD/NERL).

Throughout the course of our efforts, we partnered with local beach managers who have been leaders in conducting beach sanitary surveys and applying predictive models. These included Dr. Julie Kinzelman at the City of Racine Health Department, Dan Ziegler at the Ozaukee County Public Health Department, and Dr. Greg Kleinheinz at the University of Wisconsin-Oshkosh's Environmental and Public Health Microbiology Laboratory.

Concordia University's Center for Environmental Stewardship, under the direction of Dr. Bruce Bessert, hosted and co-sponsored the April 2009 pilot training session.

We coordinated our research and model building efforts with Susan Phillips, Nate Booth, Steve Corsi, and Carolyn Emmanuelli, scientists and database managers at the USGS Wisconsin Water Science Center in Middleton, Wisconsin. We also coordinated our efforts with David Rockwell, Beach Water Quality Forecasting Coordinator, at the University of Michigan CILER.

3.4. Semi-annual Progress Reports and Communication with U.S. EPA

Adam Mednick regularly participated in the AMI Beach Forecasting Project monthly conference calls and maintained regular contact with project leads in both Region 5 and ORD/NERL. This ongoing communication was essential for ensuring project completion.

We provided U.S. EPA Region 5 with written semi-annual progress reports for each six-month period (January 31, 2009 for July through December 2008; July 15, 2009 for January through July 2009). These reports highlighted work completed during the previous six months, documented project deliverables, outlined future plans, and served as a basis for coordinating efforts. We also shared these reports with key staff in U.S. EPA's Office of Research and Development and Great Lakes National Program Office.

We participated in two in-person status briefings with U.S. EPA Region 5 staff members: January 27, 2009 and July 16, 2009. These meetings provided U.S. EPA project contacts an opportunity to react to written reports and project deliverables, to ask questions and seek additional information, and to provide guidance and direction for future work efforts. The meetings also provided opportunities for Wisconsin DNR program staff to meet with U.S. EPA staff and managers, in addition to the project contacts, to share progress and lessons learned. To this end, Dreux Watermolen and Adam Mednick presented aspects of the Wisconsin DNR efforts during a Midwest Spatial Decision-Support Systems Partnership briefing for the U.S. EPA Region 5 Regional Administrator, Deputy Regional Administrator, and Water Program senior management in November 2009.

All products produced for the hands-on training sessions, as well as review memos providing feedback on prototypes, were posted to U.S. EPA's Science Connector.

4. Lessons Learned

Lessons learned during the course of this project will help guide future capacity-building efforts by Wisconsin DNR, leading toward expanded operational use of water quality forecasting and nowcasting models throughout Wisconsin. Activities undertaken as part of this project included outreach and technical assistance to beach managers in several other states as well as Ontario, and the lessons that we learned are relevant throughout the Great Lakes basin and potentially at marine beaches as well. Based on these lessons we make a series of recommendations (Chapter 5) for achieving a wider transfer of Beach Pathogen Forecasting Tools.

4.1. Likely Users Comprise a Small, but Accessible Group

Because our previous technology transfer work, under Wisconsin DNR's "Internet Tools for Planning, Conservation, and Environmental Protection" program (Watermolen 2008, 2009), included a comprehensive set of decision-support tools, the target audience for that effort was vastly more expansive, including municipal-level land use planners, decision-makers, and the interested public. This necessitated far-ranging technology transfer approaches, including Web-based training and capacity building among county- and watershed-based university extension educators. In contrast, the targeted users of the Bacterial Exposure Forecasting Tool–local beach managers and monitoring personnel–comprise a more tractable and accessible group. The same personnel are often responsible for managing and/or monitoring water quality at more than one beach, often all of the beaches in a county and in some cases multiple counties. In Wisconsin, there are approximately 20 individuals responsible for monitoring water quality at the 124 Great Lakes beaches. This allows for regional efficiencies in training and direct technical assistance.

