EXHIBIT H

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF: WATER QUALITY STANDARDS AND EFFLUENT LIMITATIONS FOR THE CHICAGO AREA WATERWAY SYSTEM AND THE LOWER DES PLAINES RIVER: PROPOSED AMENDMENTS TO 35 Ill. Adm. Code Parts 301, 302, 303 and 304	))))))))	R08-9 (Rulemaking - Water)

PRE-FILED TESTIMONY OF DAVID R. ZENZ

DISSOLVED OXYGEN ENHANCEMENT STUDIES

My name is Dr. David R. Zenz, P.E., and I am a Senior Associate with Consoer Townsend Envirodyne Engineers, Inc. (CTE). I was part of the CTE team which conducted the CTE studies of potential technologies and costs to directly increase dissolved oxygen in the Chicago Area Waterway System (CAWS) and am prepared to answer questions concerning these studies summarized in this pre-filed testimony.

I have a Ph.D in Environmental Engineering and am a registered professional engineer in the State of Illinois. Before joining CTE in 1997, I worked for 30 years in the Research and Development Department of the District. At the District, I eventually attained the position of Manager of Research and Technical Services. At CTE, I have worked on a variety of wastewater and sludge management projects. A resume detailing my education and experience is contained in Attachment 1.

Background

As part of the Use Attainability Analysis (UAA) of the CAWS, the Illinois Environmental Protection Agency (IEPA) requested that the Metropolitan Water Reclamation District of Greater Chicago (District) determine the technologies and costs of methods to directly increase the dissolved oxygen (DO) in the CAWS. CTE was commissioned by the District to perform this task.

IEPA specifically requested that the District conduct the following studies of DO enhancement methods as part of the UAA Study:

1. Study of Flow Augmentation of the Upper North Shore Channel
2. Study of Supplemental Aeration of the North and South Branches of the Chicago River
3. Study of Flow Augmentation and Supplemental Aeration of the South Fork of the South Branch of the Chicago River (commonly known as Bubbly Creek)

All three of these studies have been performed by CTE and these reports were submitted to the Illinois Pollution Control Board (IPCB) as part of the IEPA's proposal in this rulemaking proceeding. These reports can be found in Attachments QQ, PP and OO of the IEPA's initial filing.

Flow Augmentation of the Upper North Shore Channel

In general, flow augmentation involves bringing water from a nearby source to a waterway in order to increase its flow, eliminate stagnant conditions and improve water quality. The IEPA suggested that adding the effluent of the District's North Side plant to the headwaters of the Upper North Shore Channel could increase the DO of this CAWS waterway segment and eliminate stagnant conditions. A computer model developed by Dr. Melching of Marquette

University for simulating the dynamic flow and water quality conditions in the CAWS using DUFLOW software (Marquette University Model) – which is described in the testimony presented by Dr. Melching – was used for this task. It was determined that pumping 100 million gallons per day of effluent flow from the North Side plant, aerated to saturated conditions using U-tubes, to the headwaters of the Upper North Shore Channel at Wilmette, would bring DO levels to above 5 mg/l, 90% of the time. This waterway DO target was chosen since a rigid DO standard for the CAWS would be difficult to meet under all conditions (temperature, wet periods, etc). Thus 90% compliance with a 5 mg/l standard seemed to be a reasonable target given that at the time of this study IEPA had not made a final decision on a DO waterway standard. The estimate of probable cost for 100 million gallons per day of aerated flow augmentation to the Upper North Shore Channel included $60.0 million in capital costs, $0.74 million in annual operation and maintenance costs and a total present worth cost of $74.9 million. These costs are in June 2006 dollars.

<u>Supplemental Aeration of the North and South Branches of the Chicago River</u>

As requested by IEPA, a study was conducted of the supplemental aeration technologies and costs for the North and South Branches of the Chicago River. Again, the target DO was 5 mg/l to be achieved 90% of the time. The Marquette University Model was used to determine the amount of supplemental aeration needed to achieve this target standard on these waterways.

It was determined that 4 additional supplemental aeration stations would be required to meet the DO target - two on the North Branch, in addition to those that the District is currently operating on the waterway at Webster Avenue and Devon Avenue, and two on the South Branch.

After a review of potential supplemental aeration technologies, four supplemental aeration technologies were selected for an opinion of probable cost. These technologies are U-tubes, ceramic disc diffusers, jet aeration, and sidestream elevated pool aeration (SEPA). The District currently uses ceramic disc diffusers at its existing stations at Webster Avenue and Devon Avenue and SEPA technology at 5 aeration stations on the Calumet Area Waterways. The total capital costs ranged from $35.5 million to $89.9 million and the annual operating cost ranged from $0.55 million to $2.6 million. Total present worth costs ranged from $47.4 million to $132.8 million. These costs are in June 2006 dollars.

Flow Augmentation and Supplemental Aeration of Bubbly Creek

As requested by IEPA, a study was conducted to determine the technology and costs for flow augmentation (pumping of South Branch of the Chicago River flow to the headwaters of Bubbly Creek) and supplemental aeration of Bubbly Creek.

As for the previous studies, the Marquette University Model was used to determine the amount of flow augmentation and supplemental aeration to achieve a DO target of 5 mg/l in Bubbly Creek, 90% of the time.

It was found that flow augmentation (no aeration of the augmented flow) and supplemental aeration were needed to meet the target DO. Fifty (50) million gallons per day of augmented flow would be taken via a two mile force main from the South Branch of the Chicago River at Throop Street to the headwaters of Bubbly Creek. In addition, a total of three supplemental aeration stations would be located along the waterway, at the headwaters, midpoint and mouth of Bubbly Creek, respectively.

Similar to what was done for the supplemental aeration stations on the North and South Branches of the Chicago River, an opinion of probable cost was produced for four potential supplemental aeration technologies on Bubbly Creek. The total capital costs of the four technologies chosen for the cost estimate (U-tubes, sidestream elevated pool aeration, ceramic disc diffusers and jet aeration) in combination with 50 million gallons per day of flow augmentation ranged from $60.4 million to $102.9 million and the total annual operation and maintenance costs ranged form $1.0 million to $2.8 million. Total present worth costs ranged from $81.9 million to $145 million. These costs are in June 2006 dollars.

Developing an Integrated Approach for Directly Increasing the DO Level in the CAWS

The studies described previously conducted by CTE for the District as part of IEPA's UAA study included only parts of the CAWS. Also, these studies conducted in 2005-2006 utilized a waterway DO target different than that proposed by the IEPA in this rulemaking proceeding. Finally, the studies requested by IEPA did not include all potential technologies and did not attempt to integrate the various technologies. Such integration could lower the cost of achieving the previously assumed DO target. Only by looking at the CAWS as a whole can an overall cost-effective strategy be crafted for meeting the proposed IEPA DO waterway standards in this rulemaking proceeding.

Therefore, the District has asked CTE to conduct a new study to determine how various dissolved oxygen enhancement technologies could be integrated for the entire CAWS to meet the IEPA's proposed DO water quality standards. The CTE study was begun in December of 2007 and should be completed by mid 2009. This study will produce a level 4 cost estimate according to the Association for the Advancement of Cost Engineering (AACE) for a cost effective combination of technologies which will meet the IEPA proposed DO standards in this rulemaking proceeding.

<u>Order of Magnitude Cost Estimate for an Approach to Raise DO Levels in the CAWS and Achieve the IEPA's Proposed Target DO Levels in this Rulemaking Proceeding</u>

The District recognizes that the above described CTE Integrated Strategy Study may not be completed until after the IPCB's public hearings and deliberations in this rulemaking proceeding. Thus, the District asked CTE to produce a rough, order of magnitude, cost estimate to help the IPCB understand the cost implications of achieving the proposed IEPA DO standards for the CAWS at all times. The details of this rough cost estimate are contained in Attachment 2.

CTE's rough cost estimate is an order of magnitude cost estimate and is based upon a variety of assumptions which are subject to revision based upon the results of the above described on-going Integrated Strategy Study. This order of magnitude cost estimate is roughly equivalent to a level 5 estimate according to the cost estimate classification system recommended by the AACE and has an accuracy range of -30% to +50%.

Using the recently updated Marquette University Model of the CAWS, the following aeration enhancement of the CAWS was found necessary to meet the IEPA proposed DO standards for the entire CAWS, 100% of the time:

1) 18 Supplemental Aeration Stations
2) 3 Flow Augmentation Stations, including;

a. 100 million gallons per day of aerated North Side plant effluent for the Upper North Shore Channel

b. 50 million gallons per day of unaerated water from the South Branch of the Chicago River for Bubbly Creek

c. 182.6 million gallons per day of aerated Calumet plant effluent for the Little Calumet River

3) Existing SEPA and diffused air stations operated at full firm capacity

CTE estimated that the total capital cost for the above facilities to meet IEPA's proposed DO standard to be about $525 million. Total additional annual costs are estimated to be $6.9 million per year. Total present worth is estimated at $657 million. All costs are in June 2008 dollars.

This rough cost estimate is based on a variety of assumptions and simplifications that will be further evaluated and expanded in the detailed Integrated Strategy Study. The assumptions include the following:

1) Only one aeration technology - supplemental aeration using ceramic disc diffusers in the waterway with on-shore blower facility - was utilized.

2) Only one aerated flow augmentation technology - U-Tube aeration of pumped flow - was utilized.

3) The number, location, and sizing of the aeration stations for the cost estimate are based upon preliminary results from an updated Marquette University Model.

4) The Marquette University model was run for the representative "wet year" from October 1, 2000 to September 30, 2001.

5) The Marquette University model was calibrated for the 2001 wet year for this estimate. Further adjustment to include the dry year of 2003 and sensitivity analyses were not available for this estimate, but will be available for all integrated strategy compliance scenarios.

6) The preliminary flow augmentation modeling results do not address the issue of sediment re-suspension which may be a significant issue in Bubbly Creek and other parts of the CAWS.

7) The Marquette University Model assumes the District's existing SEPA and diffused air stations were operating at full firm capacity. It should be noted that some of the SEPA stations require further improvements to operate effectively at this capacity and that the diffused air stations are not typically operated at their full firm capacity. Costs for these improvements have not been developed or included in this estimate.

8) Inflation corrected costs derived from CTE's previous studies for the IEPA's UAA were extrapolated and form the main basis for this cost estimate. Present worth based on 20 year life with a present worth factor of 19.42 based on 3% interest rate and 3% inflation rate.

9) It was assumed that vacant land is available and can be purchased with minimal demolition costs. However, given the size of the stations and a brief review of aerial photography of the preliminary locations, this may not be possible at perhaps one-third of the locations. This issue will be further evaluated and addressed in the Integrated Strategy Study.

10) It is currently unclear what operational duration and frequency will be required to achieve 100% compliance. However, for this estimate, it was assumed all existing and additional aeration facilities will be required to operate at the equivalent of full capacity for one month per year, half capacity for 7 months of the year, and not required for the remaining 4 months of the year. This assumption is based partially on the current operations at the District's existing aeration facilities and may not apply for a worst – case year.

