Management and use of a long-term water quality monitoring database for Boston Harbor and Massachusetts Bay

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1. Database Management

The Massachusetts Water Resources Authority (MWRA) maintains an extensive environmental database, which consists of long-term monitoring data for Boston Harbor and Massachusetts Bay, and effluent testing data for MWRA treatment plants and combined sewer overflow treatment facilities. To increase the awareness and to encourage the use of the MWRA environmental database, in this presentation we highlight (1) data quality assurance and control, (2) data sources, database management, and application, (3) studies and sampling locations, and (4) examples of data use.

Most of the monitoring data have been collected by MWRA and its consultants during the past decade. These data are under stringent quality assurance (QA) and quality control (QC) following the Deming/Shewhart model for quality management (Figure 1). Data checking takes place in many stages including laboratory data collection, data entry, QC check plots (Figure 2) and statistical summary of data, QA review of data, and loading to database. Data from other agencies and organizations are included in the database only when the data are thoroughly documented.

All data are stored in an Oracle relational database management system. Sources and users of the data are diagrammed in Figure 3.

Major categories of monitoring data in the database are: water quality, effluent chemistry, fish and shellfish chemistry and pathology, sediment contaminants, plankton abundance, and benthic infauna. Sampling locations in relation to each monitoring study are shown in Figure 4.

Examples of data use by a broad range of clients are shown in Figure 5 through Figure 10.

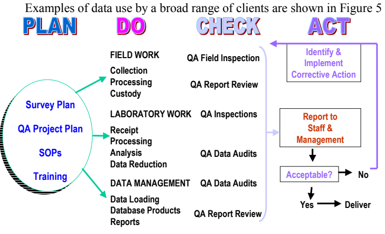

Figure 1. Data quality requires careful planning and checking that procedures are followed. Feedback from data users and refinement of procedures based on this feedback is an integral part of quality assurance.

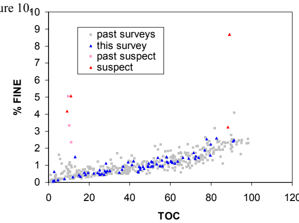

Figure 2. Example of QC check plot for total organic carbon (TOC) and percent fine sediment (% FINE). Data from each survey are compared against historical patterns. Outliers are easily detected in bivariate scatter plots of correlated variables and flagged for further investigation. Grey squares show valid historical data. Blue triangles show data being reviewed. Pink squares and red triangles represent data already flagged as suspect from past and current surveys, respectively.

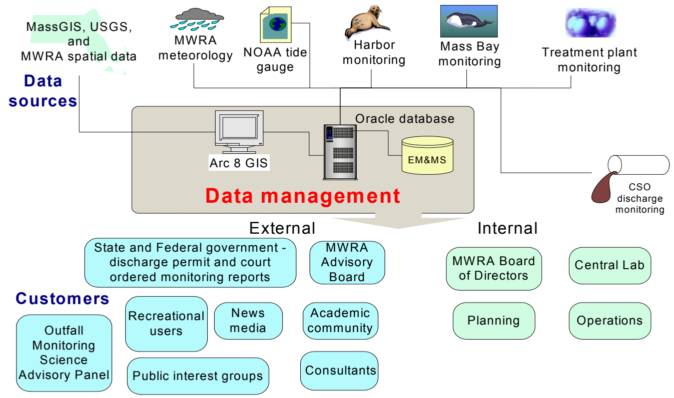

Figure 3. Data from MWRA, its consultants, and outside agencies are stored in an Oracle relational database management system in which data integrity is maintained through automated database constraints. Additional checks are made upon data loading to identify study-specific errors. These checks are continually refined as new errors are identified. Corrections are made to both new and historical data to maintain the integrity of valuable long-term data sets. Data are used internally and externally to serve the needs of managers, scientists, citizens, and regulatory agencies.

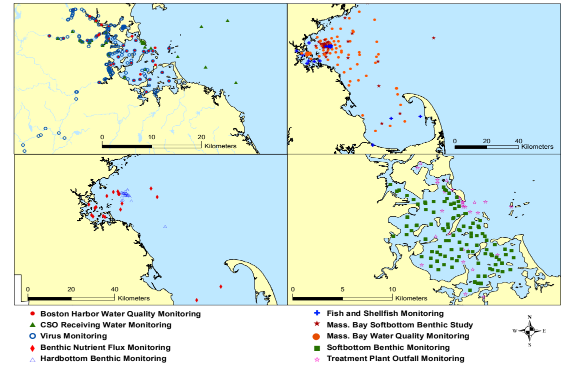

Figure 4. Long-term monitoring sampling locations for most water quality, effluent chemistry, fish and shellfish chemistry and pathology, sediment contaminants, plankton abundance, and benthic infauna conducted by MWRA and its consultants in Boston Harbor and its tributaries, Massachusetts Bay, and Cape Cod Bay since 1992. For each monitoring study, the quality control and assurance, sampling procedure and analytical methods, and the data are all well documented and can be requested from MWRA.