4.2. Effective Training Is Hands-on, Small, and Ideally Lasts a Full Day

The results of participant evaluations of the two VBMB workshops indicated that hands-on training, with one computer per participant and adequate time to experiment with the software through a real-world case study, was an effective means of training. Limiting workshops to 15 participants enabled trainers to address individual participants' learning needs. Differences between the two workshops, in terms of time available and the amount of material covered, indicated that the hands-on sessions should total at least four hours. Ideally, workshops should last a full day.

4.3. Tool Evaluation Should Be Conducted by Multiple Users in Multiple Contexts

Workshop participants provided feedback on the utility and usability of the VBMB tool, including ratings on each of ten specific functions and features (described in Section 2.3). Participants also provided suggestions for enhancements to the software through evaluation forms, as well as facilitated discussions at the end of each training session. Valuable feedback and suggestions also were generated outside of the workshops through extensive pilot-testing by Wisconsin DNR and field testing with local partners during summer 2009. These included practical suggestions dealing with the logistics of building and implementing predictive models. These suggestions led to enhancements to VBMB (and to the forthcoming Virtual Beach 2.0) that help to make the tool more operations-ready. This type of feedback may not occur to participants during workshops or through hypothetical software testing. Workshops, however, do include more users. Therefore, it is important to employ both types of testing when evaluating future versions of Virtual Beach, as well as other beach pathogen forecasting tools.

4.4. Local Managers Can Successfully Build and Operate Multivariate Predictive Models

As described in Chapter 3, local partners at the Ozaukee County Public Health Department were able, on their own, to build and operate a multivariate real-time "Rainflow" model at Upper Lake Park in 2008. With technical assistance from Wisconsin DNR, they were able to improve upon this model using VBMB. Building the VBMB model took approximately 40 hours of combined Wisconsin DNR and Ozaukee Health Department staff time. Daily operation of the model required 5 minutes per day in conjunction with entering data on Wisconsin's *Beach Health* website. Data collection–for building and operating the model–was conducted entirely as part of the county's routine monitoring and sanitary survey activities. Combining nowcasting with this routine work minimized the cost of the modeling effort.

Our experience suggests that the development of models by technical experts on behalf of local partners–without concurrent training and capacity building to maintain those models–is unlikely to be sustainable and is not an efficient means for fostering a more widespread technology/methods transfer. Among other things, local buy-in appears to be a necessary ingredient for long-term success. The *Swimcast* system in northeastern Illinois, which continuously nowcasts water quality at four beaches based on multivariate models and an automated, in-lake data collection system, was developed and continues to be maintained (and expanded) with the Lake County Health Department as the lead. Most local managers, however, do not have the resources and technical expertise on hand to develop such a sophisticated system, which is one reason why there are so few operational nowcast models in place today.

Our work with Ozaukee County represents a third approach: The VBMB model was developed collaboratively by Wisconsin DNR staff and its local partner. Wisconsin DNR provided direct modeling services and technical assistance, while local personnel provided on-the-ground expertise, which was essential to building a successful nowcast model. Operational models begin as conceptual models, which are best developed by those most familiar with conditions at the beach. Building capacity at Ozaukee County and other locales will enable technical assistance providers to work with additional local partners, thereby fostering wider adoption of forecasting and nowcasting across the Great Lakes basin.

4.5. Every Beach Is Unique

While general methods (e.g., MLR modeling) and tools likes VBMB are widely transferable from one beach to another, specific models are not. Every beach is unique in terms of the exact combination of variables and underlying conditions that influence the concentration of pathogen indicator bacteria at any given time. Efforts have been made to develop general guidelines and rules of thumb for when and where different modeling methods are appropriate for forecasting or nowcasting bacterial exposure. Francy and Darner (2006) suggest that moderately-contaminated beaches are the most suitable for multivariate statistical models and recommend at least two seasons of monitoring results and concurrent environmental conditions data collected four times per week (approximately 120 data points).