It should be noted that, for this cost estimate, no aeration stations were located in the Chicago River. It appears that supplemental aeration would not be effective for this waterway given that zero waterway flow often occurs creating dead zones between aeration stations. In downtown Chicago, there does not appear to be a source of readily available water for flow augmentation to alleviate this condition. However, this issue will be studied in greater detail as CTE's on-going Integrated Strategy Study progresses.

Based upon the preliminary results of the updated Marquette University Model runs for this cost estimate, the operation of many of the aeration stations to achieve compliance with IEPA's proposed DO standards may be relatively infrequent. Many of the stations will only be needed during large combined sewer overflow events which occur only a few times per year.

Achieving 100% compliance with the proposed DO standards will require a complex waterway DO monitoring network and an automated operating system. Providing and maintaining this monitoring network, automated system, and the infrequently used aeration stations (or other DO enhancement systems) would be a significant challenge and costs for this approach have not been included here. There are also concerns about the relatively large size of the aeration stations required to meet the proposed DO standards, 100% of the time. These concerns are related to whether it will be physically practical to effectively locate these stations in the various parts of the CAWS.

Although the updated Marquette University Model provides a sufficient level of detail for these planning studies, this one-dimensional model may not describe the complex conditions that can exist in some segments of the CAWS, including impacts due to density currents, sediment re-suspension, and mixing zone effects. Therefore, before proceeding to design of a CAWS DO enhancement system, consideration should be given to a more detailed modeling approach to produce a final aeration system sizing and location.

In short, there are numerous unknowns at present that may significantly affect the total cost for the effort as presented in this testimony. In addition, the unique and complex environmental and physical conditions in the CAWS present numerous engineering challenges to designing and operating a DO enhancement system. Since all these challenges have not been addressed or even perhaps identified at this point, it cannot be stated that it is technically feasible to meet the proposed standards under all waterway conditions. However, it is hoped that many of these can be identified and addressed through the on-going integrated strategy approach and the final design process.

Construction Schedule

Design and construction of the preliminary systems discussed in this testimony to meet the proposed DO standards in this rulemaking proceeding will involve a significant time expenditure. Pilot and or full scale studies lasting at least 2 years would be required to develop design criteria for the proposed facilities. Such studies were necessary for the District's SEPA stations on the Calumet Area Waterways. Design of the various facilities located throughout the CAWS would necessitate at least 3.5 years due to the need for lengthy field studies, land acquisitions, and further computer modeling to confirm site selection and aeration station sizing. Lastly, constructing the various facilities, perhaps the largest waterway aeration system in the U.S., would take at least 3 years. Therefore the total time for the construction schedule would be at least 8.5 years.

Testimony Attachments

1. Resume of Dr. David R. Zenz
2. Order of Magnitude Cost Estimate for Supplemental Aeration and Flow Augmentation of the Chicago Area Waterway System (CAWS)

Respectfully submitted,

By: *David Zenz*

ATTACHMENT 1

RESUME OF DR. DAVID R. ZENZ

David R. Zenz, PE, Ph.D.

Title
Senior Consulting Engineer

Registrations
PE, IL - 1972

Years of Experience
38

Education
PhD, Environmental Engineering, Illinois Institute of Technology, 1968
MS, Environmental Engineering, Illinois Institute of Technology, 1967
BS, Civil Engineering, Illinois Institute of Technology, 1965

Dr. Zenz worked for nearly 30 years in the Research and Development Department of the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) in various capacities including:

Manager of Research and Technical Services, 1991-1997
Coordinator of Research, 1972-1990
Head of the Wastewater Treatment Research Section, 1970-1972
Research Project Leader, 1968-1970

For the past several years, Dr. Zenz has worked in CTE's wastewater section on various municipal wastewater treatment and biosolids management projects.

Project Experience

Northside Water Reclamation Plant - Infrastructure and Process Needs Feasibility Study, Metropolitan Water Reclamation District, Chicago, Illinois. Task Manager for the Water Quality Strategy. CTE will assist the District to prepare a comprehensive water quality strategy which projects a reasonable "envelope" of both water quality criteria for affected Chicago Area Waterways and effluent limits for the NSWRP over the planning period. Specifically, this report will address the potential technologies, costs, and impacts associated with the following issues:

- Disinfection
- Nutrient Removal
- End of Pipe Treatment of CSOs
- Supplemental Aeration of Chicago Waterways
- Flow Augmentation for the Upper North Shore Channel and Bubbly Creek

For this project, the planning period will be considered to be up to the year 2040. Present worth financial analyses of alternatives will be based on the year 2040. Salvage value for concrete will be based on a 50 year life.

Long Range Facility Plan, Urbana/Champaign Sanitary District, Urbana, Illinois. Project Engineer in the development of a Long Range Facility Plan for the Urbana/Champaign Sanitary District. This sanitary district treats flows at two treatment plants totaling nearly 30 mgd. This plan included biological phosphorus removal, cloth media tertiary filters, and centrifuge dewatering of biosolids. Dr. Zenz participated in pilot-plant testing of cloth media filters for tertiary treatment and centrifuge dewatering of biosolids. These tests were used to determine the feasibility of the processes for application at the Urbana/Champaign Sanitary District. These studies resulted in the implementation of these processes at the Sanitary District.

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Anthony Ragnone Wastewater Treatment Plant - Long Range Facility Plan, Genesee County Drain Commission - Water and Waste Services, Flint, Michigan. Project Engineer in the development of a Long Range Facility Plan for Genesee County, Michigan. This plan was for a 30 mgd treatment plant and included biological phosphorus removal and a full-scale stress test of biological phosphorus removal at the existing treatment plant.

Long Range Biosolids Management Plan, North Shore Sanitary District, Illinois. Project Manager for a Long Range Biosolids Management Plan for the North Shore Sanitary District. This work included biosolids from 3 plants with total flows of 60 mgd. The final plan includes fluidized bed drying of biosolids followed by high temperature incineration to produce a glass aggregate.

Ammonia Removal Alternatives Study, DeKalb Sanitary District, DeKalb, Illinois. Project Manager for a study of ammonia removal alternatives for the DeKalb, Illinois Sanitary District. In this study, treatment alternatives were developed to meet new stringent ammonia effluent standards.

Headworks Odor Control System, City of West Chicago, Illinois. Project Manager for the design of an odor control system for the headworks of the City of West Chicago Treatment Plant. Based upon an alternative study, Dr. Zenz designed an activated carbon system to treat the headworks off-gases.

Air Quality Permits. Dr. Zenz was the project manager for preparation of air quality permit applications for two City of Chicago Drinking Water Pumping Stations. Air permits were ultimately issued for both plants by the Illinois Environmental Protection Agency.

Mr. Zenz prepared an air quality permit application for a 150 dry ton/day heat drying plant to be located at the MWRDGC's Stickney Water Reclamation Plant. This facility included a venturi scrubber, a baghouse and thermal oxidizer for air pollution control. A draft permit for the facility was issued for this facility in 2002 as a result of this application. For this large air emission source, the following regulatory issues were addressed:

- Best Available Control Technology (BACT)
- New Source Review (NSR)
- Prevention of Significant Deterioration (PSD)
- Title V Operating Permit

Stickney Water Reclamation Plant - Centrifuge Expansion, Metropolitan Water Reclamation District, Stickney, Illinois. Project Engineer for the design of a 400 dry ton/day centrifuge dewatering expansion for the Metropolitan Water Reclamation District. Dr. Zenz participated in the design of the polymer dosing and odor control systems for this facility.

Hanover Park Landfill Leachate Study, Village of Hanover Park, Illinois. Project Manager for a two full-scale tests of treatment of landfill leachate at the Village of Hanover Park Treatment plant. This study was designed to determine if the Village should consider accepting such leachate for treatment on a permanent basis.

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Warwick, Rhode Island - Nutrient Removal. Technical Advisor for the planning and design of a biological phosphorus and nitrogen removal system for City of Warwick. Final design used the UCT process for implementation.

McMurdo Research Station, Antarctica - Denitrification. Project Engineer for planning and design of a nitrification/denitrification wastewater treatment process at the South Pole.

Downers Grove Sanitary District, Long Range Biosolids Plan. Project Manger for a study of methods to produce Class A Biosolids for the Downers Grove Sanitary District. An engineering study was conducted to determine the feasibility and cost of various methods to meet the Class A Pathogen requirements under the Federal Part 503 Sewage Sludge Regulations.

Phosphorous and Nitrogen Removal, Wheaton, Illinois. Project Manager for a study of methods to meet future phosphorus and nitrogen standards for the Wheaton Sanitary District. A study was conducted to determine the best method of converting and expanding on existing 9.0 mgd treatment plant to meet new standards for nitrogen and phosphorous removal.

Hinsdale Sanitary District, Collection System Study. Project Engineer for a study of the collection system of the Hinsdale (Illinois) Sanitary District. This study included flow monitoring at various points in the collection system and the development of a mathematical model.

West Chicago - Design/Build of Headworks Pumping Station. Project Engineer for a design/build project to renovate the existing headworks pumping station for the West Chicago Wastewater Treatment Plant. The project involves replacement of the existing screw pumps with submersible pumps.

Illinois Association of Wastewater Agencies - Nutrient Removal Study. Project Manager for a study of the cost and feasibility of phosphorous and nitrogen removal at Illinois Municipal Wastewater Treatment Plants. This study consisted of a literature review and cost analysis to determine the technical feasibility and cost to municipal wastewater treatment agencies for meeting new water quality standards for nitrogen and phosphorus.

Experience Prior to Joining CTE

During his tenure with the MWRDGC, Dr. Zenz was connected with virtually every aspect of the MWRDGC's operation, including:

- Development and operation of the MWRDGC's 15,000 acre sludge application to land project in Fulton County, Illinois
- Development and operation of the MWRDGC's sludge give-away program in the Greater Chicago area.

