Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago

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May 16, 2007

Mr. Toby Frevert, Manager
Division of Water Pollution Control
Bureau of Water
Illinois Environmental Protection Agency
1021 North Grand Avenue East
P.O. Box 19276
Springfield, Illinois 62794-9276

Dear Mr. Frevert:

Subject: Evaluation of Management Alternatives for the Chicago Area Waterways (CAWs): Development of a Framework for an Integrated Water Quality Strategy for the Chicago Area Waterways

The District, at the request of the Illinois Environmental Protection Agency (IEPA), hereby submits the enclosed report entitled "Technical Memorandum 7WQ: Development of an Integrated Water Quality Strategy for the Chicago Area Waterways."

Using the services of Consoer Townsend Envirodyne Engineers, Inc., this report has been developed to produce a framework for an integrated water quality strategy for the CAWs. This strategy, once developed, would contain a prioritized list of those water quality management options for the CAWs which will produce the most benefit at the least cost.

Please note that prior to undertaking Task 1 - Develop Long List of Potential Water Quality Management Options outlined in the subject report, the District plans to perform modifications and improvements to the existing water quality model as alluded to under Task 3 - Audit Model and Information and Task 4 - Model Modifications and Improvements.

When we are prepared to address Task 1, we will contact the IEPA to assemble appropriate stakeholders.

If you have any questions, please contact Mr. Lou Kollias at (312) 751-5190.

Very truly yours,

R Lanyon

Richard Lanyon
General Superintendent

JS:TK
Attachments

cc: J. Sobanski, MWRD
L. Kollias, MWRD
R. Sulski, IEPA

FINAL - 04/09/07

TECHNICAL MEMORANDUM 7WQ

DEVELOPMENT OF A FRAMEWORK FOR AN INTEGRATED WATER QUALITY STRATEGY FOR THE CHICAGO AREA WATERWAYS

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

NORTH SIDE WATER RECLAMATION PLANT

Submitted by:

CTE | AECOM

April 09, 2007

MWRDGC Project No. 04-014-2P
CTE Project No. 40779

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INTRODUCTION

The Illinois Environmental Protection Agency (IEPA) is conducting a Use Attainability Analysis (UAA) study of the Chicago Area Waterways (CAWs) to evaluate existing conditions, including waterway use practices and anticipated future uses. The purpose of this UAA is to determine if use classification revisions are warranted. As part of this UAA study, the IEPA requested that the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) study the technologies and costs for specific water quality management options. These options include such processes as supplemental aeration. All the options offer the possibility of improving the water quality of the CAWs. Consoer Townsend Envirodyne Engineers, Inc. (CTE) was commissioned by the MWRDGC to conduct these studies. As part of the scope of work for the CTE studies, the District also asked CTE to develop a framework or plan needed to develop an integrated water quality strategy for the CAWs. This strategy would ultimately consist of a prioritized list of the water quality management options and/or combinations of options for the CAWs which will produce the most benefit at the least cost.

As part of its UAA of the CAWs, the IEPA requested that the MWRDGC study certain water quality management options for parts of the CAWs. These options included:

1) Effluent Disinfection
2) End-of-Pipe Combined Sewer Overflow Treatment
3) Supplemental Aeration
4) Flow Augmentation

CTE evaluated these options individually and presented the results in a series of technical memorandums. It should be noted that these studies did not include combinations of the water quality management options described above. But there are other water quality management options and/or combinations of options which warrant evaluation. Thus, the MWRDGC has asked that CTE develop a framework which will show the tasks needed to evaluate additional water quality options and/or combinations of options and ultimately determine the water quality management options that will produce the most benefit at the lowest cost. A prioritized list of the selected options will constitute the integrated strategy for the CAWs.

Study Objective

The objective of this technical memorandum is to produce a framework for an integrated water quality strategy for the CAWs. This process is needed as it is likely that a combination of specific technology options (i.e., the integrated strategy) will result in improved water quality at lower cost than can be achieved through the application of any one technology. This strategy, once developed, would contain a prioritized list of those water quality management options for the CAWs which will produce the most benefit at the least cost.

Background

Study Area

The CAWs are shown in Figure 7.1. These waterways include:

- North Shore Channel (NSC)
- North Branch of the Chicago River (NBCR) Downstream of the Confluence with the NSC
- The Chicago River (CR)

- The South Branch of the Chicago River (SBCR)
- The South Fork of the South Branch of the Chicago River (commonly known as Bubbly Creek)
- The Chicago Sanitary and Ship Canal (CSSC)
- The Calumet-Sag Channel
- Lake Calumet
- Calumet River
- Grand Calumet River (In Illinois)
- The Little Calumet River from its Junction with the Grand Calumet River to the Calumet-Sag Channel.