Because beaches are unique, however, the predictive ability of nowcast models varies considerably from beach to beach and is not necessarily dependent on the number or quality of observations available for model-building (Mednick 2009b). The case study for the VBMB training (Red Arrow Park Beach in Manitowoc) had only 40 data points, yet was still more accurate than the persistence model. Similarly, results of experimental models built for North Beach in Racine, Wisconsin, showed that beaches with very few exceedances can still be successfully modeled. Ultimately, a model's predictive power – as measured by model sensitivity and specificity, in addition to various goodness of fit measures–will determine whether input data were adequate or the beach was a good candidate for modeling.

Because the underlying conditions of any given beach change over time–both between and within beach seasons–it is critical that model performance be evaluated and re-evaluated over time. Models should be refined at least once a year (i.e. prior to each new beach season), in order to add new data and if necessary remove older data. One of the novel strategies we developed at North Beach was to employ a simple categorical (0/1) variable demarcating the seasons before and after a series of significant changes were made to the beach (including the installation of a mechanical filtration system and constructed wetland at a stormwater outfall and improved beach grooming practices). This enabled us to use several additional years' worth of data without confounding the model. In all of our models, we employed categorical data on the "quarter" of the beach season (i.e. first, second, third, and fourth) to capture seasonal variation that could not otherwise be accounted for.

4.6. Real-time Predictive Models Are Typically More Accurate than the "Persistence" Model

Standard monitoring presents a low bar of comparison for predictive models. Prior to our study no comprehensive baseline assessment of the accuracy of the "persistence model" had been conducted. We analyzed statewide monitoring and notification data archived on Wisconsin's *Beach Health* website[3] and found that at least 576 (63%) of the 912 beach closings issued in Wisconsin between 2003 and 2009 were reflective of *Type I* monitoring errors (false exceedances), relative to the state's 1,000 CFU/100 mL closure guideline. At the same time, 1,552 (42%) of the 3,737 posted swim advisories were identified as false exceedances of the federal standard (235 CFU/100 mL). Of the non-advisory beach-days on which water quality samples were collected[4], 269 or 3% were found to have significant *Type II* errors (i.e. should have been closed), while an addition 928 (9%) exceeded the federal standard (i.e. should have been posted). The elimination of all *Type I* and *Type II* errors associated with the state's closure guideline would have reduced the total number of beach closures between 2003 and 2009 by 307, or 34%.

While predictive models will obviously not eliminate all monitoring errors, they have consistently been shown to be more accurate (Olyphant and Whitman 2004; Nevers and Whitman 2005; Hou, et al. 2006; Francy and Darner 2007; Frick, et al. 2008; Nevers and Whitman 2008; Francy 2009; Olyphant and Pfister 2009), particularly with respect to *Type I* errors. Our findings at Upper Lake Park are consistent with these other studies.

We conducted a meta-analysis of those studies reporting model-based errors relative to monitoring-based errors (Nevers and Whitman 2005; Francy and Darner 2008; Mednick et al. 2009; and the *Ohio Nowcast* website) and found that mean and median percent reduction in *Type I* errors was 48% and 43%, respectively. For *Type II* errors, mean and median reductions were 43% and 39%. From this, we estimate that standard MLR models could reduce *Type I* monitoring errors by approximately 40% and *Type II* errors by 30%. As of the 2009, just six of the 539 monitored Great Lakes beaches had an operational MLR model in place[5]. A more widespread adoption of even this basic method, using tools like VBMB, could markedly reduce monitoring errors. And because of the bias toward *Type I* errors by the "persistence" method, this technology transfer could by itself reduce the number of advisories and closures.