2. Examples of data use

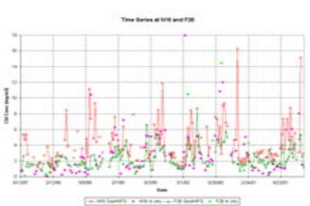

Figure 5a. A time series (open symbols) from September 1997 to December 2001 of chlorophyll *a* concentration constructed from Sea-viewing Wide Field-of-view Sensor (SeaWiFS) satellite data from the two locations in Massachusetts Bay. Solid symbols show the chlorophyll concentrations measured by MWRA in water samples at the same locations.

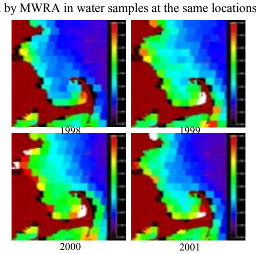

Figure 5b. SeaWIFS-derived annual mean chlorophyll concentration in Massachusetts Bay.

MWRA chlorophyll data are used to calibrate satellite images. Annual and seasonal chlorophyll maps derived from the SeaWiFS ocean color sensor were used to study the temporal (Figure 5a) and spatial (Figure 5b) variability of chlorophyll concentrations over a five-year period from fall 1997 to fall 2002. Data show large inter-annual variability in chlorophyll concentrations but no indication of increases specifically tied to outfall effects.

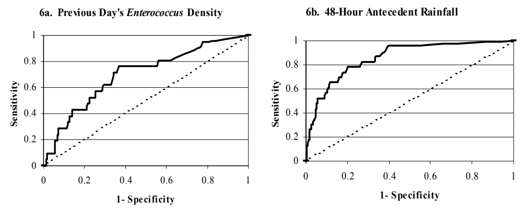

Figure 6. Receiver operating characteristic (ROC) curves of previous day *Enterococcus* density (a) and 48-Hour antecedent rainfall (b) for Constitution Beach. ROC curve analysis is used to compare the accuracy of indicator variables of bacterial beach water quality. For each indicator, sensitivity (true positive rate) is plotted against 1- specificity (false positive rate). Accuracy is measured by the area under the ROC curve. An area of one is simply perfect. For Boston beaches strongly affected by rainfall, antecedent rainfall is a more accurate predictor of high *Enterococcus* density than previous day *Enterococcus* density. All data are from MWRA beach water quality monitoring.

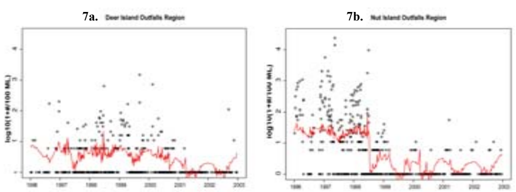

Figure 7. Observed (black circles) and predicted (red line) *Enterococcus* counts between 1996 and 2003 at Deer Island (a) and Nut Island (b) outfalls regions.

A statistical model, which accounts for possible serial correlation, was constructed to investigate the effect of the closure of the Nut Island Treatment Plant in 1998 and the cessation of discharges to the harbor in 2000 on pathogen counts in Boston Harbor. The model suggests that it was these 1998 and 2000 events which led to significant reductions in geometric mean and variability of pathogen counts observed in the former outfall regions in the harbor. It also suggests that rainfall is positively correlated with pathogen counts.

MWRA rain gauge and indicator bacteria data were used for this study.

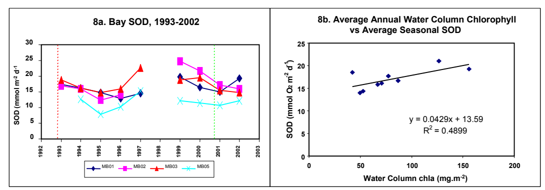

Figure 8. Data from across studies are synthesized to improve our understanding of ecological processes in Mass. Bay. Seasonal (May – Oct.) average in sediment oxygen demand (SOD) (a) show strong bay-wide inter-annual variability. Red dotted line indicates Dec. 1992 storm, green dotted line indicates the startup of the outfall in 2000. Average annual water column chlorophyll from 1992 to 2000 (b) is linearly related to and explains nearly 50% of the variation in average seasonal SOD There was no abrupt transition in inter-annual cycles of SOD as a result of outfall startup. Data are from MWRA benthic nutrient flux and water column studies.