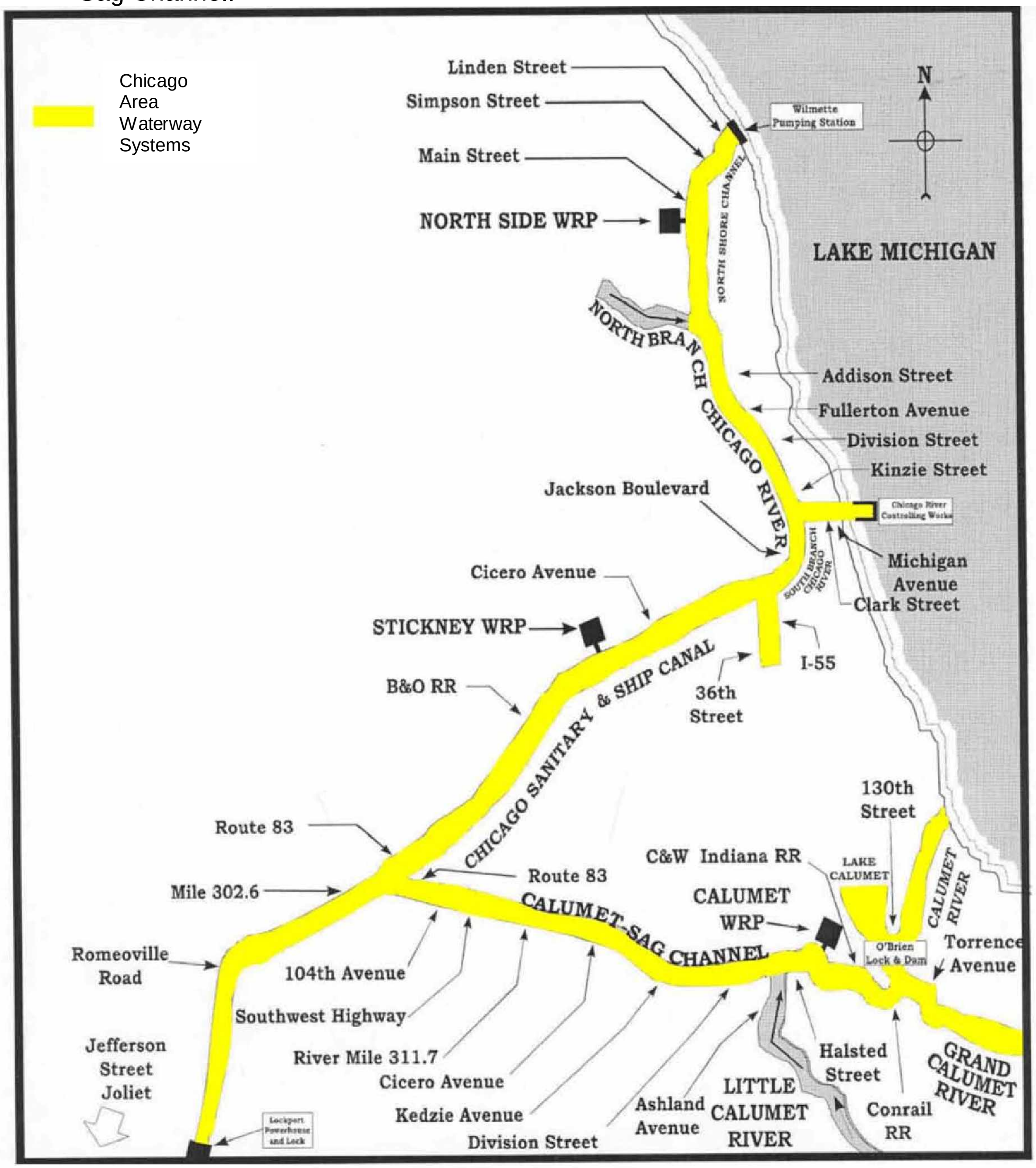

Figure 7.1 – Map of Chicago Area Waterways

Current Water Quality Standards for Chicago Area Waterways

The Upper NSC (UNSC), the CR and the Calumet River upstream of the O'Brien locks are presently classified by the State of Illinois as General Use Waters. The goals of these standards are to help protect aquatic life, wildlife, agricultural use, secondary contact, most industrial uses and the safeguarding of the aesthetic quality of the aquatic environment (35 IL Adm. Code 302.202). Significant portions of the General Use Standards are shown below.

- Offensive Conditions: Waters of the State shall be free from sludge or bottom deposits, floating debris, visible oil, odor, plant or algal growth, color or turbidity of other than of natural origin. (35 IL Adm. Code 302.203)

- Dissolved Oxygen: ≥6.0 milligrams per liter (mg/l) 16 Hours out of 24 Hours and ≥5.0 mg/l at any time (35 IL Adm. Code 302.206)

- Total Residual Chlorine: ≤0.019 mg/l (35 IL Adm. Code 302.208.d)

- Fecal Coliform: ≤200 per 100 milliliters (/100 mL) geometric mean of 5 samples per 30-day period, May-October, and ≤400 /100 ml in 90% of samples in any 30-day period (35 IL Adm. Code 302.209.a)

All other portions of CAWs are presently classified by the State of Illinois as Secondary Contact and Indigenous Aquatic Life Waters (35 IL Adm. Code 303.204). These standards are intended for those waters not suited for general use activities but which will be appropriate for all secondary contact uses and which will be capable of supporting an indigenous aquatic life limited only by the physical configuration of the body of water, characteristics and origin of the water, and the presence of contaminants in amounts that do not exceed the water quality standards listed in Subpart D (35 IL Adm. Code 302.401). "Secondary Contact" means any recreational or other water use in which contact with the water is either incidental or accidental and in which the probability of ingesting appreciable quantities of water is minimal, such as fishing, commercial and recreational boating and any limited contact incident to shoreline activity (35 IL Adm. Code 301.380).

- Secondary contact waters subject to these standards shall be free from unnatural sludge or bottom deposits, floating debris, visible oil, odor, unnatural plant or algal growth, color or unnatural turbidity of other than natural origin (35 IL Adm. Code 302.403).

- Dissolved Oxygen: ≥4.0 mg/l at any time. Exception: Cal-Sag Channel, ≥3.0 mg/l at any time (35 IL Adm. Code 302.405).

- Total Residual Chlorine: No Limit

- Fecal Coliform: No Limit

Figures 7.2 and 7.3 illustrate the current Dissolved Oxygen (DO) and current Bacteria standards, respectively, for the CAWs.