[3] Due to limitations with other states' monitoring and notification sites, this baseline assessment was limited to Wisconsin. The findings are consistent with studies of individual beaches in Illinois, Indiana, and Ohio (cited above) and are assumed to be reflective of the baseline accuracy of the current monitoring regime across the Great Lakes, which is biased toward *Type I* errors. Analyses are planned for other states.
[4] A "beach-day" represents one day per one beach. Between 2003 and 2009, there were 10,432 non-advisory beach days on which water quality samples were collected. The total number of non-advisory beach days during this time period is not known, however, as managers do not report all non-advisory days.
[5] Prior to 2009, five additional beaches in northwestern Indiana had operational nowcast models under the USGS's *Project S.A.F.E.* (Swimming Advisory Forecast Estimate).

5. Recommendations

Based on the lessons we learned during the course of this project (Chapter 4), we offer five broad recommendations with the aim of facilitating a widespread adoption of beach pathogen forecasting and nowcasting methods and technologies. These recommendations are included in a policy analysis manuscript– "Reducing Great Lakes Swim Advisories and Beach Closures through the Integration of Monitoring, Sanitary Surveys, and Real-time Predictive Models" –that we plan to submit for publication in a peer-reviewed journal.

5.1. Enhance Modeling Tools Based on User-Testing

Expanding operational beach water quality nowcasting and forecasting beyond the current handful of test beaches requires tools that meet the needs of local beach managers and monitoring personnel. While Wisconsin DNR made several suggestions regarding VBMB in advance of the pilot training workshop, local partners identified and articulated the key enhancements necessary to make the software both useful and usable in an operational context. Feedback from potential local users at the hands-on training workshops, and from actual users during extensive field-testing in the summer of 2009, led to significant enhancements to VBMB and the forthcoming Virtual Beach 2.0. We recommend that this feedback loop be maintained for the updated software, and be applied more broadly to the various tools and data systems that potentially form an integrated Bacterial Exposure Forecasting *System* as outlined below.

Enhancements recommended during the project period, and their current status, are listed in **Table 1**. The U.S. EPA ORD/NERL team has indicated that modifications listed in this table as "Virtual Beach 2.0" will be included in the updated software. Among the key new features of Virtual Beach 2.0 that were informed by these recommendations are:

1) portable files that save selected models separate from underlying data;
2) automated model-building processes that can build, evaluate, and rank exhaustive combinations of explanatory variables, transformations and interaction terms based on user-defined criteria; and
3) the automatic transformation and/or combination of data entered as "native variables" (i.e. real-world measurements) by users when conducting daily nowcasting, so that they match the model.

These enhancements alone will greatly improve the usability of the software by "de-coupling" the model-building and nowcasting process – such that models can be evaluated and refined continuously if need be, without affecting daily data input and nowcasting procedures.

5.2. Provide Regional Training and Technical Assistance to Local Users

In order to maximize efficiency, we recommend that training and technical assistance activities be conducted on a regional (i.e. statewide or multi-county) basis, as opposed to either localized or Great Lakes basin-wide. As discussed under "Lessons Learned," targeted users comprise a relatively small group with individual agencies or institutions typically responsible for multiple beaches across one or more counties. In Wisconsin this group is comprised of approximately 20 individuals. In practice, just four local health departments and the University of Wisconsin-Oshkosh are responsible for almost all of the beach monitoring work conducted in the sate.

At the same time, we found that training was optimal when it was intensive (i.e. hands-on and at least a full-day) and limited to small groups. Improvements made to Virtual Beach 2.0, particularly the automated model building process and the de-coupling of model-building from daily data entry, will enable centralized technical assistance providers to work with several local managers at a time. One possible approach to regional technical assistance–which we hope to implement in Wisconsin–is for the technical assistance provider to build the initial models and then provide the models, underlying data, and training to the local managers, after which they would take responsibility for maintaining, evaluating, and refining the models over time, with technical assistance provided as needed. State environmental agencies, federal research and technical assistance centers (e.g., USGS State Water Science Centers), and universities could play this or a similar role in other coastal states and regions. The process of providing such services will be greatly improved by the creation of Web-based data archive and retrieval systems and continued federal support for routine sanitary survey work, as described below.