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Development and operation of the following sludge processing systems currently used at the MWRDGC, including:

- Anaerobic Digestion
- Centrifugal Dewatering
- Agitation Drying
- Gravity Thickening
- Gravity Belt Thickening
- Centrifugal Thickening

Development and operation of wastewater treatment operations currently used at the MWRDGC, including

- Two stage biological nitrification
- Single stage biological nitrification
- Sand filtration
- Chlorination-Dechlorination
- In-stream Aeration

During his tenure at the MWRDGC, Dr. Zenz was involved in pilot and full testing of various wastewater treatment and sludge processing systems, including:

Wastewater Treatment Systems

Bio-Discs
Biological Phosphorus Removal
Chemical Phosphorus Removal
Biological Denitrification
Ozonation
Ion-Exchange
Multi-Media Filtration

Sludge Processing Systems

Alkaline Stabilization
Composting
Vacuum Filtration
Belt-Filter Dewatering
Thermophilic Digestion
High Energy Radiation

Dr. Zenz was responsible for coordinating the work needed to obtain air permits for the MWRDGC's treatment plants. This work included:

- Estimating fugitive air emissions based upon available mathematical models.
- Estimating air emissions based upon stack testing.
- Estimating air emissions based upon established emission factors

In 1994-1996, Dr. Zenz was involved in obtaining a Title V permit for the MWRDGC's Stickney Plant and Federally Enforceable State Operating Permits for the Northside and Calumet Plants. This effort included:

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- Estimating fugitive air emissions from the wastewater treatment systems of the MWRDGC's Major Plants using the Bay Area Sewage Toxic Emissions (BASTE) Model and the USEPA's Water 7 Model.
- Performing required sewage analysis for 107 Hazardous Air Pollutants (HAP's) and 82 Volatile Organic Compounds (VOC's).
- Estimating emissions from other sources within the MWRDGC's major plants using established emission factors.
- Working with a consultant in interpreting the applicable Air Pollution Regulations.
- Assisting in the preparation of air permit applications for the MWRDGC Major Plants

ATTACHMENT 2

ORDER OF MAGNITUDE COST ESTIMATE FOR SUPPLEMENTAL AERATION AND FLOW AUGMENTATION OF THE CHICAGO AREA WATERWAY SYSTEM (CAWS)

ORDER OF MAGNITUDE COST ESTIMATE FOR SUPPLEMENTAL AERATION AND FLOW AUGMENTATION OF THE CHICAGO AREA WATERWAY SYSTEM (CAWS)

Prepared by

CTE | AECOM

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For

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

July 2008

Introduction

An Integrated Strategy study is currently underway to determine the most cost-effective approach, utilizing a variety of technologies, to meet the IEPA's proposed dissolved oxygen standards for the CAWS. This study, however, will not be completed until the middle of 2009. The District recognizes that the IPCB has an immediate need for information on the cost of meeting the IEPA proposed dissolved oxygen standards and therefore requested that CTE prepare an order of magnitude cost estimate for meeting the IEPA proposed standards. This document summarizes the approach and assumptions utilized to prepare this order of magnitude cost estimate.

Basis of Cost Estimate

CTE's estimate is an order of magnitude cost estimate and is based upon a variety of assumptions which are subject to revision based upon the results of the above described on-going Integrated Strategy study. This order of magnitude cost estimate is roughly equivalent to a level 5 estimate according to the cost estimate classification system recommended by the AACE and has an accuracy range of -30% to +50%.

Assumptions

The following are the assumptions and simplifications utilized to prepare this rough cost estimate:

1) Only one aeration technology - supplemental aeration using ceramic disc diffusers in the waterway with on-shore blower facility - was utilized.
2) Only one aerated flow augmentation technology - U-Tube aeration of pumped flow - was utilized.
3) The number, location, and sizing of the aeration stations for the cost estimate are based upon preliminary results from an updated Marquette University Model. A summary of the approach and results of this effort are included as Attachment A.
4) The Marquette University model was run for the representative "wet year" from October 1, 2000 to September 30, 2001.
5) The Marquette University model was calibrated for the 2001 wet year for this estimate. Further adjustment to include the dry year of 2003 and sensitivity analyses were not available for this estimate, but will be available for all integrated strategy compliance scenarios.
6) The preliminary flow augmentation modeling results do not address the issue of sediment re-suspension which may be a significant issue in Bubbly Creek and other parts of the CAWS.
7) The Marquette University Model assumes the District's existing SEPA and diffused air stations were operating at full firm capacity. It should be noted that some of the SEPA stations require further improvements to operate effectively at this capacity and that the diffused air stations are not typically operated at their full firm capacity. Costs for these improvements have not been developed or included in this estimate.
8) Inflation corrected costs derived from CTE's previous studies for the IEPA's UAA were extrapolated and form the main basis for this cost estimate. Present worth based on 20 year life with a present worth factor of 19.42 based on 3% interest rate and 3% inflation rate.

9) It was assumed that vacant land is available and can be purchased with minimal demolition costs. However, given the size of the stations and a brief review of aerial photography of the preliminary locations, this may not be possible at perhaps one-third of the locations. This issue will be further evaluated and addressed in the Integrated Strategy Study.

10) It is currently unclear what operational duration and frequency will be required to achieve 100% compliance. However, for this estimate, it was assumed all existing and additional aeration facilities will be required to operate at the equivalent of full capacity for one month per year, half capacity for 7 months of the year, and not required for the remaining 4 months of the year. This assumption is based partially on the current operations at the District's existing aeration facilities and may not apply for a worst – case year.

It should be noted that these assumptions will be further evaluated and expanded in the detailed Integrated Strategy.

Required Facilities

As stated above, the recently updated Marquette University Model of the CAWS was utilized to determine the additional aeration facilities necessary to meet the IEPA proposed DO standards for the entire CAWS, 100% of the time. Table 1 summarizes the estimated facilities required, based on the modeling results.

TABLE 1
Required Facilities for 100% Compliance with Proposed DO Standards in the CAWS

CAWS REACH	LOCATION	STATION OXYGEN CAPACITY (GRAMS/SEC.)
UNSC	Central Street	80
UNSC	0.2 miles downstream from Simpson St.	80
UNSC	0.4 miles upstream from Main Street	80
UNSC	Aerated Flow Augmentation Station at NSWRP	18
NBCR	0.3 miles upstream from Diversey Parkway	80
SBCR	0.2 miles downstream from NBCR junction	80
SBCR	1.5 miles downstream from NBCR junction	80
SBCR	Halsted St.	80
Bubbly Creek	Mouth of Bubbly Creek	80
Bubbly Creek	Approximate midpoint of Bubbly Creek	80
Bubbly Creek	Headwaters of Bubbly Creek	80
Bubbly Creek	Flow Augmentation Station at Mouth of Bubbly Creek	N/A
CSSC	0.24 miles upstream from Western Avenue	80
CSSC	0.8 miles downstream from Western Avenue	80
CSSC	Cicero Avenue	80
CSSC	1.2 miles upstream from Willow Springs	80
CSSC	1.8 miles downstream from Willow Springs	80
Little Calumet (North)	0.35 miles upstream of Little Calumet River Junction	80
Cal-Sag Channel	1.8 miles upstream from SEPA Station No. 4	70
Cal-Sag Channel	1.3 miles upstream from Route 83 (Calumet-Sag)	80
Little Calumet	Aerated Flow Augmentation Station at CWRP	33

As shown in the table, the majority of the facilities are assumed to be ceramic disc diffuser type aeration stations. However, flow augmentation facilities previously recommended for the UAA for the UNSC and Bubbly Creek also are required. In addition, a new aerated flow augmentation station was required for the Calumet and Little Calumet reaches of the CAWS.

The model results did not include supplemental aeration for the Grand Calumet and Chicago River reaches of the CAWS. It should be noted that supplemental aeration would not be effective for the Chicago River given that zero waterway flow often occurs that would create dead zones between aeration stations. In downtown Chicago, there does not appear to be a source of readily available water for flow augmentation to alleviate this condition. This issue will be studied in greater detail as the on-going Integrated Strategy study progresses.

Order of Magnitude Cost Estimate

Based upon the evaluations and assumptions above, CTE estimated the total Capital Cost for meeting the IEPA's proposed dissolved oxygen standards to be about $525 million. Total annual costs are estimated to be $6.9 million. The total present worth is estimated at approximately $657 million. Table 2 on the following page presents an itemized listing of costs for each waterway segment.

Based upon the preliminary results of the Marquette University Model runs for this cost estimate, the operation of many of the aeration stations to achieve compliance with IEPA's proposed DO standards may be relatively infrequent. Many of the stations will only be needed during large combined sewer overflow events which occur only a few times per year. Although an operational duration and frequency has been assumed to complete this cost estimate, achieving 100% compliance with the IEPA's DO standards may require a complex waterway DO monitoring network and an automated operating system. Providing and maintaining this monitoring network and automated system, and the infrequent use of these aeration stations (or other DO enhancement systems) would be a significant challenge and costs for this approach have not been included here.

It should again be made clear that the order of magnitude estimate of costs presented here is rough and that the evaluations, simplifications, assumptions, operational parameters, unit costs, etc. are all subject to change, depending upon the results of the Integrated Strategy.

TABLE 2

Cost Estimate for 100% Compliance with Proposed DO Standards in the CAWS

Supplemental Aeration Station Location	Aeration Capacity (gps)	Capital Cost†			Operations & Maintanence†			Total Present Worth Cost†
		Capital Cost	Land Acquisition Cost	Total Capital Cost	Unit O&M Cost ($/hr)	Total Annual Cost	Total Present Worth O&M Cost	
UNSC[1]	18	$63,800,000	NONE[3]	$63,800,000	110.53	$370,000	$7,100,000	$70,900,000
UNSC #1	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
UNSC #2	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
UNSC #3	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
North Branch	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
South Branch #1	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
South Branch #2	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
South Branch #3	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
Bubbly Creek #1	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
Bubbly Creek #2	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
Bubbly Creek #3	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
Bubbly Creek[2]	N/A	$31,900,000	$1,280,000	$33,200,000	61.63	$150,000	$2,900,000	$36,100,000
CSSC #1	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
CSSC #2	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
CSSC #3	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
CSSC #4	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
CSSC #5	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
Little Calumet (North)	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
Cal-Sag Station #1	70	$14,300,000	$1,280,000	$15,600,000	76.92	$260,000	$5,000,000	$20,600,000
Cal-Sag Station #2	80	$16,300,000	$1,280,000	$17,600,000	86.86	$290,000	$5,600,000	$23,200,000
Little Calumet[4]	33	$111,000,000	$1,280,000	$113,000,000	196.57	$700,000	$12,600,000	$125,600,000
SEPA Station No. 3[5]	N/A	None	None	None	44.56	$150,000	$2,900,000	$2,900,000
SEPA Station No. 4[5]	N/A	None	None	None	44.56	$150,000	$2,900,000	$2,900,000
SEPA Station No. 5[5]	N/A	None	None	None	48.70	$160,000	$3,200,000	$3,200,000
Totals				**$524,800,000**	**$2,100**	**$6,870,000**	**$131,800,000**	**$656,600,000**

† Costs were taken from TM-4WQ, pgs. B-9 and C-9 for the 80 gps station,
TM-5WQ, pgs. 5-16, G-2, and G-3 for UNSC, and TM-6WQ, pgs. 6-17 and I-2 for Bubbly Creek.
All capital costs were adjusted to 2008 dollar values based on Engineering News-Record (ENR)
National Construction Cost Indices (CCI) of 7699.59 for June 2006 and 8184.94 for June 2008.
Land acquisition and operation and maintenance costs from previous TMs were inflated at 3% per year to June 2008
Present worth is based on a 20 year life with NPV value of 19.42 based on a 3% interest rate and 3% inflation rate.
Annual O&M costs assume operating the equivalent of full firm capacity for 1 month, half capacity for 7 months, and non-operational 4 months each year.
Costs are for additional facilities required to meet 100% compliance with proposed DO standards.

1 Cost includes an 18 g/s U-Tube aerator and a 100 mgd firm capacity pump station and forcemain for flow augmentation and aeration.