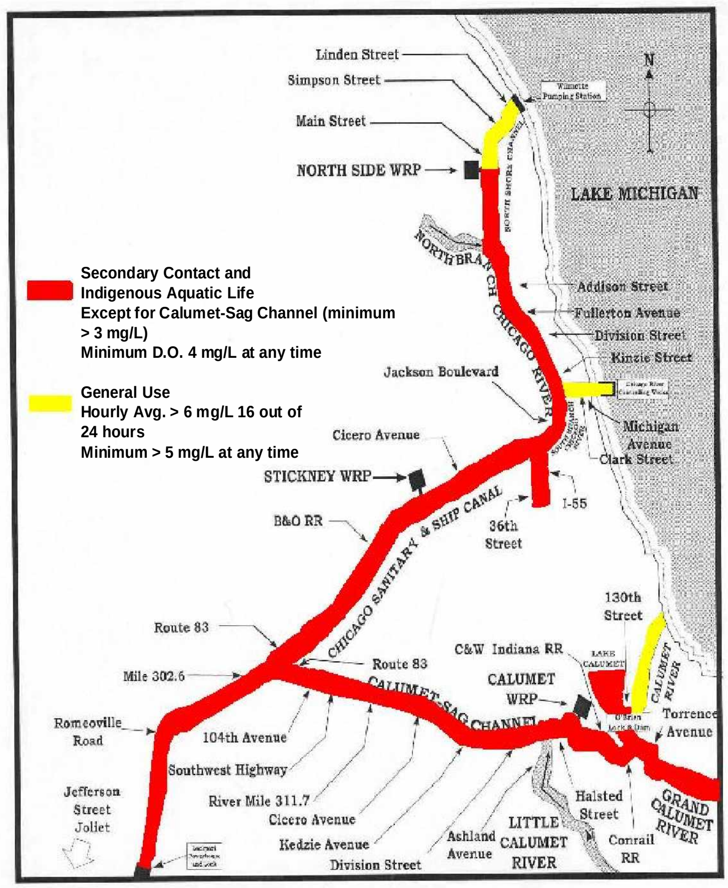

Figure 7.2 – Current Chicago Area Waterways Dissolved Oxygen Standards

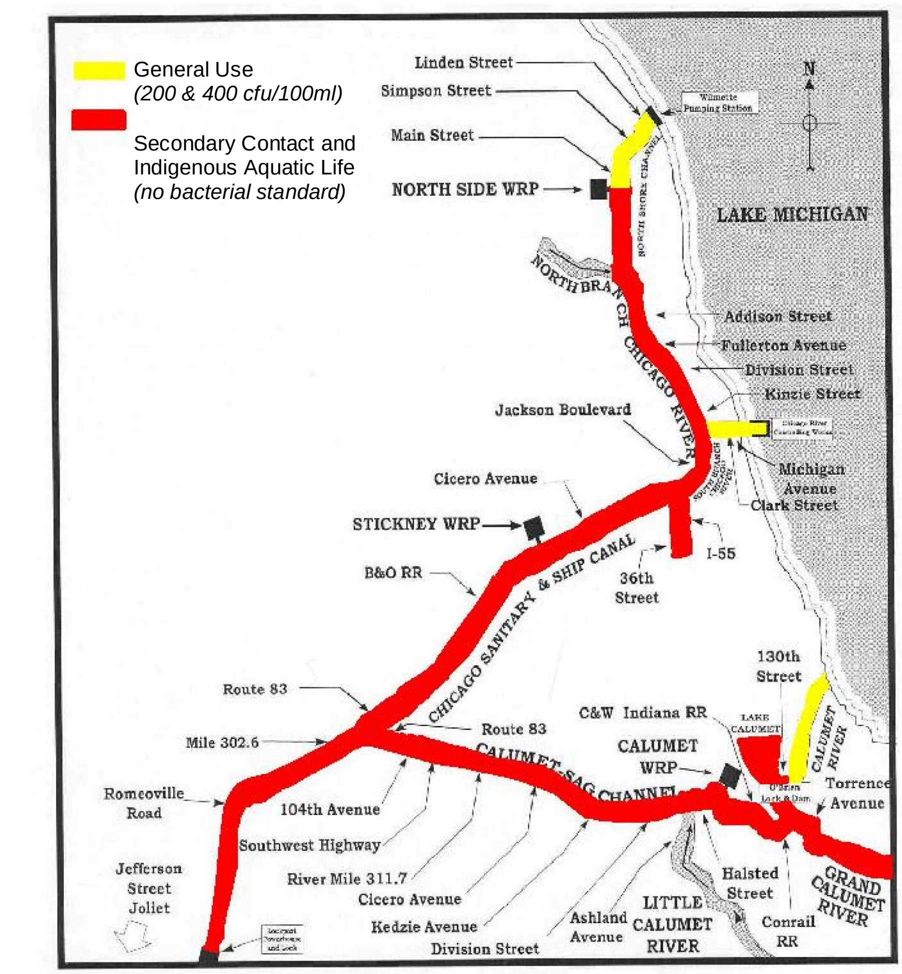

Figure 7.3 – Current Bacterial Standards for Chicago Area Waterways

<u>Proposed UAA for the CAWs</u>

The IEPA is conducting the Use Attainability Analysis (UAA) to evaluate appropriate designated uses and water quality criteria for the CAWs. Currently, IEPA has proposed two new designated use categories and draft criteria for bacteria in the UAA. IEPA has also indicated that DO criteria of 4, 5 and 6 mg/l are being evaluated. In general, the UAA (Second Draft Report “Use Attainability Analysis of the Chicago Area Waterways”, May 2004) proposes more stringent bacteria criteria for the following:

- The NSC downstream of the MWRDGC North Side Water Reclamation Plant (WRP)
- The NBCR from its confluence with the NSC to its confluence with the South Branch
- CSSC
- SBCR and Bubbly Creek
- Calumet-Sag Channel

- The Little Calumet River from its junction with the Grand Calumet River to the Calumet-Sag Channel

- The Grand Calumet River

- The Calumet River, except the 6.8 mile segment extending from the O'Brien Locks and Dam to Lake Michigan

- Lake Calumet

Specifically, the following criteria are proposed in the draft UAA report:

E. Coli

- Limited Contact Recreation: A geometric mean of 1,030 colony forming units per 100 milliliters (cfu/100 mL) *E. coli*. This criterion will apply to all water bodies except the Chicago Sanitary and Ship Canal (downstream of the Stickney Water Reclamation Plant) and the Calumet River (O'Brien Lock and Dam to Lake Michigan).

- Recreational Navigation: A geometric mean of 2,740 cfu/100 mL *E. coli*. This criterion will apply to the CSSC (downstream of the Stickney WRP) and the Calumet River (O'Brien Lock and Dam to Lake Michigan).

The criteria are to be compared to the geometric mean of measured values in the receiving water calculated over a 30-day period from March 1 to November 30.

The draft UAA report also recommends the following aquatic life uses and dissolved oxygen standards for the CAWs.

Dissolved Oxygen

- Modified Warm Water Aquatic Life (MWAL): Current general use standards or more appropriate standards based upon recent guidance. These criteria would apply to the UNSC, NSC, and Upper North Branch Chicago River (UNBCR). Calumet-Sag Channel, Grand Calumet River, the Calumet River (downstream of O'Brien Locks and the Little Calumet River from the junction with the Grand Calumet River to the Calumet-Sag Channel). The UNBCR includes the length of the North Branch Chicago River from the confluence with North Shore Channel to the North Avenue Turning Basin. These waters are presently not capable of supporting and maintaining a balanced, integrated, adaptive community of a warm-water fish and macroinvertebrate community due to significant modifications of the channel morphology, hydrology and physical habitat that may be recoverable. These waters are capable of supporting and maintaining communities of native fish and macroinvertebrates that are moderately tolerant and may include desired sport fish species such as channel catfish, largemouth bass, bluegill, and black crappie. Water quality standards are identified in existing Illinois Pollution Control Board Regulations (35 Ill. Adm. Code Part 302, Subpart B.)

- Limited Warm Water Aquatic Life (LWAL): Current general use standards or more appropriate standards based upon recent guidance. These criteria would apply to the Lower NBCR (LNBCR), CR, SBCR, Bubbly Creek and the CSSC. These waters are incapable of sustaining a balanced and diverse warm-water fish and macroinvertebrate community due to irreversible modifications that result in poor physical habitat and stream hydrology. Such physical modifications are of long-duration (i.e. twenty years or longer) and may include artificially constructed channels consisting of vertical sheet-pile, concrete and rip-rap walls designed to support commercial navigation and the conveyance of stormwater and wastewater. Hydrological modifications include locks and dams that artificially control water discharges and levels. The fish community is comprised of tolerant species including central mudminnow, golden shiner, white sucker, bluntnose minnow, yellow bullhead and green sunfish. These waters shall allow for fish passage.

Figure 7.4 shows the proposed Bacterial standards for the Chicago Area Waterways. Table 7.1 lists the proposed Dissolved Oxygen standards for the CAWs and Figure 7.5 illustrates these standards as they relate to the CAWs.

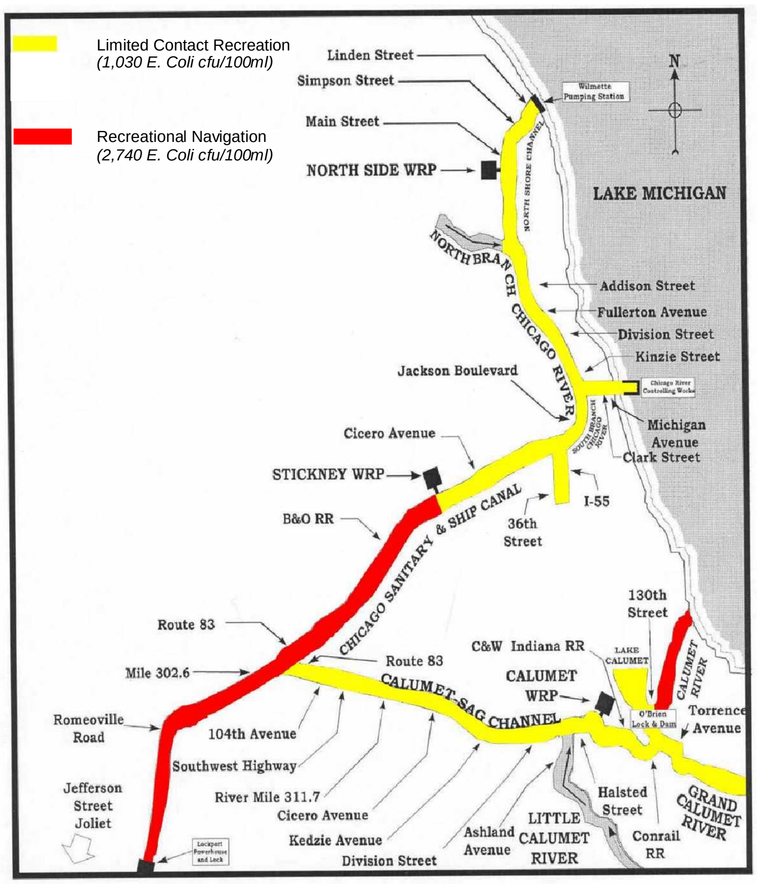

Figure 7.4 – Proposed Bacterial Standards for Chicago Area Waterways

TABLE 7.1
PROPOSED DISSOLVED OXYGEN STANDARDS FOR THE CHICAGO AREA WATERWAYS

Parameter	Aquatic Life Use Designation Proposed in Draft UAA	Proposed UAA Standard	UNSC	LNSC	UNBCR	LNBCR	CR	SBCR	Bubbly Creek	Chicago Sanitary Ship Canal	Calumet River	Grand Calumet	Little Calumet River	Calumet Sag Channel
Dissolved Oxygen	Modified warmwater aquatic life (MWAL)	Current general use standards or Minimum >4, 5, or 6 mg/l	♦	♦	♦							♦	♦	♦
Dissolved Oxygen	Limited warmwater aquatic life (LWAL)	Current general use standards or Minimum >4, 5, or 6 mg/l				♦	♦	♦	♦	♦	♦			