5.3. Maintain and Expand Routine Beach Sanitary Surveys

One of the key lessons learned during this project is that the development and implementation of predictive models is facilitated by–and for the most part, requires–the local collection of data on beach conditions through routine (daily) sanitary surveys. The U.S. EPA's Standardized Beach Sanitary Survey Tool provides a protocol for collecting consistent, quality-controlled data on a wide-range of variables that are potentially correlated to pathogen indicator concentrations. Daily data are collected over time to conduct detailed analyses of likely sources and mitigation strategies; however, these data are also critical for building predictive models[6]. With a few notable exceptions, such as the *Swimcast* beaches in Lake County Illinois, beaches do not have automated data collection systems on site. Data on water and air temperature, wave height, wind speed and direction, currents, and turbidity are collected and recorded by beach personnel. It may be possible in a handful of cases to completely substitute locally-collected data with data recorded at nearby automated weather stations, buoys, and/or stream gauges. These data, however, will only be substituted partially–augmenting, rather than completely replacing field-collected data. In our pilot testing of VBMB, we found that field-collected wind data in particular are better predictors than wind data collected at nearby weather stations.

5.4. Develop a Basin-wide, Web-based System for Field-collected Data

In addition to providing the necessary data to build and run predictive models, routine data reporting (for monitoring and sanitary survey work) provides the practical basis for operating the predictive models. Our field-testing with the Ozaukee County Public Health Department at Upper Lake Park Beach in 2009 would not have been practicable without the advance data storage and retrieval functions of the Wisconsin *Beach Health* website. In Wisconsin, monitoring personnel already enter daily monitoring and beach conditions data onto this site via a secure Web data entry form for combined monitoring and sanitary survey data. As our local partners in Ozaukee Country demonstrated, this process can easily be adapted to accommodate simultaneous data entry into a Bacterial Exposure Forecasting Tool.

The *Beach Guard* websites and similar systems in other states could add this functionality to accommodate efficient model-building and technical assistance services by state and federal agencies throughout the Great Lakes basin. It is anticipated that future updates to Virtual Beach and similar tools will close the loop between routine data reporting and predictive modeling, such that 24-hour monitoring results and current beach conditions will only need to be entered one time in the online system, from which the modeling tools will access the data automatically to run the models. Ideally, there will be a single data system for the Great Lakes basin as a whole, or at a minimum, the state systems will have consistent enough functionality and/or architecture to enable one-time integration with the modeling tools.

[6] Beyond their ability to predict pathogen indicator concentrations at a given point in time, from the perspective of sanitary surveys and mitigation planning, predictive models can be used to estimate the relative contribution of different sources or environmental factors, in the form of model coefficients for different predictive variables.

Table 1. *Suggested Enhancements to Virtual Beach-Model Builder*.