2 Cost includes one 50 mgd firm capacity pump station and forcemain.

3 These facilities can be accommodated at the North Side WRP based on the Master Plan 2040 layout.

4 Costs include a 33 gps U-Tube aerator and a 182.6 mgd firm capacity pump station and forcemain.

5 Power usage for SEPA pumps provided by MWRDGC.

ATTACHMENT A

WATER-QUALITY SIMULATION IN SUPPORT OF THE DEVELOPMENT OF AN INTEGRATED STRATEGY TO MEET DISSOLVED OXYGEN STANDARDS FOR THE CHICAGO AREA WATERWAYS

-Supplementary Aeration Stations-
100% Compliance (Rough Cut)

Institute for Urban Environmental Risk Management
Marquette University, Milwaukee WI 53201-1881

TECHNICAL MEMORANDUM

WATER-QUALITY SIMULATION IN SUPPORT OF THE DEVELOPMENT OF AN INTEGRATED STRATEGY TO MEET DISSOLVED OXYGEN STANDARDS FOR THE CHICAGO AREA WATERWAYS

-Supplementary Aeration Stations- 100% Compliance (Rough Cut)

SUBMITTED TO

The Metropolitan Water Reclamation District of Greater Chicago

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Department of Civil and Environmental Engineering

Milwaukee, Wisconsin

July 2008

Background

In early 2003, the Illinois Environmental Protection Agency (IEPA) initiated an Use Attainability Analysis (UAA) for the Chicago Area Waterway System with Camp, Dresser & McKee (CDM) as the lead consultant and the Metropolitan Water Reclamation District of Greater Chicago (District) promising to provide data and modeling support for the UAA process. As a result of the UAA process a number of water-quality problems have been identified in the CAWS.

Simulations done by Marquette University (Alp and Melching, 2006) and by the District Research and Development (R & D) Department and subsequent preliminary design and cost analysis done by Consoer Townsend Envirodyne (CTE) Engineers (CTE, 2006, 2007a-c) indicated the following results.

1) Treatment of gravity combined sewer overflows (CSOs) would result in little water quality benefit at a large cost, and, thus, such treatment was eliminated as a potential approach to improve dissolved oxygen (DO) concentrations in the CAWS.
2) Transfer of aerated (to saturation) effluent from the North Side Water Reclamation Plant (WRP) to the upstream end of the North Shore Channel (NSC) could substantially improve DO concentrations in the upper NSC, and, thus this is a possible component of an integrated plan to improve DO in the CAWS.
3) Transfer of unaerated flow from the South Branch Chicago River (SBCR) to the upstream end of the South Fork of the South Branch Chicago River (commonly known as Bubbly Creek) and supplemental aeration of Bubbly Creek could substantially improve DO in Bubbly Creek, and, thus, this is a possible component of an integrated plan to improve DO in the CAWS.
4) Addition of supplemental aeration along the North Branch Chicago River (NBCR), SBCR, and Chicago Sanitary and Ship Canal (CSSC) could substantially improve DO throughout the CAWS, and, thus, this is a possible component of an integrated plan to improve DO in the CAWS.

In all these findings, the target for substantially improved DO concentrations is exceed 5 mg/L at least 90% of the time under the summer and fall conditions in 2001 and 2002. However, the above water quality management alternatives were evaluated individually. There are potential benefits of integrating these alternatives into one integrated strategy for water quality improvement in the CAWS. In 2007, the District retained CTE to develop such an integrated strategy for meeting the proposed DO standards for the CAWS. CTE's integrated strategy study is ongoing and is planned to be completed in mid-2009. The District recognizes that the IPCB has an immediate need for information on the cost of meeting the IEPA proposed dissolved oxygen standards and therefore requested that CTE prepare an order of magnitude cost estimate for meeting the IEPA proposed standards, and the proposed aeration stations and flow augmentation facilities in this memorandum are provided to support this particular effort.

This memorandum summarizes outcomes of the water quality simulations in support of the development of an integrated strategy to meet the proposed dissolved oxygen standards 100% of the time for the Chicago Area Waterways. In the study described in this memorandum, the integrated strategy includes flow augmentation, supplemental aeration, and the combination of both in the CAWS. The proposed dissolved oxygen standards for the CAWS aquatic life use designations, which are part of the IEPA's proposal to the Illinois Pollution Control Board for rulemaking, are given in Table 1.

Table 1. The proposed dissolved oxygen standards for the Chicago Area Waterway System (CAWS) aquatic life use designations

Designation	March-July Hourly minimum (mg/L)	August-February (mg/L)	
		Hourly Minimum	7-day average of Daily minima
CAWS Aquatic life Use A Waters	5.0	3.5	4.0
CAWS and Brandon Pool Aquatic life Use B waters	3.5	3.5	4.0

DUFLOW Water Quality Model

Improvements to the Model and Its Input

In the following sections, improvements to the DUFLOW model developed for the Chicago Waterway System subset of the CAWS by Marquette University (Alp and Melching, 2006) are explained. There are three major improvements to the previous model. First, new CSO locations on the North Shore Channel have been added to the previous DUFLOW model. Second, sediment oxygen demand (SOD) values were adjusted based on the measured SOD values. The third improvement is to use the CSO discharges simulated by the U.S. Army Corps of Engineers (Corps). Moreover, the downstream boundary was moved from Romeoville to the Lockport Controlling Works on the CSSC.

Temporal and Spatial Distribution of CSO Inputs

In the previous applications of the Marquette Model (e.g., Alp and Melching, 2006) the inflows from gravity CSOs were estimated. During storm events, the measured and estimated (for ungaged tributaries) inflows were insufficient for simulated water-surface elevations at Romeoville to match the measured water-surface elevations. If the simulated water-surface elevation is substantially below the observed value, the hydraulic model is artificially dewatering the CAWS in order to match the observed flow at Romeoville indicating that the CAWS is receiving insufficient inflow without considering the gravity CSOs. Thus, gravity CSO volume (starting with the volume imbalance between measured outflows at Romeoville and measured and estimated inflows) was added until reasonable water-surface elevations were simulated at Romeoville. This gravity CSO volume was added at the representative CSO inflow locations on a per area basis at the time of operation of the Racine Avenue Pumping Station.

The estimated gravity CSO volumes yielded excellent hydraulic results for all periods considered (Shrestha and Melching, 2003; Neugebauer and Melching, 2005; Alp and Melching, 2006). However, the percentage of impervious area varies substantially throughout the CAWS watershed and the rainfall varies substantially throughout the CAWS watershed and among events. Thus, the runoff and related pollutant loads must vary throughout the CAWS watershed on more than a per area basis, and the time distribution of CSO flows is not uniform and may be longer or shorter than the operation hours of the Racine Avenue Pumping Station. Thus, simulations of flows, loads, and water-quality conditions could potentially be improved if the CSO discharges could be reliably modeled. Thus, CTE (2007d) suggested that "The certainty in CSO and pump station volumes could be improved through the development of a collection system model." and "Identifying locations where CSO discharges are more frequent is the first step to improve the CSO volume input in the model."

Currently the rated pump capacities and pump on-and-off times are used to develop an hourly time series of pumping station flows whose volume is within 1 or 2 percent of the exact volume from on-and-off times and rated pump capacities. Thus, a collection system model is unlikely to improve the certainty of the pump station volumes. However, a collection system model could potentially improve the spatial and temporal distribution of the estimated gravity CSOs. For the purposes of the design of the Tunnel and Reservoir Plan (TARP) the U.S. Army Corps of Engineers (Corps) developed a series of models to simulate the surface and subsurface runoff in the TARP drainage area (which includes the CAWS watershed); the flows in the major interceptors; the distribution of the flows to the Water Reclamation Plants or potentially to gravity CSO outfalls or TARP drop shafts; and the flows in the TARP tunnels. These models are run by the Corps for each water year in support of the Lake Michigan Diversion Accounting. The gravity CSOs simulated by these models during the months in which water from the CAWS flowed to Lake Michigan at Wilmette and/or the Chicago River Controlling Works were obtained by Marquette University from the U.S. Army Corps of Engineers for 1990 through 2002 as part of the project "Evaluation of Procedures to Prevent Backflows to Lake Michigan from the Chicago Waterway System" for the District. Evaluations for events in 2001 and 2002 of simulated water-surface elevations in the CAWS for the case of gravity CSO flows from the Corps models and pumping station flows from the operation records have yielded reasonable results throughout the CAWS in comparison to the results for the original input to the Marquette Model (Alp and Melching, 2008). Hence, in the study reported here, simulated gravity CSO flows obtained from the Corps are used in simulations to identify an integrated strategy for DO improvement in the CAWS. Detailed discussion of the Corps models (a combination of the Hydrological Simulation Program-Fortran, Special Contribution Area Loading Program, and Tunnel Network Model) is given in Espey et al. (2004).

New Representative CSO Locations on the North Shore Channel

There are nearly 240 CSOs in the modeled portion of the CAWS watershed. Since it is practically difficult to introduce all CSO locations in the modeling, in the previous CAWS DUFLOW model, 28 representative CSO locations were identified and flow distribution was done on the basis of drainage area for each of these locations. Whereas this worked fine for the system wide simulations (Alp and Melching, 2006) and the results were used in the preliminary evaluation of potential water-quality improvement alternatives (CTE, 2006, 2007a-c), it is inadequate for a more detailed evaluation of water-quality improvement options. This is particularly true when considering conditions on the upper NSC where CSO flows dominate the stream flow and water quality conditions in the channel. For the NSC, the original Marquette Model had four CSO inflow points that represent 24 TARP drop shaft overflow locations (there may be more than one CSO per drop shaft drainage area). With only four inflow points, the CSO flows can overpower the flows transferred as part of flow augmentation requiring higher amounts of transfer than might be needed if the flows were distributed as in reality. Thus, 19 gravity CSO locations, representing 24 TARP drop shaft overflow locations, are included as CSO inflow points to the revised DUFLOW model and the flows were redistributed to the these locations using the Corps models.

In other areas of the CAWS the CSO flows are not as dominant and the representative CSO locations were not changed outside of the NSC.

Improvements to the Simulation of Sediment Oxygen Demand (SOD)

DUFLOW includes the DiToro and Fitzpatrick (1993) sediment flux model with a model of water quality in the water column. This sediment flux model distinguishes among transported material that flows with water, bottom materials that are not transported with the water flow, and pore water in bottom materials that are not transported but that can be subject to similar water-quality interactions to those for the water column. In DUFLOW (2000), SOD is simulated as a diffusive exchange of oxygen between the water column and the active (top) sediment layer (which has it own carbonaceous biochemical oxygen demand (CBOD), DO, nutrients, etc. in the pore water). In the previous DUFLOW Model (e.g., Alp and Melching, 2006), SOD was calibrated based on a survey of sediment depth and composition conducted by the District at 20 locations in the CAWS. In this study, SOD is recalibrated and compared with SOD values measured in 2001. The average simulated SOD values and measured SOD values are listed in Table 2.