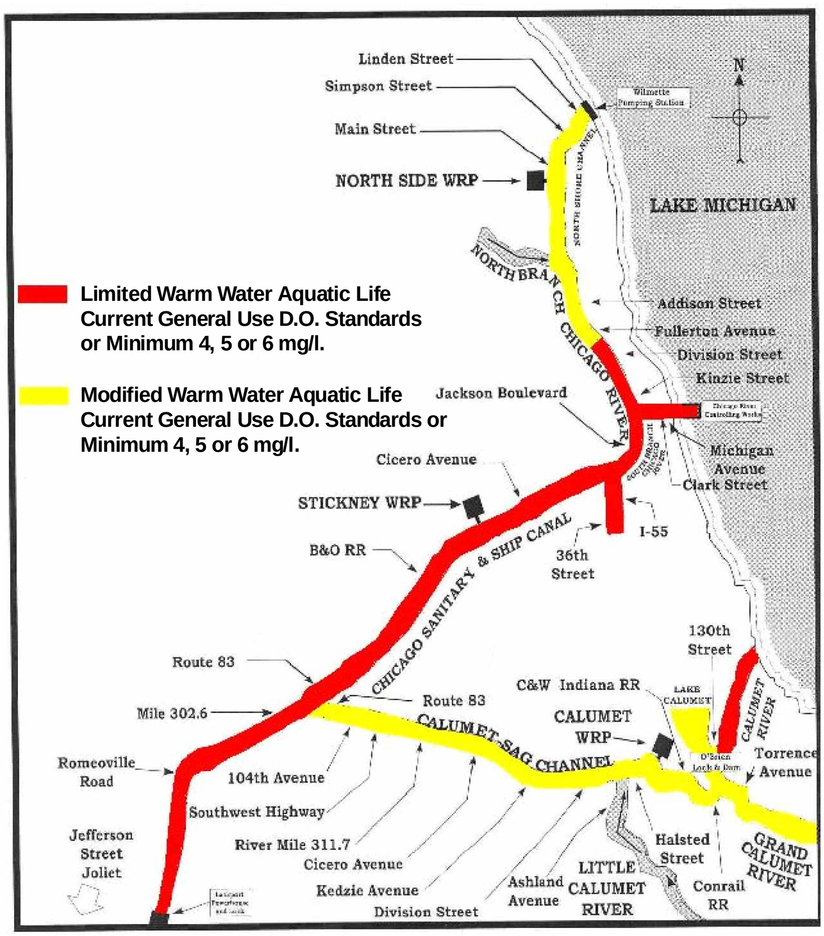

Figure 7.5 – Proposed Chicago Area Waterways Aquatic Life Use Designations and Proposed Dissolved Oxygen Standards

STUDIES OF WATER QUALITY MANAGEMENT OPTIONS

As mentioned previously, as part of the UAA process the MWRDGC was requested by the IEPA to determine the technologies and costs for certain CAWs water quality management options. CTE studied these options for the MWRDGC and prepared technical memorandums which document the results of these studies. These technical memorandums and their titles are listed bellows:

Technical Memorandum No.	Title
TM-1WQ	Disinfection Evaluation
TM-2WQ *	Study of Nutrient Removal Processes for the North Side Water Reclamation Plant
TM-3WQ	Study of End-of-Pipe Combined Sewer Overflow Treatment
TM-4WQ	Supplemental Aeration of the North and South Branches of the Chicago River
TM-5WQ	Flow Augmentation of the Upper North Shore Channel
TM-6WQ	Flow Augmentation and Supplemental Aeration of the South Fork of the South Branch of the Chicago River (Bubbly Creek)

* A summary of TM-2WQ is presented but this document contains mainly a study of potential nutrient removal process for the North Side WRP. The study is specific only to the North Side WRP and does not directly relate to the water quality of the CAWs.

These technical memorandums contain information on those water quality management options recommended for study by the IEPA as part of the UAA process. But of course there are other options that may warrant study in the future.

Water Quality Modeling

As an aid to conducting the studies documented in TM-1WQ and TM-3WQ through TM-6WQ, CTE utilized a water quality model (Marquette Model) developed by Marquette University's Institute for Urban Environmental Risk Management under the supervision of Dr. Charles Melching of the Department of Civil and Environmental Engineering.

The Marquette Model was used to locate and conceptually size water quality management option facilities based upon meeting certain water quality objectives. For example, the model allows simulations of supplemental aeration stations of various sizes and locations in the CAWs and can determine the effect of these stations on instream dissolved oxygen.

Summary of Water Quality Management Studies

In this section of TM-7WQ, a brief summary of TM-1WQ, TM-2WQ, TM-3WQ, TM-4WQ, TM-5WQ and TM-6WQ will be presented. In these technical memorandums, each water quality management option was studied independently of other options. For example, flow augmentation of the upper North Shore Channel was studied assuming that no other new water quality management option was operational. Therefore, the cost estimates for the water quality management options do not reflect the potential cost impacts if other options were operating at the same time.

It should be noted that in TM-4WQ, TM-5WQ and TM-6WQ the water quality target selected upon which to base sizing and costs, was 5 mg/l of waterway dissolved oxygen (DO) to be achieved 90% of the time at any location. This target was selected since the IEPA has not yet reached a decision as to the water quality DO standards for the CAWs. The target was a consensus decision with the MWRDGC.

Effluent Disinfection Study (TM-1WQ)

Various effluent disinfection options were studied to determine the most practical and environmentally acceptable alternative for potential implementation at the Stickney, Calumet and North Side WRPs, all of which discharge to the CAWs. Based upon an evaluation of the various potential effluent disinfection options by a Blue Ribbon Panel of experts and with input from the staff of the MWRDGC, it was determined that ozonation and ultraviolet disinfection (UV) should be carried forward for cost estimating purposes.

Cost estimates for ozonation and UV disinfection were prepared for the three MWRDGC WRPs by the consulting firms who were commissioned by the MWRDGC to prepare master plans for these WRPs. The detailed cost estimates are contained in TM-1WQ. If effluent filtration is needed as part of the disinfection process, the combined capital costs for effluent disinfection at the three WRPs could exceed $1.8 billion and annual operation and maintenance (O&M) costs could exceed $43 million.

Since the completion of TM-1WQ, the District has commissioned the following two reports:

1. Report No. 2006-38 Expert Review Regarding United States Environmental Protection Agency's Water Quality Criteria for Bacteria – 1986: Application to Secondary Contact Recreation. July 2006.
2. Interim Phase I Dry Weather Risk Assessment of Human Health Impacts of Disinfection vs. no Disinfection of the Chicago Area Waterways System (CWS). November 2006.

These reports concluded that effluent disinfection at the District's 3 major plants is not justified.