Suggested Enhancement	Status
Add 235 CFU/100 mL thresholds to residual plots	Completed
Add function for operational nowcasting/forecasting ("Prediction" tab)	Completed
Add log10 transformation for the dependent variable	Completed
Add unadjusted R-square (in addition to Adjusted R-square, which is difficult to interpret)	Completed
Create a guidance manual and tutorial	Completed
Enable back-transformation of the response variable for easier interpretation	Completed
Enable easier importing/exporting of the spreadsheet in the "Prediction" tab	Completed
Make variable naming and numbering consistent across program tabs/processes	Completed
Remove extraneous program tabs	Completed
Add a GIS function for measuring beach orientation	Virtual Beach 2.0
Add a "Help" menu and FAQs	Virtual Beach 2.0
Add ability to easily/intuitively key-in today's values (native variables)	Virtual Beach 2.0
Add ability to export regression results (tabular and graphics) to a document	Virtual Beach 2.0
Add ability to read/write current versions of MS Excel spreadsheets	Virtual Beach 2.0
Add ability to save/name models as portable files	Virtual Beach 2.0
Add additional *diagnostic* metrics; e.g., A.I. criteria, RMSE	Virtual Beach 2.0
Add Pearson's correlation matrix for multi-collinearity (in addition to VIF)	Virtual Beach 2.0
Add time-series graphic of observed versus predicted levels	Virtual Beach 2.0
Add utility to convert quantitative data to categorical; e.g., wind direction	Virtual Beach 2.0
Automate model-building and evaluation	Virtual Beach 2.0
Enable multi-column (variable) exclusion	Virtual Beach 2.0
Fix input/output spreadsheet formatting issues; e.g., numeric data re-formatting to text.	Virtual Beach 2.0
Fix right and left arrow key stroke responsiveness	Virtual Beach 2.0
Improve graphic capabilities, including ability to view entire window without scrolling	Virtual Beach 2.0
Enable logistic regression	Virtual Beach 2.0
Make input spreadsheet editing tools easier to use	Virtual Beach 2.0
Make steps simpler; i.e. one click to get to end point	Virtual Beach 2.0
More intuitive user interface	Virtual Beach 2.0
Store model-performance history and analysis	Virtual Beach 2.0
Add ability to composite monitoring data from multiple sites/beaches within the software	N/A
Add ability to interpolate missing data	N/A
Add ability to select individual records from scatter plots	N/A
Add Box Cox transformations	N/A
Add explanation of how influential outliers are calculated	N/A
Add *prognostic* (validation) metrics; e.g., R-square, EMS, MAPE, sensitivity/specificity	N/A
Add variable names to plot titles (and the various model evaluation summaries)	N/A
Include as many scatter plots as explanatory variables	N/A
Add regression line and correlation coefficients to scatter plots	N/A

5.5. Integrate Modeling Tools with Web-based Data Systems

In addition to field-collected monitoring and beach conditions data, hydro-meteorological data collected at automated and cooperative weather observing stations, data buoys, and stream gauges should be seamlessly integrated with the modeling tools. Eventually, tools like Virtual Beach will enable nowcast and forecast models to automatically stream data from these various sources via the Web. In pursuit of this objective, an inter-agency effort is presently underway between the USGS, NOAA, and U.S. EPA to integrate data collected by these agencies for use in various modeling applications. Initial efforts have focused on data that can be used for recreational water quality forecasting and nowcasting. Wisconsin DNR's report *Accessing Online Data for Building and Evaluating Real-Time Models to Predict Beach Water Quality* (Mednick 2009b) is being used to guide this effort. When completed, data will be made available as streamable Web services with consistent formatting (e.g., date and time). This will facilitate more rapid model-building and execution and will enhance local capacity to use modeling tools like Virtual Beach.

6. Acknowledgments

Bob Masnado, Wisconsin DNR's Chief of Water Evaluation, helped us ensure that our efforts addressed Beach Program needs and aligned with the Bureau of Watershed Management's priorities. Jerry Sullivan, GIS Project Manager in the Bureau of Science Services, was extremely helpful in identifying and helping us obtain and format data. Technology Transfer Specialist Michelle Voss designed and helped prepare workshop materials. Science Communications Manager R. Chris Welch developed the Internet Web site, managed online registration for our workshops, and captured training sessions with streaming video. We appreciate the efforts of all of these Wisconsin DNR colleagues.

Our work could not have been completed without the assistance of our U.S. EPA colleagues. Richard Zdanowicz and Holly Wirick (Region 5) served as our principal contacts for our Federal Assistance Agreement. Their ongoing discussions, direction, and support ensured our project outputs and outcomes met the Region's needs. Michael Bland (Region 5) helped coordinate our efforts with those of the Midwest Spatial Decision-Support Systems Partnership. Tom Brody (Region 5) participated in the pilot training session and assisted with our computer needs. Richard Zepp, Mike Cyterski, Rajbir Parmar, Kurt Wolfe, and John Wong at ORD/NERL were highly accessible and responsive to our requests for modifications to the Virtual Beach software, which enabled us to conduct effective training, technical assistance, and field-testing. Rajbir and Kurt contributed to both of the training workshops as well. We are especially grateful for the efforts of all of these individuals.