Measured and simulated SOD values are in close agreement for most of the locations in the CAWS. The biggest difference between the simulated and measured SOD values is observed on the North Branch Chicago River at Belmont Avenue. In order to achieve the significant drop in the DO concentration observed between Addison Street and Fullerton Avenue, a higher SOD value was used in this section of the CAWS. While a similar DO trend is observed at Fullerton Avenue and Addison Street and there are just 1.9 miles between Addison Street and Fullerton Avenue, the average measured DO concentration at Fullerton Avenue is significantly lower than that of Addison Street. In the calibration process, since it is difficult to obtain a significant DO drop by manipulating $CBOD_5$ and ammonium kinetic rates in such a short distance, SOD was increased within this section of the model to capture the substantial DO decrease between Addison Street and Fullerton Avenue. Existence of a wide area on the NBCR at Diversey Parkway that has shallow water and deep sediments off to the side of the river channel makes the assumption of using high SOD values in this area reasonable.

Table 2. Comparison of measured and average simulated (for July 12 to November 9, 2001) sediment oxygen demand (SOD) values at various locations in the Chicago Area Waterways

	Average Simulated SOD ($g/m^2/day$)	**Measured SOD @ 20°C ($g/m^2/day$)**	**Measured Date**
Simpson St. (NSC)	2.58	3.89	12/5/01
Main St. (NSC)	3.86	1.85	12/6/01
Belmont Ave. (NBCR)	8.71	3.10	10/24/01
Grand Ave. (NBCR)	2.64	1.80	10/23/01
LaSalle St. (Chicago River)	0.67	0.77	10/22/01
Congress Pkwy. (SBCR)	1.22	1.93	10/26/01
Halsted St. (SBCR)	1.35	3.32	10/29/01
Interstate Hwy. 55 (Bubbly Creek)	3.55	3.64	11/2/01
Cicero Ave. (CSSC)	1.25	1.71	10/31/01
Lockport Powerhouse (CSSC)	2.70	2.71	11/7/01
Conrail Railroad (Little Calumet River, LCR)	1.16	0.59	11/14/01
Indiana Ave. (LCR)	1.15	1.25	11/20/01
Halsted St. (LCR)	1.33	1.14	11/21/01
Division St (Cal-Sag)	1.23	1.07	11/21/01
Southwest Hwy. (Cal-Sag)	1.09	0.80	11/6/01
Route 83 (Cal-Sag)	1.03	0.63	11/5/01

Calibration results

Results of the Hydraulic Verification

The comparison of measured and simulated water-surface elevations at Romeoville is shown in Figure 1. The simulated water-surface elevations were within 5 % of the measured values with respect to the depth for 77-100% of the values and within 10% for 95-100% of the values at all locations with water-surface elevation measurements in the CAWS: Wilmette (NSC), CRCW (Chicago River Main Stem), O'Brien Lock and Dam (Calumet River), Lawrence Aevnue (NBCR), Western Avenue (CSSC), Willow Springs (CSSC), Calumet-Sag Junction, Romeoville (CSSC) and Southwest Highway (Calumet-Sag Channel). These high percentages of small errors and the high correlation coefficients (0.66-0.91) indicate an excellent hydraulic verification of the model. The comparison of measured and simulated average daily flows at Romeoville is shown in Figure 2. The average flow for the period of October 1, 2000 -September 30, 2001 at Romeoville was 2710.5 cfs and the difference between simulated and measured average flow at Romeoville was just 162.2 cfs, 6% of the average measured flow. Since the calibrated model can predict stages throughout the CAWS with high accuracy, this model can be safely used for the water-quality calibration.

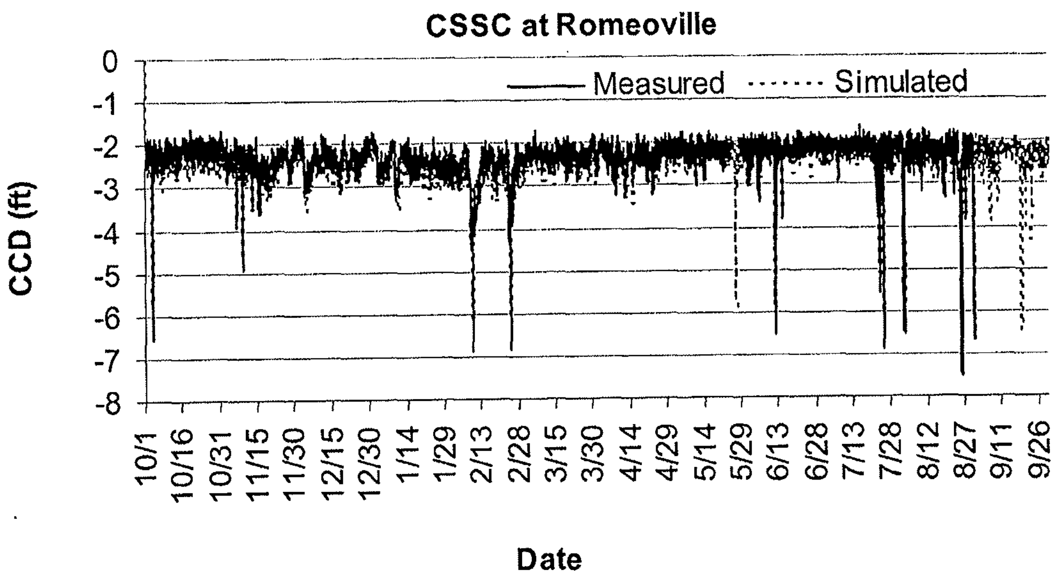

Figure 1. Comparison of measured and simulated water-surface elevations relative to the City of Chicago Datum (CCD) at Romeoville for October 1, 2000- September 30, 2001

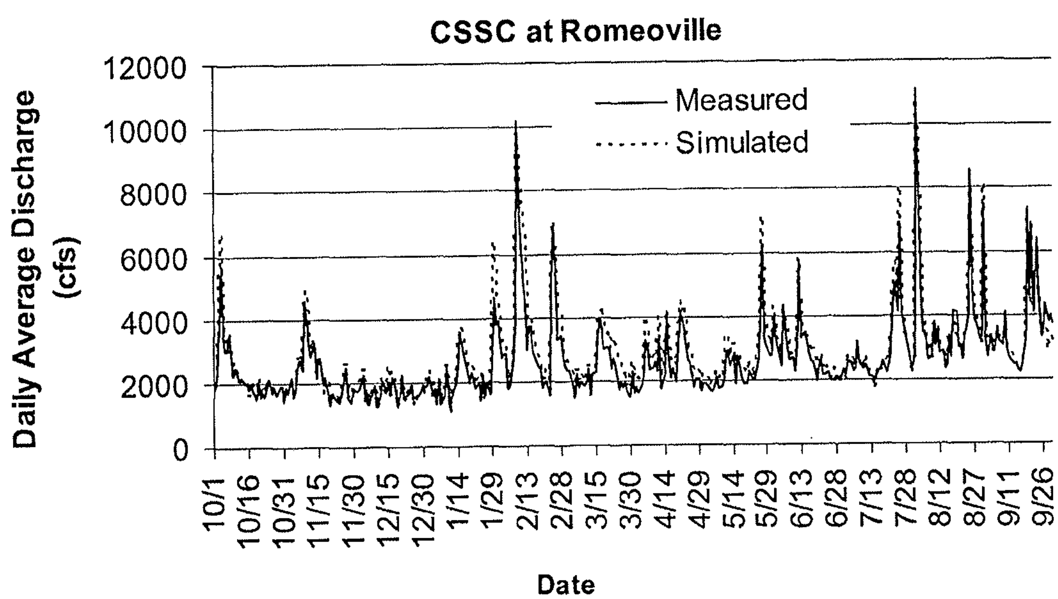

Figure 2. Comparison of measured and simulated daily average discharges at Romeoville for October 1, 2000- September 30, 2001

Water Quality Calibration

The DUFLOW water-quality model was re-calibrated for the period of October 1, 2000-September 30, 2001. Complete details of the previous calibration and verification are given in Alp and Melching (2006).

An extensive data set including hourly in-stream DO data at 25 locations, monthly in-stream water-quality measurements at 18 locations, daily composite WRP effluent measurements, event mean concentrations for storm runoff from major tributaries and CSO pumping stations determined from multiple samples collected by the District during selected events in 2001, daily solar radiation data, and detailed hydraulic data (at 15-min and 1-hour time steps) were used to calibrate the water-quality model at a 1-hour output time step. All water quality variables including DO were measured by the District. Comparison of the simulated and measured hourly DO concentrations at selected locations in the CAWS is shown in Figure 3. There are approximately 8,760 measured hourly DO values at each location within the calibration period and throughout the calibration process it was aimed to match hourly measured and simulated DO concentrations as much as possible. On the other hand, as Harremoës et al. (1996) mentioned, it is almost impossible to match all the measured hourly data if there are a large number of data to be fitted to. Hence, calibration was done manually in a way that the model can capture low DO concentrations resulting from CSOs and produce similar probability of exceedences for different DO concentrations. The focus on low concentrations was taken so that reliable management practices to mitigate the CSO effects could be determined. Comparisons of the percentage of DO concentrations greater than 3, 4, 5, and 6 mg/L, respectively, at different locations in the CAWS for the calibration period for the selected locations are listed in Table 3.

Close agreement between the calibrated and measured DO concentrations were obtained especially for the lower DO concentrations. The differences between the percentage of DO concentrations greater than 3 mg/L for the calibrated and measured DO concentrations are smaller than 10 percentage points in the CAWS except for the NSC. The differences between the percentage of DO concentrations greater than 4 mg/L for the calibrated and measured DO concentrations are less than or equal to 12 percentage points in the CAWS except for the NSC, Michigan Avenue on the Chicago River Main Stem, and Division Street on the Little Calumet River (north). Along the upper NSC it was difficult to match the measured DO concentrations because of the hydraulic conditions in the upper NSC, i.e. flow near zero except during CSO events. The differences between the percentage of DO concentrations greater than 3 and 4 mg/L for the calibrated and measured DO concentrations reach up to 20 percentage points in the upper NSC.