Study of Nutrient Removal Processes for the North Side Water Reclamation Plant (TM-2WQ)

CTE conducted a study of nutrient removal unit process alternatives for the North Side WRP. CTE evaluated nutrient removal technologies, including biological and chemical treatment options for potential future implementation at the North Side WRP. TM-2WQ contains the short list of nutrient removal technologies for the North Side WRP.

This short list was further evaluated with other potential liquid treatment processes for the North Side WRP in Technical Memorandum 8 (TM-8). In TM-8, a final nutrient removal technology was selected for the North Side WRP. This study was done to be sure that space was allocated on the North Side WRP site for possible future effluent permit limit changes. It should be noted that the future final effluent requirements for nutrient removal and the future water quality requirements in the North Shore Channel are unknown at this time. Although the North Side WRP master plan considered the necessary improvements required to meet future nutrient limit requirements, it was intended for planning purposes only. The exact final effluent limits and the timing for such requirements are unknown. Therefore, the master plan presented possible technologies to meet the more stringent final effluent requirements. It does not imply that the

District is planning any specific projects to implement the nutrient removal technologies as recommended in the master plan.

In the UAA process, the IEPA did not ask the MWRDGC to determine the costs or technologies for nutrient removal since the UAA did not include the development of water quality standards for nutrients. Thus,TM-2WQ does not directly relate to the UAA process. It is discussed here since this study was part of the scope of work for the water quality studies conducted for the North Side Master Planning Project.

Study of End-of-Pipe Combined Sewer Overflow (CSO) Treatment – TM-3WQ

CTE conducted the IEPA requested study of end-of-pipe CSO treatment. The CSO treatment objective is the equivalent of primary treatment which is typically defined as 30-35% removal of biochemical oxygen demand and 50-60% removal of total suspended solids. Based upon an evaluation of various CSO treatment alternatives and an analysis of state and federal CSO regulations, CTE determined for planning purposes that an end-of-pipe treatment plant should consist of :

- Coarse Screening
- Submersible Centrifugal Pumps
- Catenary Bar Screens (Fine Screens)
- Vortex Separators
- High Intensity UV Disinfection

There are a total of 170 CSOs in the study area. Based upon the needed space requirements for an end-of-pipe treatment plant at each site and the available land, it was determined that treatment plants could be located at 105 of the 170 sites. Placement of treatment plants at the other 65 sites would require demolition of large multi-story buildings or relocation of major roads.

To provide end-of-pipe treatment for the 105 sites would require a total capital expenditure of approximately $893 million and have a continuing annual cost of nearly $3.8 million. The total present worth for CSO treatment (capital and annual) would be $966 million.

It should be noted that the construction of 105 end-of-pipe treatment plants on the NBCR and SBCR would involve overcoming numerous political, aesthetic and economic obstacles. In addition, the USEPA's 85% guideline applies to all 170 CSO discharges in the study area and not just the 105 where land is available. The fact that only 105 CSOs in the study area would be disinfected, it is logical to conclude that bacteria standards would be violated since 65 CSO discharges in the study area would not be disinfected. Therefore, even if all of the above obstacles could be overcome and the MWRDGC invests $966 million on a present worth basis, given that only 105 CSO sites in the study area will receive disinfection because of land availability, end-of-pipe treatment will still not achieve the 85% guideline.

Study of Supplemental Aeration of North and South Branches of the Chicago River – TM-4WQ

A study was conducted to determine the potential technologies and costs for adding supplemental aeration to the NBCR and SBCR. The supplemental aeration provided would be in addition to the aeration provided currently at the Devon and Webster Avenue diffused aeration stations. To determine the size and location of the additional aeration stations, the Marquette Model was used. Since the IEPA has not reached a decision on the DO target levels for the NBCR and SBCR, a target DO of a minimum of 5 mg/l to be achieved 90% of time was selected based upon a consensus decision with the MWRDGC.

After a review of a long list of technologies using an evaluation matrix which included both non-economic and economic factors, four technologies (U-tubes, ceramic diffusers, jet aerators and free fall weirs) were selected for a detailed opinion of probable costs. The opinion of probable costs was based upon constructing a total of 4 additional stations on the SBCR and NBCR. These 4 stations were found to be necessary by Marquette Model runs to achieve the 5 mg/l DO target level 90% of the time for the data base simulated in the Marquette Model (2001 and 2002). The total capital cost ranged from $35.5 to $89.9 million. The total annual O&M cost ranged from $554,000 to $2.6 million.

It should be noted that the main purpose of the study was to determine the magnitude of the costs associated with supplemental aeration of the NBCR and SBCR and not to select a technology for possible application. Thus, it would be necessary to conduct an in depth study of the operating experience of the four technologies for supplemental aeration before proceeding further.

<u>Flow Augmentation of the Upper North Shore Channel – TM-5WQ</u>

A study was conducted to determine the costs for flow augmentation of the UNSC using effluent from the North Side WRP. The effluent discharge point for the North Side WRP would be moved from its current location at Howard Street to the headwaters of the UNSC at Wilmette.

Two flow augmentation alternatives were studied:

1. Using the unaerated North Side WRP effluent
2. Aerating the North Side WRP effluent to saturation DO before discharge at Wilmette

Using the Marquette water quality model, the amount of flow for these two alternatives to produce a waterway target DO level of 5 mg/l, 90% of the time, was determined.

The modeling runs conducted by Marquette University showed the following:

1) For the unaerated flow augmentation scenario, the entire available daily flow (up to 450 mgd at maximum flow) from the North Side WRP was not sufficient to meet the DO target which is 5 mg/l of waterway DO at any given location, 90% of the time
2) For the aerated flow alternative, a constant flow of 100 mgd was needed from the North Side WRP to meet the target.

The total present worth of the unaerated alternative was $447 million. The total present worth of the aerated alternative was $74.9 million. Aerating the augmented flow lowers the pumping rate from 450 mgd to 100 mgd and the pumping station cost savings are significantly more than the cost of the force main aeration system.

<u>Study of Flow Augmentation and Supplemental Aeration of Bubbly Creek – TM-6WQ</u>

A study was conducted to determine the technology and costs for flow augmentation and supplemental aeration of Bubbly Creek.

Simulations were undertaken using the Marquette University water quality model developed for the MWRDGC 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.

Three water quality management options were studied:

1) Flow Augmentation without aeration of the transferred flow
2) Flow Augmentation with aeration of the transferred flow
3) Supplemental aeration in combination with flow augmentation without aeration of the transferred flow

Based upon simulations conducted by Marquette University, it was found that bringing up to 550 mgd of unaerated flow from the SBCR to Bubbly Creek would not significantly raise the DO of Bubbly Creek. This is mainly due to the relatively low levels of DO present in the SBCR at Throop Street during summer conditions.

Based upon the Marquette Model simulations, bringing 550 mgd of aerated flow from SBCR to the headwaters for Bubbly Creek will improve the DO of Bubbly Creek but will not achieve the DO target level at the end of this waterway near the mouth of its junction with the SBCR. It is not practical to bring more than 550 mgd from the SBCR since flows in the SBCR are generally lower than this amount during the summer months.

Since aerated flow augmentation did not achieve the DO target chosen for this study, a combination of flow augmentation (no aeration of the augmented flow) and supplemental aeration was studied. It was found that a combination of flow augmentation of 50 mgd from the SBCR and supplemental aeration stations at the following locations and of the following sizes would achieve the DO target for Bubbly Creek:

Station	Oxygen Delivery Capacity	Location
1	80 g/sec (15,200 lbs/day)	Approximate Mouth of Bubbly Creek
2	50 g/sec (9,500 lbs/day)	Approximate midpoint of Bubbly Creek
3	10 g/sec (1,900 lbs/day)	Headwaters of Bubbly Creek

The total capital cost for the 4 supplemental aeration technologies chosen for this cost estimate (U-Tubes, Free Fall Weirs, Ceramic Diffusers and Jet Aeration) in combination with flow augmentation ranged from $60.4 Million to $102.9 Million. The total annual O&M costs ranged from $1.0 Million to $2.8 Million. A final decision as to the supplemental aeration technology that is most appropriate for implementation in Bubbly Creek would require additional study.