We are also grateful to our other AMI Beach Forecasting Project partners for their expert guidance, encouragement, and direct assistance. These include David Rockwell, Beach Water Quality Forecasting Coordinator at the University of Michigan CILER, David Schwab of the NOAA Great Lakes Environmental Research Laboratory, and a number of scientists from the USGS. We would especially like to thank Nate Booth, Steve Corsi, Carolyn Emmanuelli, and Susan Phillips (Wisconsin Water Science Center); Richard Whitman (Great Lakes Water Science Center); Donna Francy (Ohio Water Science Center); Zhongfu Ge (Lake Michigan Ecological Research Station); and Sheridan Haack (Michigan Water Science Center).

Throughout the course of our project, we relied heavily on local public health officials to help us understand the challenges associated with Beach Program implementation and the needs of local beach managers. We would especially like to thank Julie Kinzelman, City of Racine Health Department, and Dan Ziegler, Ozaukee County Wisconsin Public Health Department, for their extensive collaboration and assistance. Stephan Kurdas (Racine Health Department) and Justin Hall (Ozaukee County Public Health Department) provided valuable assistance as well, including guided site visits and assistance with data assembly and modeling. We would also like to thank Mark Pfister of the Lake County Illinois Health Department for providing expert insight regarding predictive modeling from a local perspective.

We also received assistance from the University of Wisconsin-Oshkosh Biology/Microbiology Department, which is responsible for monitoring beaches throughout northern Wisconsin. Professors Gregory Kleinheinz and Colleen McDermott, and graduate research assistant Sashidhar Yerram, provided expert guidance and data from their model-building and sanitary survey projects conducted in 2007 and 2008. Sashi also presented at our pilot training workshop with Julie Kinzelman and Stephan Kurdas.

Professor Bruce Bessert of Concordia University's Center for Environmental Stewardship hosted our pilot workshop. We appreciate his assistance with the logistics. We would also like to thank James Blaha of the Manitowoc County Wisconsin Health Department for allowing us to use Red Arrow Park Beach as the case study for our training materials and workshops.

Lastly, we would like to acknowledge members of the Midwest Spatial Decision-Support Systems Partnership. In particular, Professor Bernie Engle, Larry Theller, James Hunter, and Joseph Quansah of Purdue University provided assistance on a parallel effort to link beach water quality predictive models to real-time watershed models.

7. Literature Cited, Further Reading, and Background Material

Here, we list all works cited throughout the report, as well as additional sources that we found helpful in defining, developing, and evaluating our pilot testing, outreach, training, and technical assistance program. These include references related to recreational water quality standards, beach pathogen modeling, technology acceptance, and technology transfer. We hope others will find this consolidated list useful.

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Appendix A –Presentations Resulting from Wisconsin DNR's Work

EPA staff requested that Wisconsin DNR make a concerted effort to transfer findings from its efforts for broader regional and national applications. The following presentations resulted directly from work undertaken as a part of the federal assistance agreement and transferred lessons learned from Wisconsin DNR's outreach, training, technical assistance, and evaluation efforts. Links to conference proceedings, presentation slides, or related sites are provided when these are available on the Internet.

Mednick, A.C. 2010. Using real-time statistical models to "nowcast" Great Lakes beach water quality. "Science Seminar" series. Bureau of Science Services, Wisconsin DNR, Madison, WI. (March 11, 2010.)

Mednick, A.C. 2010. Recreational water quality modeling tools for local beach managers. 34th Annual Meeting, American Water Resources Association–Wisconsin Section. Madison Marriott West, Middleton, WI. (March 5, 2010). For conference information, see http://state.awra.org/wisconsin/2010meeting.html.