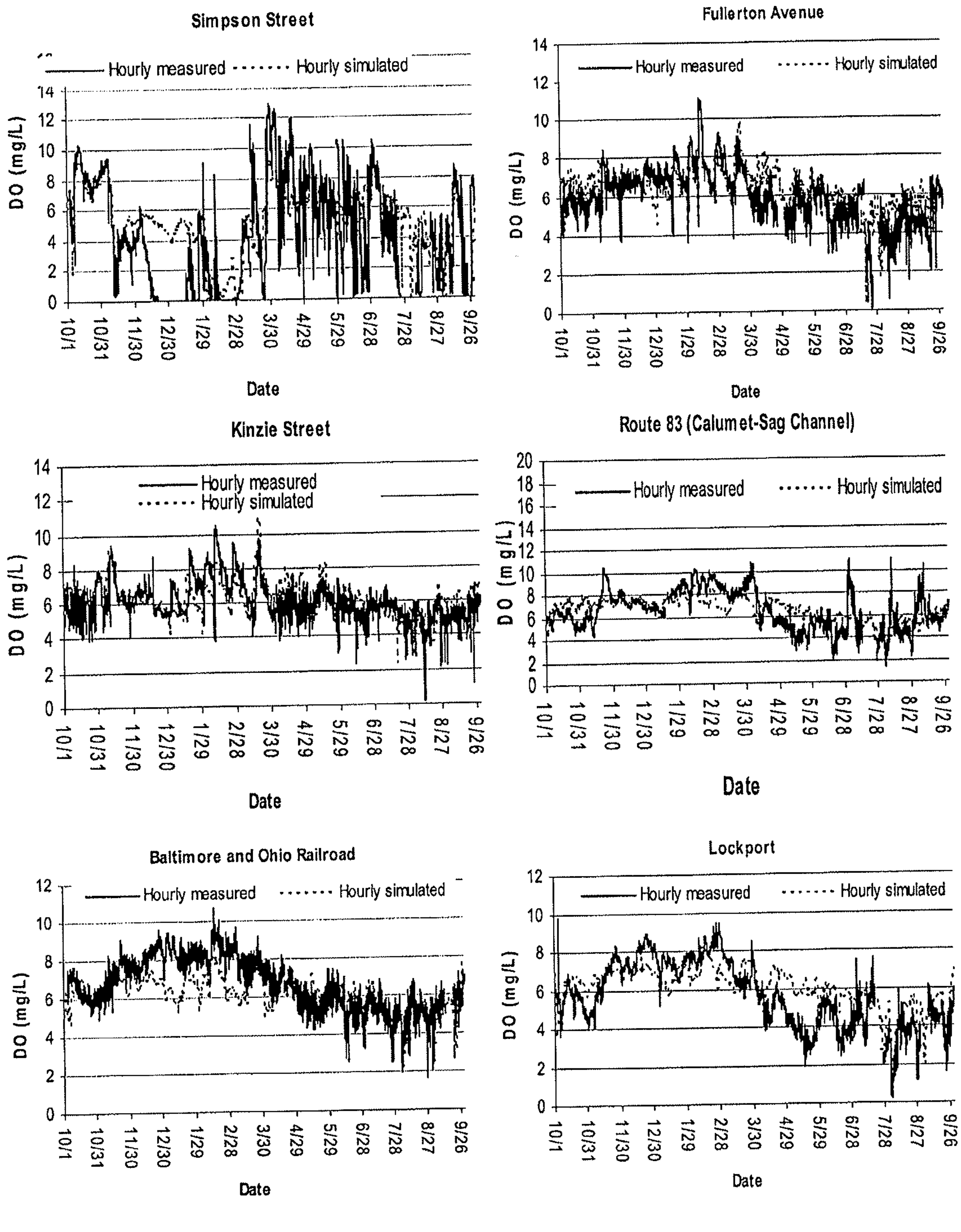

Figure 3. Comparison of measured and simulated dissolved oxygen (DO) concentrations at selected locations for October 1, 2000 – September 30, 2001

Table 3. Comparison of percentages of values greater than various target dissolved oxygen (DO) concentrations between hourly simulated and measured DO concentrations for the Chicago Area Waterway System for October 1, 2000 – September 30, 2001

	Percent of DO higher than							
	>3		>4		>5		>6	
	Mea.	**Sim.**	**Mea.**	**Sim.**	**Mea.**	**Sim.**	**Mea.**	**Sim.**
Linden Street	85	81	80	72	78	57	75	49
Simpson Street	63	81	53	71	42	58	36	34
Main Street	70	89	61	80	52	66	42	34
Addison Street	100	99	99	98	96	94	73	74
Fullerton Avenue	98	99	93	98	75	89	51	63
Division Street	100	100	98	99	91	93	63	65
Kinzie Street	99	100	97	98	84	89	46	55
CRCW	100	97	99	88	99	78	98	68
Michigan Avenue	100	96	100	83	99	71	91	52
Clark Street	99	98	99	89	95	72	88	40
Jackson Boulevard	99	99	95	95	79	72	47	26
Cicero Avenue	91	94	76	79	53	46	34	15
Baltimore and Ohio Railroad	99	99	97	96	87	89	62	57
Route 83	95	98	85	94	61	85	45	54
River Mile 11.6	97	99	89	95	68	88	48	61
Romeoville	95	97	81	93	57	84	46	56
Lockport	94	97	80	92	61	83	43	54
Conrail RR	*100*	*100*	*100*	*100*	*97*	*87*	*88*	*27*
Central and Wisconsin Railroad	*100*	*100*	*100*	*100*	*98*	*89*	*87*	*30*
Halsted Street	*100*	*100*	*99*	*100*	*91*	*92*	*59*	*32*
Division Street	*96*	*100*	*84*	*99*	*59*	*79*	*28*	*16*
Kedzie Street	*98*	*100*	*93*	*100*	*78*	*88*	*45*	*31*
Cicero Avenue	*98*	*100*	*91*	*98*	*74*	*73*	*40*	*18*
Harlem Avenue	*96*	*100*	*87*	*97*	*68*	*82*	*27*	*35*
Southwest Highway	*97*	*100*	*84*	*95*	*63*	*76*	*30*	*26*
104th Avenue	*90*	*99*	*84*	*93*	*67*	*63*	*33*	*17*
Route 83	*92*	*96*	*82*	*90*	*57*	*56*	*27*	*10*

*Mea. = Measured; Sim. = Simulated

Calumet Waterway System DO locations: Measured DO data are only available between July 12- Spetember 30, 2001

SIMULATION RESULTS

Baseline Simulation

The first set of simulations (baseline) were performed considering the existing Devon Avenue and Webster Street in-stream aeration stations operating at full capacity, 3 blowers each, the 4-SEPA stations operation with 3 pumps each. In addition to the current aeration stations operating at full capacity, the baseline simulation also includes the following management practices:

- Transfer of aerated (to saturation) effluent from the North Side Water Reclamation Plant to the upstream end of the NSC—100 MGD
- Transfer of unaerated flow from the SBCR (at Throop Street) to the upstream end of the Bubbly Creek—50 MGD

As can be seen in Table 3 DO concentrations in the Little Calumet River (north) exceed 5 mg/L more than 90% of the time, but to meet the early life stages DO requirement in this reach 100% of the time it was necessary to consider transfer of aerated (to saturation) effluent from the Calumet WRP to the upstream boundary, Calumet River at O'Brien Lock and Dam. In order to determine the amount of aerated Calumet WRP flow to be tranferred, a new set of simulations were completed. Daily mean temperature data for the CWRP influent for the period of October 1, 2000- September 30, 2001 were used to determine the saturation DO concentration in the force main. The transfer amount was taken as the lesser of the selected transfer value or the actual effluent flow for a particular hour. Ten different flow values have been tried to compare the percentage of time compliance is achieved with the proposed DO standards of 3.5 and 5 mg/L (Figure 4). As can be seen in Figure 4, an aerated flow of 182.6 MGD needs to be transferred from the Calumet WRP to O'Brien Lock and Dam to achieve DO above 5 mg/L 100% of the time.

Identification of Aeration Station Locations

The purpose of adding the new aeration stations is to raise DO concentrations above 5 and 3.5 mg/L for the periods of March-July and August-February, respectively, for Aquatic Life Use A waters and above 3.5 mg/L throughout the year for Aquatic Life Use B waters 100 % of the time. In this exercise new aeration stations were added to the river network wherever needed. This means that when the simulated DO concentration drops below 5 or 3.5 mg/L, as appropriate, at a location a new aeration station would be introduced upstream from that location (Figure 5).

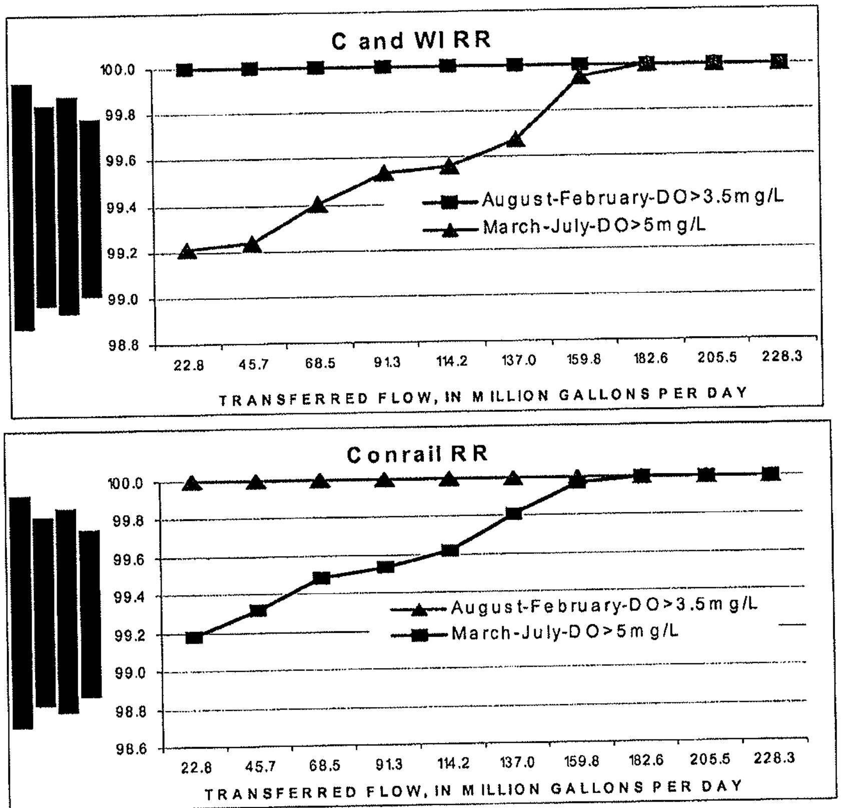

Figure 4. Relation between the amount of aerated transferred flow and percentage compliance with the dissolved oxygen concentration criteria for October 1, 2000 – September 30, 2001 on the Little Calumet River (north).