The study did show that the combination of flow augmentation (50 mgd) and three supplemental aeration stations achieved the DO target while aerated flow augmentation alone did not. Also the combination of flow augmentation and supplemental aeration was considerably lower in cost than aerated flow augmentation. Thus, it would appear that the combination of flow augmentation and supplementation aeration would be the most cost effective of the DO control alternatives suggested by IEPA for Bubbly Creek.

FRAMEWORK FOR DEVELOPING AN INTEGRATED WATER QUALITY STRATEGY FOR THE CHICAGO AREA WATERWAYS

Background

As previously summarized, CTE conducted studies of specific water quality management options suggested by the IEPA for certain portions of the CAWs. These studies assumed that only a particular option was operating on the CAWs and there was no attempt to determine the water quality impact and cost of combinations of these options.

For example, as shown in TM-5WQ, flow augmentation improves the DO levels in the UNSC but actually reduces DO levels in the LNSC. If flow augmentation were to be implemented in the UNSC in combination with supplemental aeration of the NBCR, the size and location of the aeration stations described in TM-5WQ would change. The aeration stations in TM-5WQ would need to move further upstream to account for the lower DO levels downstream of the North Side WRP due to flow augmentation of the UNSC.

Therefore, in order to determine an integrated strategy for improving the water quality of the CAWs, it would be necessary to conduct additional studies to determine how various water quality management options could be best combined to meet water quality objectives at the lowest cost. Such a study would include simulation of these combinations of alternative options using a water quality model of the CAWs and preparing planning level cost estimates of these combinations.

Development of the integrated strategy would include the study of water quality management option for the entire CAWs. Thus, the integrated strategy studies would include a broader range of water quality management options than that studied by CTE.

Suggested Integrated Water Quality Strategy Development

This section contains a plan for developing an integrated water quality strategy for the CAWs. The tasks discussed below should be considered to be a starting point for developing a plan for the Integrated Water Quality Strategy. The District at its discretion may elect to modify, combine, or eliminate some of these tasks.

<u>Task 1 – Develop Long List of Potential Water Quality Management Options</u>

Working with the IEPA and other stakeholders in the UAA process, a potential long list of water quality management options should be determined for the entire CAWs in a one-day workshop. The water quality management options considered in TM-1WQ thru TM-7WQ did not include the entire CAWs. Obviously, the results of the studies contained in TM-1WQ through TM-7WQ should be considered in the development of the long list. This task will include identifying specific water quality management needs for the CAWs pertinent to development of the integrated strategy for improving water quality. The workshop should also include identification of the time periods that are best suited for determining percent compliance with water quality criteria and the locations of interest for evaluating compliance with water quality standards.

It would be advisable for the MWRDGC to prepare an initial list of questions and issues to help in the development of the long list of water quality management options. This list of questions and issues should be prepared and presented prior to the one-day workshop.

In the interests of helping the District develop the long list, CTE has prepared a listing of those water quality management options that appear to hold the most future promise. But this list is not meant to be comprehensive and should not preclude an effort on the part of the District and other UAA stakeholders to develop the long list as described in Task 1.

Some suggested potential options may include:

1) Supplemental aeration on those parts of the CAWS that cannot consistently meet dissolved oxygen water quality standards.
2) Flow augmentation on those parts of the CAWS that have insufficient flow during dry weather to permit achievement of dissolved oxygen water quality standards.
3) Sediment remediation that significantly impact water quality in the CAWS.
4) Construction of the McCook and Thornton Reservoirs of the TARP system

Combinations of the above options should be considered depending upon waterway characteristics. For example, flow augmentation combined with supplemental aeration may be a potential combination in one segment of the waterway. While in another segment, supplemental aeration and sediment remediation maybe a potential combination.

<u>Task 2 – Prepare Short List of Potential Water Quality Management Options</u>

The long list developed in Task 1 should be thoroughly reviewed based upon the following qualitative economic and non-economic criteria:

1) Economic Impacts
2) Maintainability
3) Operability
4) Ability to Meet the Regulatory Targets
5) Public Perception
6) Indirect Environmental and Health Impacts
7) Safety

Each water quality management option should be evaluated relative to a weighting factor for each criteria. For each option, the score for that option is multiplied by the criteria's weight to arrive at a total score. Available information will also be reviewed to ensure that sufficient information exists to support desired model applications.

The evaluation criteria weights and scores should be a consensus decision by the MWRDGC and other stakeholders.

It would be advisable to conduct a one-day workshop to reach a consensus decision on the criteria and weights and the scoring for each option. Available information will also be reviewed to ensure that sufficient information exists to support desired model applications.

Ultimately the one-day workshop will be used to develop a short-list of water quality options for detailed evaluation.

<u>Task 3 – Audit Model and Information</u>

A water quality model should be used to simulate the short-listed water quality management options (from Task 2) and to help determine the sizing and location of these options by evaluating water quality impacts. The model to be used would be the Marquette Model or another water quality model selected by the MWRDGC. Alternatively a combination of the Marquette Model and other alternative models may be selected. Thus, it will be important to review the capability of the Marquette Model and other applicable water quality models and the adequacy of MWRDGC resources to apply these models. Available information will also be reviewed to ensure that sufficient information exists to support desired model applications. Sufficient information is needed for pollutant loadings and/or hydraulic and/or hydrologic conditions under desired scenarios. This may include evaluating whether a collection system model is available and suitable for simulating the CSO and pump station overflows under forecasted conditions. Information about how to apply the Marquette Model and other available models to answer specific questions will also be evaluated.

If there is a perceived need to construct a collection system model, this model could be integrated into the Marquette Model and/or combined with other models. This collection system model can be used for a variety of tasks including developing CSO flows and pump station discharges to the waterways as a result of the Tunnel and Reservoir Plan (TARP) system. The collection system model could be used to simulate both the current operation of the TARP tunnels and the future operation of the TARP Reservoirs.

Available model calibration/verification runs will be obtained and model documentation should be reviewed after the workshop. A separate meeting should be held to discuss model review results. The MWRDGC's hardware/software needs for preprocessing (for preparing model inputs), and postprocessing (of the models' output) should be evaluated.

Ultimately, a summary of model enhancements will be recommended.

<u>Task 4 – Model Modifications and Improvements</u>

Based upon the results of Task 3, model enhancements will be made. These modifications could include:

1. Revised calibration and verification
2. Adding additional data bases to the model input
3. Revised methods for addressing compliance during wet and dry periods
4. Adding the ability to simulate future Sediment Oxygen Demand (SOD) as a result of water quality improvements.

If there is a need to construct a collection system model based upon the results of Task 3, this could be integrated into the water quality model. The collection system model could be used for a variety of tasks including simulating CSO flows and pump station discharges as a result of the completed MWRDGC's Tunnel and Reservoir Plan (TARP).

It is anticipated that there may be a need to conduct additional water quality sampling and analysis for the CAWs as part of model enhancements. This may necessitate the need for additional calibration and verification. Adjusting kinetic rates and other model coefficients may also be required.