Kinzelman, J. and A. Mednick. 2009. Integrating urban planning into municipal water quality monitoring programs. "On Public Health" seminar series. School of Public Health, University of Wisconsin-Milwaukee, Milwaukee, WI. (December 8, 2009).

Mednick, A.C. 2009. Predictive modeling tools for local beach managers: Virtual Beach. Presentation at Midwest Spatial Decision-Support Systems Partnership briefing with EPA Region 5 Administrator, Deputy Regional Administrator, and Water Program senior management. Chicago, IL. (November 18, 2009).

Mednick, A.C., J. Hall, J. Kinzelman, S. Kurdas, R. Parmar, K. Wolfe, J. Wong, and D. Ziegler. 2009. A predictive modeling tool for local beach managers: Virtual Beach-Model Builder. Lake Michigan: State of the Lake and Great Lakes Beach Association 2009 joint conference. Hyatt Regency, Milwaukee, WI (September 29-October 1, 2009). For conference information, see http://aqua.wisc.edu/SOLM/.

Mednick, A.C. 2009. Virtual Beach-Model Builder technical assistance and outreach: Project overview. Presentation at Midwest Spatial Decision-Support Systems Partnership summer meeting. Chicago, IL. (July 16, 2009).

Watermolen, D.J. 2010. Evolution and recent developments of Web-based decision-support systems for watershed management. 34th Annual Meeting, American Water Resources Association–Wisconsin Section. Madison Marriott West, Middleton, WI. (March 4-5, 2010). For conference information, see http://state.awra.org/wisconsin/2010meeting.html.

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Appendix B – Publications Resulting from Wisconsin DNR's Work

Over the course of the grant period, we published results of our work in various outlets. We here list publications resulting from our work.

Mednick, A.C. 2009. Reducing Bacterial Contamination at Great Lakes Beaches. American Planning Association -Environment, Natural Resources, and Energy Division *Environmental Planning Journal*

Mednick, A.C. 2009. *Accessing Online Data for Building and Evaluating Real-Time Models to Predict Beach Water Quality*. Bureau of Science Services, Wisconsin Dept. Natural Resources, Madison. 18 pp. [Miscellaneous Publication PUB-SS-1063].

In addition to our formal publications, we prepared promotional materials for our workshops and instructional materials for use in our training and technical assistance efforts.

"Learn to use Virtual Beach" flyer accompanying e-mail invitation to register for VBMB pilot training workshop (sent on March 19, 2009).

"Virtual Beach Pilot Training Workshop, April 30, 2009" folder of training materials provided to pilot workshop participants, including:

- Workshop Agenda
- Module 1. "Data Input, Evaluation, and Transformation"
- Module 2. "Fitting and Evaluating Predictive Models"
- CD-ROM containing VBMB software, training data set, and .pdf copies of documents
- "References and Contacts for Predictive Models" (Assembled by Donna Francy, USGS)
- "Workshop Participant Feedback Form"

"Summary of *Virtual Beach–Model Builder* Pilot Workshop - April 30, 2009" detailed report on the VBMB pilot training workshop, including evaluation results and participant feedback on VBMB software.

"Virtual Beach–Model Builder: Updated Software and Materials" email update to pilot workshop participants (sent July 13, 2009).

"Technical Assistance and Outreach for Pathogen Indicator Forecasting Tools: Project Description and Update" Beachnet listserve email (August 14, 2009)

"Sign-up for "Virtual Beach" Training at SOLM/GLBA Conference" Beachnet listserve email (September 15, 2009)

Notes

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- analyzing new information and emerging technologies.
- synthesizing information for policy and management decisions.
- applying the scientific method to the solution of environmental and natural resources problems.
- providing science-based support services for department initiatives.
- collaborating with local, state, regional, and federal agencies and academic institutions in Wisconsin and around the world.