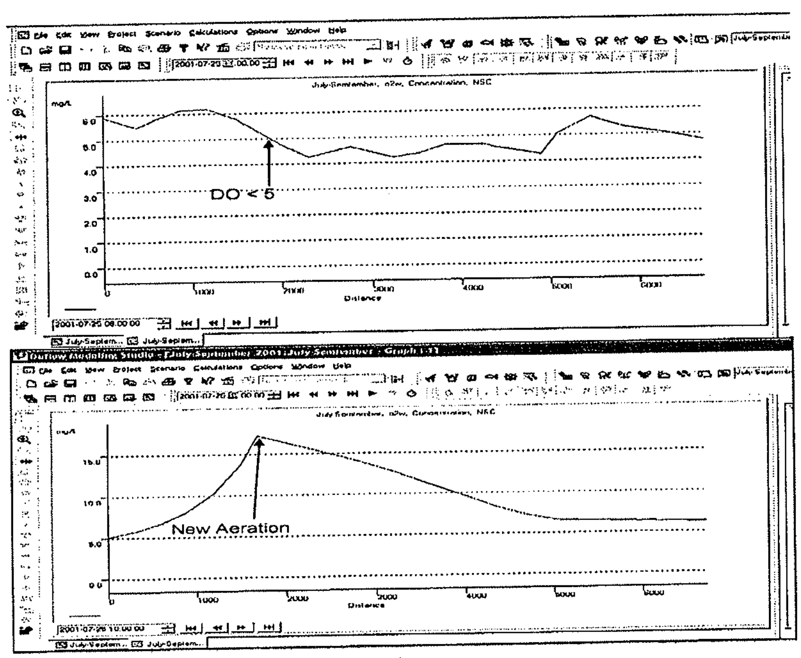

Figure 5. Identification of Aeration Station Locations

Simulation results showed that 18 new supplementary aeration stations with a maximum oxygen load of 80 g/s are needed to achieve the proposed DO standards of 3.5 and 5 mg/L for periods of August-February and March-July, respectively, for Aquatic Life Use A waters and of 3.5 mg/L throughout the year for Aquatic Life Use B waters. Locations of the proposed aeration stations are shown in Figure 6 and descriptions of the locations are presented in Table 4.

Especially after large storms, low DO concentrations are observed for an extended period of time. There were two critical time periods in which the proposed DO standards would not be met at almost all locations. July 25, 2001 and August 2, 2001 events were the most critical events for the proposed DO standards of 5 and 3.5 mg/L, respectively. Simulations showed that 3 new aeration stations would be needed on the Upper NSC, whereas no new aeration would be needed for the lower NSC since NSWRP and Devon Avenue In-stream aeration station provided enough dissolved oxygen for the river system. Only one new aeration station on the Upper NBCR that would be upstream from the Webster Avenue in-stream aeration station would be added to meet the the proposed DO standards.

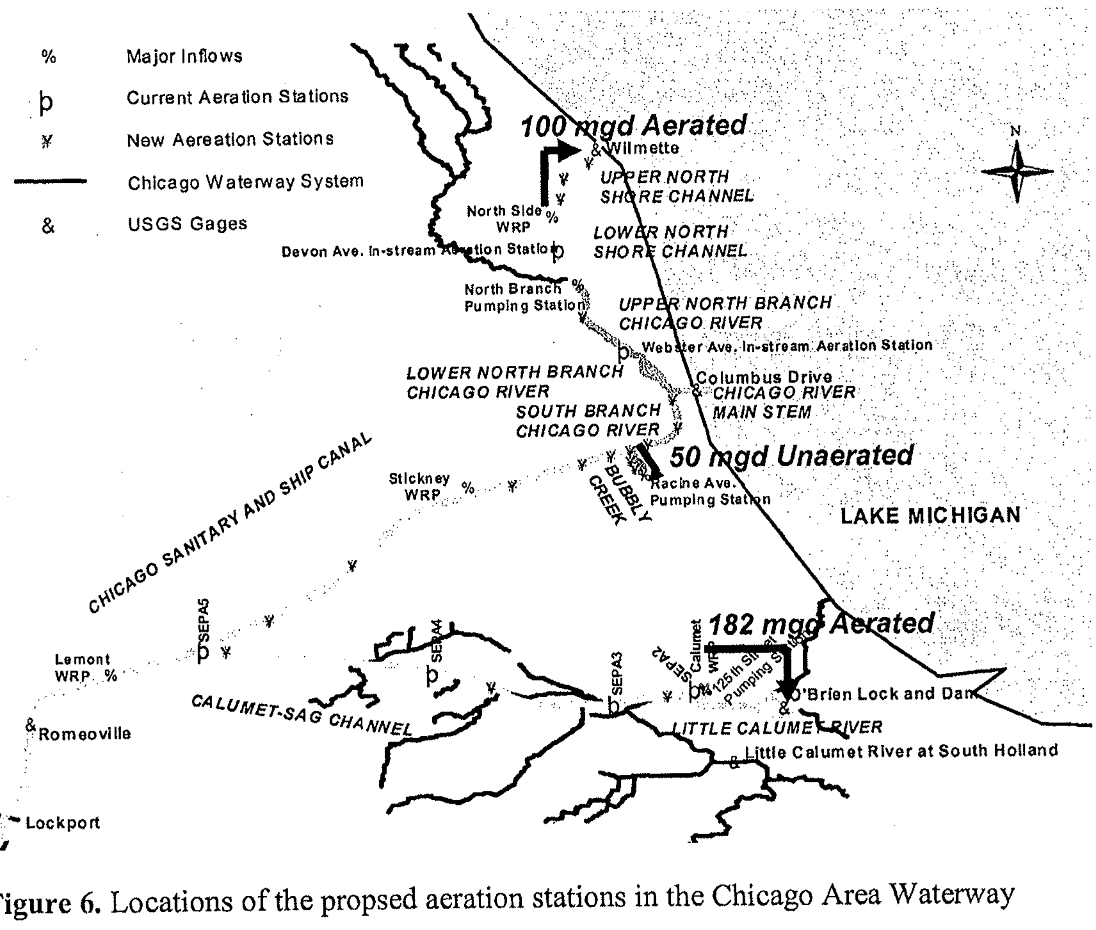

Figure 6. Locations of the propsed aeration stations in the Chicago Area Waterway System.

Because of the water quality conditions on the SBCR, three new aeration stations would be needed to bring DO concentration above 3.5 mg/L 100% of the time. Previous assessment by the R&D Department of the District showed that 3 aeration stations would be needed for Bubbly Creek (CTE, 2007c). In this exercise, the same locations suggested by the District would be used with higher DO loads at the stations. Three new aeration stations between the Bubbly Creek Junction and Stickney WRP and 2 new aeration stations between the Stickney WRP and Calumet-Sag Junction would be added to raise DO concentration above 3.5 mg/L. Because of transfer of 182.6 MGD of aerated Calumet WRP effluent to O'Brien Lock and Dam, the proposed DO standards would be met along the Little Calumet River (north) between O'Brien Lock and Dam and the Calumet WRP and one new aeration station would be needed between the Calumet WRP and the Little Calumet River junction with the Calumet-Sag Channel. Since the SEPA stations would be assumed to be working at full capacity, 2 new aeration stations would provide enough dissolved oxygen to meet the the proposed DO standards. Dissolved oxygen concentration profiles along the waterway segments with the 18 new aeration stations in the CAWS for the selected critical periods are shown Figures 7-9.

Table 4. Locations of the proposed new aeration stations in the Chicago Area Waterway System.

No.	Waterway	River Mile	Max. Load (g/s)	Location
1	Upper North Shore Channel	340.2	80	Central Street
2	Upper North Shore Channel	339.3	80	0.2 miles downstream from Simpson Street
3	Upper North Shore Channel	337.9	80	0.4 miles upstream from Main Street
4	North Branch Chicago River	330.4	80	0.3 miles upstream from Diversey Parkway
5	South Branch Chicago River	325.4	80	0.2 miles downstream from the junction with the North Branch Chicago River
6	South Branch Chicago River	324.1	80	1.5 miles downstream from the junction with the North Branch Chicago River
7	South Branch Chicago River	322.9	80	Halsted Street
8	Bubbly Creek		80	Mouth of Bubbly Creek
9	Bubby Creek		80	Approximate midpoint of Bubbly Creek
10	Bubbly Creek		80	Headwaters of Bubbly Creek
11	CSSC	320.8	80	0.24 miles upstream from Western Avenue
12	CSSC	319.8	80	0.8 miles downstream from Western Avenue
13	CSSC	317.3	80	Cicero Avenue
14	CSSC	309.4	80	1.2 miles upstream from Willow Springs Road
15	CSSC	306.4	80	1.8 miles downstream from Willow Springs Road
16	Little Calumet River (North)	320.0	80	0.35 miles upstream from the junction with the Little Calumet River
17	Calumet-Sag Channel	313.5	70	1.8 miles upstream from SEPA Station No. 4 at Worth (Harlem Ave.)
18	Calumet-Sag Channel	305.6	80	1.3 miles upstream from Route 83

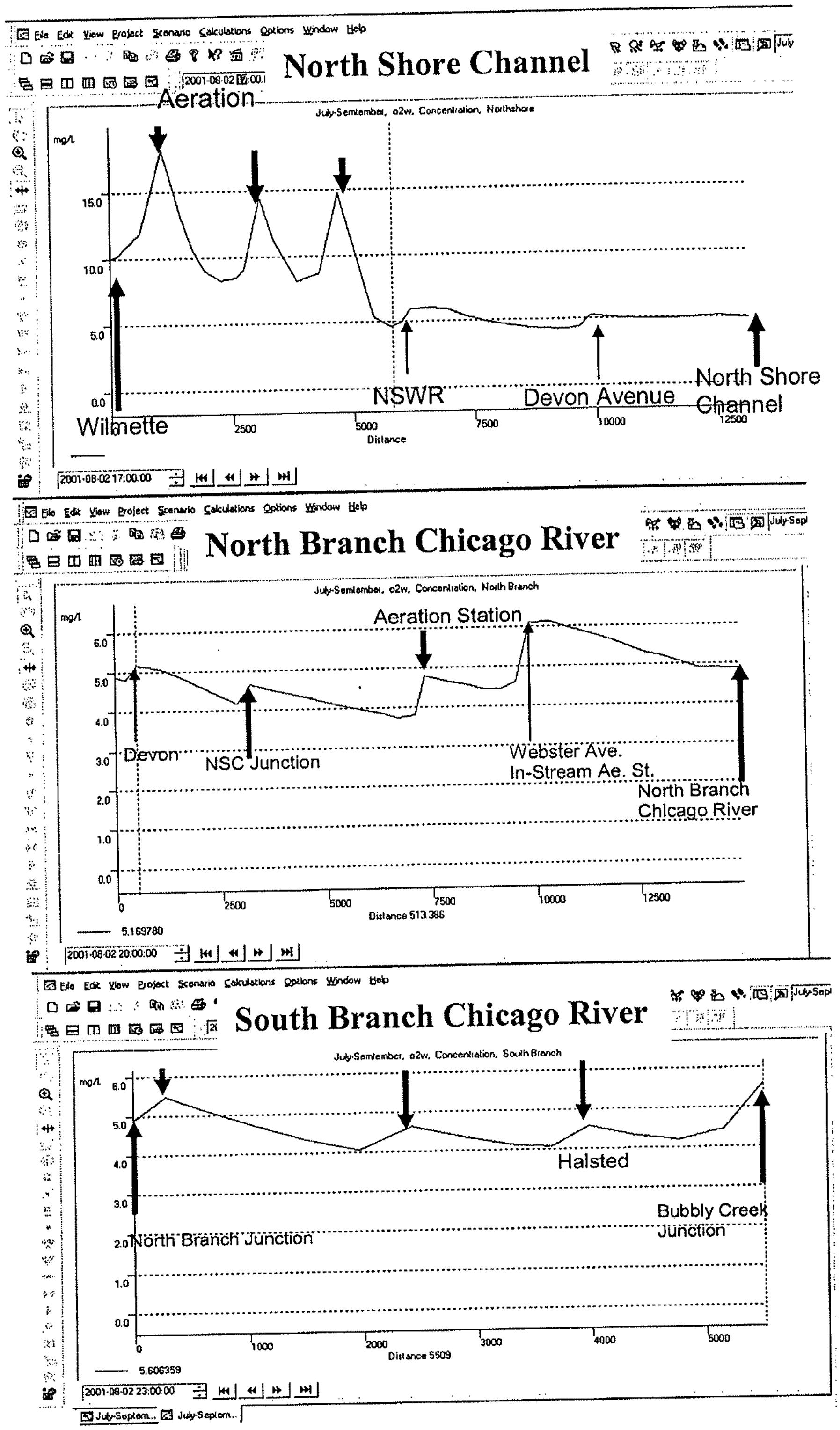

Figure 7. Dissolved oxygen concentration profile in the Chicago Area Waterway System for a selected critical period of the August 2, 2001 storm where the downward arrows indicate locations of new aeration stations.