Finally, sensitivity testing of the model should be conducted to quantify the uncertainty associated with how well the water quality management options will comply with water quality standards. This sensitivity analysis will include simulating a selected subset of the short-listed water quality management options. The model's sensitivity to various model inputs that could affect these options should be tested.

Task 5 – Evaluate Short Listed Water Quality Options

The upgraded model will be applied to evaluate the short-listed water quality management points alone and in combination. The model will be used to determine the following for various combinations of options:

1) Sizing of water quality management options to meet water quality objectives
2) Simulating the water quality benefits of each option

The model will help to eliminate the combinations of options which have limited benefit and/or cannot meet water quality objectives. Ultimately, those options or combination of options which can meet water quality objectives should be evaluated using a evaluation matrix similar to that discussed in Task 2. The matrix should score the economic impact of each option based upon a planning level cost estimate. The matrix criteria and weights should be consensus decision by the MWRDGC and other stakeholders.

Task 6 – Workshop to Determine the Most Cost-Effective Water Quality Management Options

It is suggested that a one-day workshop be conducted to reach a consensus decision on scoring for the evaluation matrix from Task 5. This workshop would be attended by the MWRDGC and other stakeholders. The scoring would be based upon the model runs and costs estimates from Task 5.

After the scoring is completed, the highest scoring alternatives should be reviewed for possible inclusion into an integrated MWRDGC water quality strategy. This strategy will essentially include a priority listing of the highest ranked water quality management options. In developing the list, the MWRDGC will need to analyze its financial ability to fund these projects. This analysis should include a review of all future revenue requirements including planned improvements and expansions at the MWRDGC's water reclamation plants.

Task 7 – Prepare Final Water Quality Strategy

In a one-day workshop, the District should review the results of Task 6 and finalize its recommended Water Quality Strategy for the CAWs.

SUGGESTED ENHANCEMENTS TO THE MARQUETTE DUFLOW MODEL

The MWRDGC has commissioned a variety of hydraulic and water quality models which relate to the CAWs. However, the model which has the greatest potential use for helping to determine the integrated water quality strategy is the DUFLOW model which was developed for the CAWs. This one-dimensional hydraulic and water quality model was commissioned by the MWRDGC and constructed by Marquette University.

The Marquette Model was entirely adequate for developing the water quality impacts and conceptual level costs for the various water quality management studies in TM-1WQ through TM-6WQ. However, serious consideration should be given to enhancing and modifying the model if it is to be used for developing the integrated water quality strategy for the MWRDGC.

During the development of TM-1WQ through TM-6WQ, various issues were found during the use of this model. This section of TM-7WQ includes a discussion of these issues, including estimation of CSO and pump station inputs, definition of dry vs. wet weather conditions, model formulation of SOD rates, model instabilities, and application of the model to determine long-term compliance with water quality standards. Addressing these issues may result in adjustments to pollutant loads and/or kinetic coefficients which would necessitate revisiting the calibration and verification of the model.

CSO and Pump Station Inputs

CSO volume and concentration estimates could be improved. There is some question as to the reliability of the estimates of CSO volumes in the model. CSO inputs for 200 CSOs are specified by estimating total CSO volume based on flow at Romeoville and distributing this flow to just 28 locations. A change in CSO flow could considerably alter the hydraulics of the system, which has not been tested. The certainty in CSO and pump station volumes could be improved through the development of a collection system model.

Identifying the locations where CSO discharges are more frequent is the first step to improve CSO volume input in the model. Current and past CSO discharge flows at pump stations are available and could be used to improve existing pump station volume inputs for the model. Improvements in pollutant concentrations currently used in the model could be obtained through more sampling and analysis.

In addition, two different fecal coliform concentrations are currently used to represent the CSO and pump station overflows. These two fecal coliform concentrations are 1.1 million/100 ml and 175,000/100 ml. Model predictions of peak coliform levels and percent compliance with the geometric mean differ depending on which concentration is selected, particularly for CSO treatment runs. Specification of CSO concentrations could be improved through collection of additional CSO concentration data or estimation of stormwater versus sanitary flow in the CSOs.

Definition of Dry versus Wet Weather Conditions

The model currently has difficulty separately evaluating the water quality effects of technologies during dry weather conditions as opposed to wet weather conditions. A better process for applying the model separately to evaluate dry weather conditions (i.e., non-CSO and non-runoff related conditions) should be established. This could be explored by deleting wet weather effects from the model inputs.

Model Formulation of Sediment Oxygen Demand Rates

The model specifies Sediment Oxygen Demand (SOD) at a rate that does not vary with changes in pollutant loads, making it difficult to evaluate strategies that might consider, for example, supplemental aeration or flow augmentation combined with pollutant reduction approaches. It is anticipated that SOD will decrease when CSO loads are decreased and hence DO should improve in portions of the CAWs (e.g. Bubbly Creek) where SOD is important. A SOD subroutine can be incorporated into DUFLOW that relates SOD to pollutant loads, and the calibration revisited. The suggested SOD subroutine could be developed from field measurements of SOD in the CAWS and/or SOD values from the scientific literature.

Model Instabilities

The model calculations at certain times and locations are not stable and may oscillate or produce unrealistic values, especially during storms or significant changes in loads. The extent and significance of this issue should be explored for the different technologies under consideration, and corrective formulations included in the model code as necessary.

Application of the Model to Determine Long-Term Compliance with Water Quality Standards

Assessing compliance for a “typical” year is important to the UAA effort and any future NPDES permit that assures compliance with water quality standards. It is not clear that the time periods simulated in the Marquette Model are typical. For example, the time periods in the model may not represent the typical rainfall for the Chicago Area. The water quality portion of the Marquette Model has been developed for summer periods in 2001 and 2002 per MWRDGC’s request. The availability of data for other years and the “typicalness” of those years should be examined. For example, combinations of rainfall and flow in the CAWs should be evaluated so that typical conditions are represented in the model simulations. Ultimately, model inputs should be developed for the selected “typical” year(s) and the sensitivity of the model calculations to these conditions established.

ON-GOING MWRDGC MODELING PROJECTS

The MWRDGC has an on-going effort underway to develop various hydraulic and water quality models which directly relate to the CAWs. Among the various reasons for developing these models is the MWRDGC’s decision to determine the benefits and costs of various water quality management options. Since these models alone or in various combinations will be used to develop the integrated water quality strategy, a short summary of these modeling efforts will be presented here.

These models are currently in the development stage and thus no attempt will be made here to discuss model results or conclusions. The purpose is to describe the objectives of the model development projects.

University of Illinois Hydraulic Model of the Tunnel and Reservoir Plan (TARP) System

The MWRDGC has commissioned the development of a hydraulic model of the Tunnel and Reservoir Plan (TARP) system by Dr. Marcelo H. Garcia who is the Chester and Helen Siess Professor on the facility of the Department of Civil and Environmental Engineering at the University of Illinois (Urbana, Illinois). Professor Garcia is a leader in the field of river mechanics and environmental hydraulics.

The objective of the modeling project is to develop a real time hydraulic model of the TARP Tunnels and Reservoirs.

Specifically the objectives of the model are:

1. Optimize the operation of the TARP system to reduce CSO flows to the CAWs.
2. Determine the effects of transient hydraulic conditions within the TARP system.
3. Provide a framework so that the various previous models of TARP can be integrated into a single system.

The model will combine a hydraulic model of the TARP system with a hydrologic model so that the effects of various storms can be determined on hydraulic conditions within the TARP system. Ultimately the model could potentially be used to predict CSO overflows to the CAWs. Thus, this model could be used as an input to the Marquette Model to simulate CSO flows during rainstorm events.