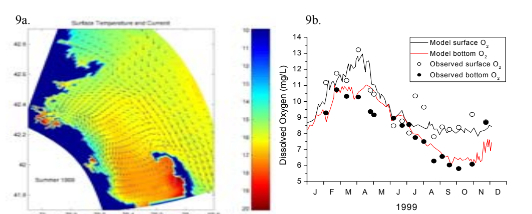

Figure 9. Surface temperature (color gradients) and current (arrows) in summer 1999 from Massachusetts Bay hydrodynamic model (a) and correspondence between model predictions and MWRA surface and bottom dissolved oxygen at a station near the new outfall in Massachusetts Bay (b).

MWRA water quality data is used to maintain, enhance and apply the existing Massachusetts Bay hydrodynamic model developed by USGS and water quality model developed by Hydroqual results. Since 2002, a long-term cooperative research project between MWRA and the UMass Boston is helping to understand the environmental issues with advanced models. Model results will be calibrated with observational data as was done with the existing model in 1999 (b) to assess the impacts of new outfall on the Mass. Bay water quality.

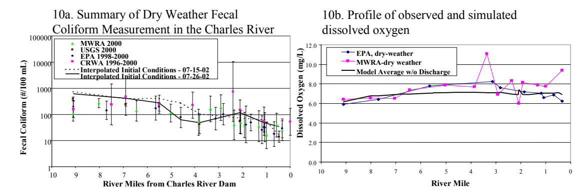

FIGURE 10. A two-dimensional hydrodynamic and water quality model of the Lower Charles River in Boston, Massachusetts was developed to simulate fecal coliform and dissolved oxygen in the river during storm events with varying precipitation and rainfall intensity and to evaluate the benefits of combined sewer overflow reductions and stormwater best management practices. Water quality measurements collected by MWRA and other agencies were used for model initial conditions (a) and model calibrations (b).

3. Summary

MWRA water quality database has been used intensively for management internally and for compliance with MWRA's discharge permit and court orders. It also serves as a data warehouse for the public and the academic community interested in the health, ecology and physical characteristics of Boston Harbor and Massachusetts Bay. Water quality data and reports are available to the public upon request. For complete list of the reports about our water quality monitoring studies, please visit our website at http://www.mwra.state.ma.us/harbor/enquad/.

4. References

Figure 1. Courtesy of **Battelle Ocean Sciences**, Duxbury, MA.

Figure 5a. **Subramaniam A.[†], C. Hunt[‡], and M. Mickelson[§]**. (in preparation) Temporal and spatial variability of satellite derived chlorophyll in Massachusetts Bay. [†] University of Maryland, College Park. [‡] Battelle Ocean Sciences. [§] MWRA.

Figure 5b. **Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies**, NASA, Goddard Space Flight Center, Greenbelt, MD.

Figure 6. **Morrison A.M.[†], K. Coughlin[†‡], J.P. Shine[†], B.A. Coull[†], A.C. Rex[‡] (in press)** Receiver Operating Characteristic (ROC) curve analysis of beach water quality indicator variables. Applied Environmental Microbiology. [†] Harvard University. [‡] MWRA.

Figure 7. **Houseman, E.A., B.A. Coull, L.M. Ryan, and Shine J.P.** (in preparation) Pathogen count in Boston Harbor: a case study. Harvard University.

Figure8. **Tucker J. [†], A. Giblin[†], B. Howes[‡], and C. Hopkinson[†],** 2003. Inter-annual variation in Massachusetts Bay: tantalizing linkages and monitoring lessons. Estuarine Research Federation, September 14018, Seattle, WA. [†]Marine Biological Laboratory. [‡] University of Massachusetts, Dartmouth.

Figure 9a. **Jiang M., M. Zhou and G T. Wallace,** 2003. Seasonal and inter-annual variability of the Massachusetts Bay ecosystem: A modeling and observation study. NEERS/SNECAFS joint meeting, Fairhaven, MA. University of Massachusetts, Boston.

Figure 9b. **HydroQual,** 2003. Bays Eutrophication Model (BEM): Model Verification for the Period 1998-1999. Boston: Massachusetts Water Resources Authority. Report 2003-03. 318 p.

Figure 10a. **Tsay[†] S., Y. Kinfu[†], D. Brocard[†], L. Marx[‡], W. Leo[‡],** 2003. Modeling wet weather impacts to Boston's Charles River. Water Environment Federation's Technical Exhibition and Conference, Los Angeles, CA. [†] Metcalf and Eddy. [‡] MWRA.

Figure 10b. **Metcalf and Eddy**. 2003. Draft report on development and calibration of the lower Charles River water quality model.