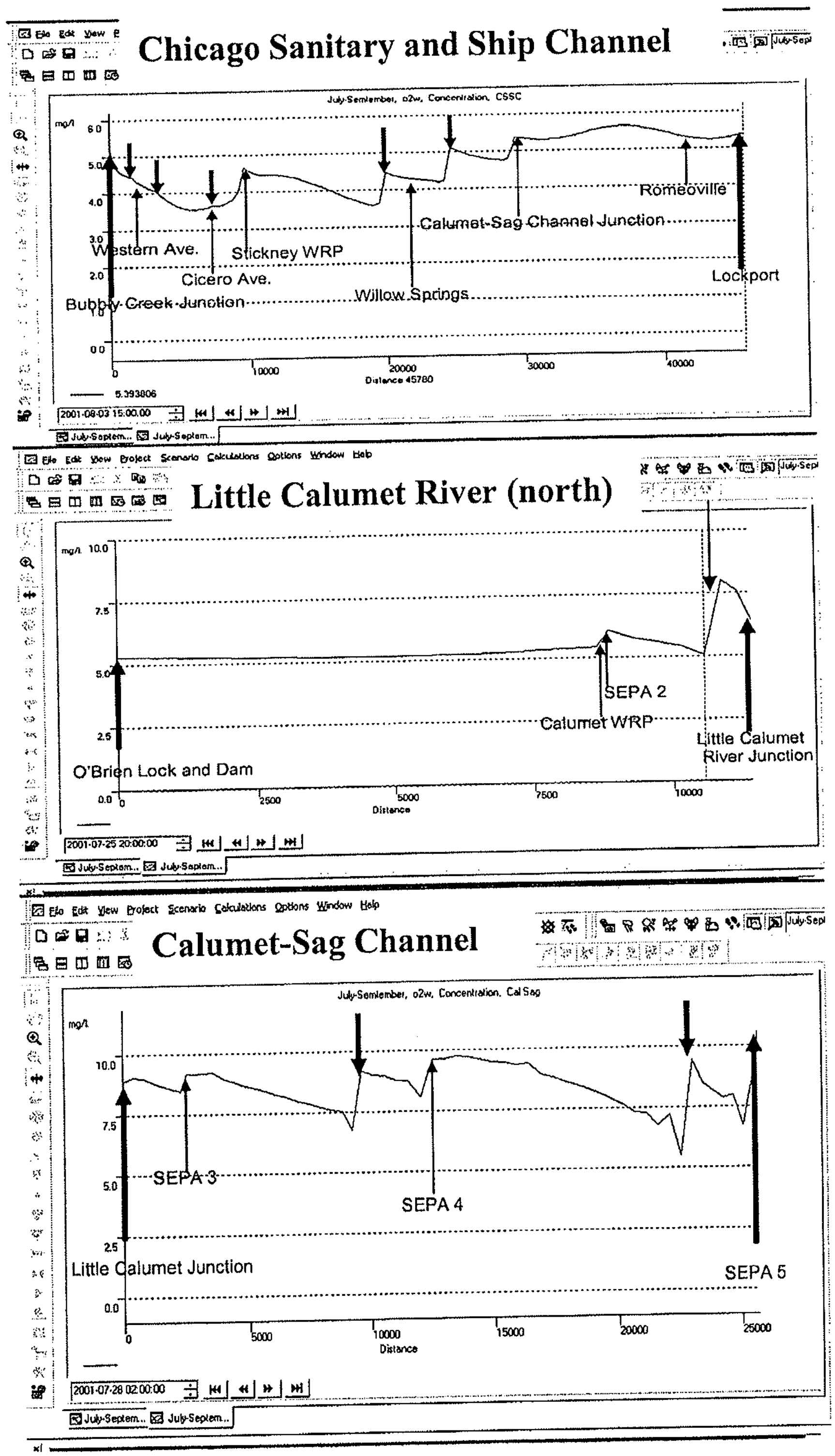

Figure 8. Dissolved oxygen concentration profile in the Chicago Waterway System for selected critical periods of August 2, 2001 (Chicago Sanitary and Ship Canal) and July 25, 2001 (Little Calumet River (north) and Calumet-Sag Channel) storms where the downward arrows indicate locations of new aeration stations.

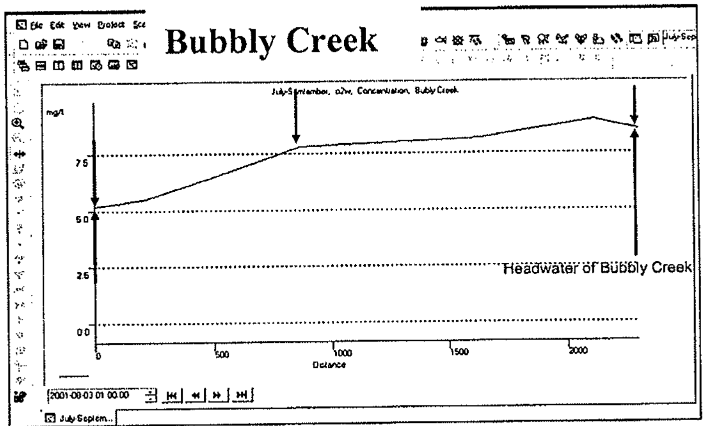

Figure 9. Dissolved oxygen concentration profile in Bubbly Creek for a selected critical period of August 2, 2001 where the downward arrows indicate locations of new aeration stations.

In this exercise, new aeration stations are not added on the Chicago River Main Stem (CRMS) because this segment of the waterway is stagnant most of the time. As can be seen in Figure 10, the effect of new aeration stations on DO concentrations in the CRMS is significant especially for the period of October 2000 to May 2001. After May 2001, the effect of new aeration stations on DO in the CRMS diminishes.

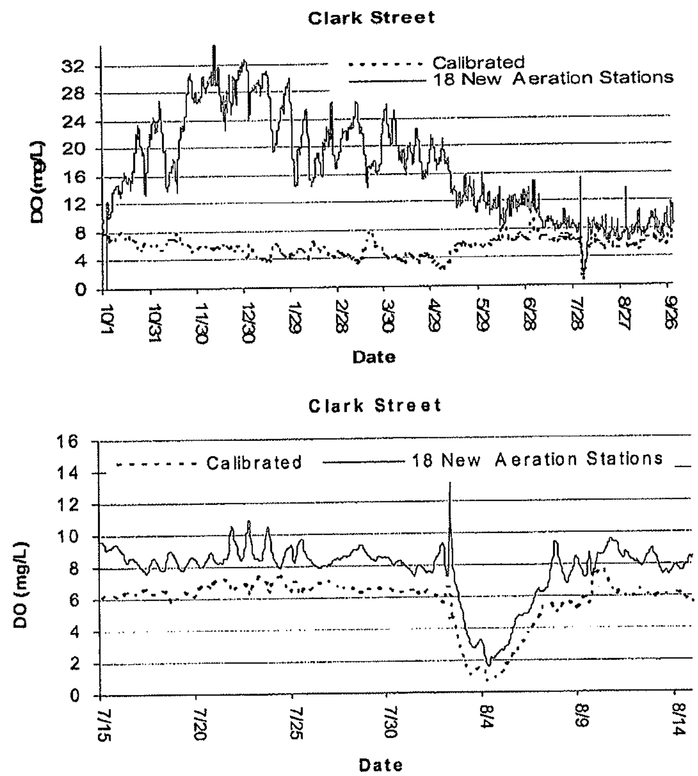

Figure 10. Simulated dissolved oxygen concentration at Clark Street on the Chicago River Main Stem

In Summary, the unsteady flow water quality model previously developed by Marquette University for the CAWS using the Duflow Modeling Studio software has been updated in three major areas, in addition to the expansion of the simulation period from 4 months to an entire water year. First, the gravity CSO locations in the NSC were increased from four to 19 to better simulate the gravity CSO discharges in this segment, in which the impact of CSOs is the largest of the entire system. Secondly, sediment oxygen demand (SOD) values were adjusted based on the measured SOD values. Thirdly, the gravity CSO discharges were obtained using the runoff models developed by the U.S. Army Corps of Engineers for the region. The updated model was calibrated for the water year of October 1, 2000, to September 30, 2001, and good agreements between hourly simulated and measured DO concentrations were achieved. The updated, calibrated model was used to simulate an integrated strategy that combines flow augmentation, flow aeration and instream aeration for 100% compliance with the IEPA's proposed DO standards for the CAWS. The simulation results indicate that the critical periods occurred during and after the July 25, 2001 and August 2, 2001 storm events. The following DO enhancement measures and new facilities would be required to meet the proposed DO standards for the critical periods.

a. Maximize the capacity of the existing two instream and three of the existing sidestream aeration stations in the CAWS;
b. Add three flow augmentation facilities with some flow aeration, i.e. (1) pumping 100 mgd of the NSWRP's final effluent with aeration to saturation from the NSWRP to the headwaters of the upper NSC, (2) transferring 50 mgd of river water without aeration from the SBCR to the headwaters of Bubbly Creek, and (3) pumping 182.6 mgd of the Calumet WRP's final effluent with aeration to saturation from the Calumet WRP to downstream of the O'Brien Lock and Dam on the Calumet River; and
c. Construct 18 new instream aeration stations within the CAWS . The 18 new instream aeration stations would be located throughout the CAWS with three on the upper NSC, one on the NBCR, three on SBCR, five on the CSSC, three on Bubbly Creek, one on the Little Calumet River (North), and two on the Calumet-Sag Channel. Even with these enhancements potential non-compliance with the proposed DO standards might occur, particularly under wet weather conditions during the summer months which could be more severe than the conditions that materialized in 2001 which were used for this modeling.
d. Enhancements will also be required to ensure 100 percent compliance with the proposed DO standard in the Chicago River. However, further study is required before a solution can be proposed and costs can be determined.

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