<u>United States Geological Survey Measurements for TARP System</u>

In order to calibrate and verify the University of Illinois hydraulic model of the TARP system, the services of the United States Geological Survey (USGS) are being used to measure flows, and water elevations in service sewers, control structures, and outfall. These measurements are scheduled to take place in late 2006 and early 2007.

University of Illinois Water Quality Model of the Chicago River, South Branch of the Chicago River, Bubbly Creek and Chicago and Sanitary and Ship Canal

The MWRDGC has also commissioned Dr. Garcia to prepare a three dimensional water quality model of certain parts of the CAWs. This model will be considerably more complex than the one-dimensional Marquette Model of the CAWs. However, unlike the Marquette Model of the entire CAWs, the University of Illinois model will only include the CR, SBCR, Bubbly Creek and the CSSC. These waterways are among the most complex in the CAWs. The MWRDGC believes that a more complex water quality model of these waterways will be useful not only to the MWRDGC but others who discharge to these waterways as well.

Ultimately, the University of Illinois water quality model could be used to simulate water quality conditions in the CR, SBCR, Bubbly Creek and the CSSC. The model could be used independently or in combination with the Marquette Model to simulate the effects of water quality management options on these waterways. Thus, this model could be used to help the MWRDGC develop an integrated water quality strategy of the CAWs.

<u>USGS Measurement for University of Illinois Water Quality Model</u>

Dr. Garcia will be using the services of the USGS in the calibration and verification of the three dimensional model. The USGS will measure flows, water elevations, stream geometry and water quality for input into the model.

POSSIBLE WATER QUALITY MANAGEMENT OPTIONS FOR BUBBLY CREEK

The MWRDGC has requested that CTE prepare a list of potential water quality management options for Bubbly Creek. In TM-6WQ, several IEPA recommended options were studied. The MWRDGC asked CTE to speculate on water quality management options in addition to those in TM-6WQ. This list will contain a description of possible options but no attempt will be made to evaluate these options.

Ideas for Improving Bubbly Creek Water Quality

Three general approaches to improving water quality in Bubbly Creek have been identified. These are: flow augmentation / supplemental aeration (discussed in TM-6WQ, Flow Augmentation and Supplemental Aeration of the South Fork of the South Branch of the Chicago

River), Racine Avenue Pump Station (RAPS) overflow reduction and sediment oxygen demand reduction. These are discussed conceptually below:

- **Flow Augmentation/Supplemental Aeration** – This approach would use a combination of adding flow to the creek along with supplemental aeration to improve general circulation and DO levels in the creek. Several concepts have been developed in TM-6WQ.

- **RAPS Overflow Reduction** – This approach is targeted at methods to decrease the combined sewer overflows from the RAPS. RAPS contributes a large volume of CSO overflows to Bubbly Creek each year. Reduction in this volume would improve water quality. Several different options are outlined below:

    - ***Impact of McCook Reservoir on Overflows.*** Once the McCook Reservoir is brought on line, RAPS overflows should be reduced. Taking full advantage of the McCook Reservoir would require a change to the operational procedures for the regulating structures at RAPS and an analysis of the changes to the overall TARP system operation due to the addition of the reservoir. An assessment of the effect of the McCook Reservoir options should be considered in formulating Water Quality Management Options for Bubbly Creek.

    - ***Impact of 39th Street Tunnel on Overflows.*** Since the 39th Street tunnel project adds storage volume to the MWRDGC collection system, the tunnel could have an impact on CSO overflows. But this impact should be evaluated. The average RAPS overflow is about 300 MG and the 39th Street tunnel volume is about 20MG. This potential storage volume would have to be evaluated in terms of overflow reduction to Bubbly Creek.

    - ***Additional Tunnel Storage.*** Additional storage capacity could be added to the Bubbly Creek collection system by adding a tunnel (in addition to the 39th Street Tunnel Project). But the additional storage volume needed would also have to be evaluated in terms of impacts upon overflow reduction to Bubbly Creek. This tunnel and/or the 39Th Street Tunnel could be used for treating the stored wastewater by providing aeration systems or other systems designed for removing pollutants. The treated wastewater could than be pumped back to Bubbly Creek or sent to the Stickney WRP for further treatment.

    - ***Extend the 39th Street Tunnel.*** The 39th Street Tunnel could be extended north to the South Branch of the Chicago River so that CSO's to Bubbly Creek can be discharged directly to this waterway.

- **Sediment Oxygen Demand Reduction** – The sediments in Bubbly Creek have been polluted by RAPS and commercial and industrial users dating back to the original use of the creek as drainage for the stockyards. There are a number of combined sewer overflows in addition to RAPS that contribute pollutants to the sediment. These sediments exert an oxygen demand on the water column that results in reduced DO levels. Reduction of the SOD would result in improved water quality. All SOD reduction concepts would require additional modeling of sediments and / or sediment sampling and characterization. Several options for reducing SOD are outlined below:

    - ***Sediment Remediation Via Capping.*** In sediment capping submerged contaminated sediments are covered by stable layers of sediment, gravel, rock, and/or synthetic materials. The cap reduces contaminant mobility and subsequent interaction between aquatic organisms and the contaminants. This approach has been employed by the Corps of Engineers and USEPA for contaminated harbor and dredged materials disposal sites.

- ***SOD Degradation*.** Sediment oxygen demand will decrease as a result of implementing other water quality management options. As general water quality is improved, SOD is likely to decrease over time. Again, model improvements would be required to document the reduction of SOD and simulate the resulting water quality improvement.

MWRDGC Suggested Water Quality Management Options for Bubbly Creek

During preparation of the TM-6WQ the MWRDGC's Maintenance and Operations Departments offered three potential Water Quality Management options for improvements to Bubbly Creek.

These were:

- Pumping effluent from the Stickney WRP to the headwaters of Bubbly Creek
- Pumping the headwaters of Bubbly Creek directly to the CSSC
- Diverting flow from Bubbly Creek to the Stickney WRP

SUMMARY AND PROCESS FORWARD

This technical memorandum (TM-7WQ) contains a summary of previous technical memorandums (TM-1WQ through TM-6WQ) which studied water quality management options for the CAWs. These previous technical memorandums were prepared at the request of the IEPA who is currently conducting an UAA for the CAWs. The IEPA requested the studies contained in the technical memorandums so that they could consider the costs and water quality impacts of these options as they deliberate potential changes to the waterway uses designations of the CAWs.

The studies contained in TM-1WQ and TM-3WQ through TM-6WQ assumed that each water quality option was operated independently of other options. However, there are potential water quality and cost benefits if combinations of the various options are considered. Also, there are potentially other water quality options besides those addressed in TM-1WQ and TM-3WQ through TM-6WQ that may merit consideration. Lastly, the studies included in TM-1WQ through TM-6WQ only include parts of the CAWs. Thus, there is a need to consider combinations of water quality options potentially operating within the entire CAWs.

As a result of the above considerations, the MWRDGC requested that TM-7WQ be prepared to develop a framework for an integrated water quality strategy for the CAWs. Ultimately, this framework would produce a prioritized list of the water quality management options and/or combinations of options which will produce the most benefit at the lowest cost. TM-7WQ includes a detailed description of the tasks associated with this framework.

The MWRDGC also asked that TM-7WQ include the following:

1) Potential Enhancements to the Marquette University Model
2) Summary of on-going Modeling Work by the University of Illinois & USGS
3) List of Potential Water Quality Management Options for Bubbly Creek

These three items were included in TM-7WQ since they represent potential information that could be used to develop the integrated water quality strategy. They should be considered for potential input into the framework used to develop the integrated strategy.

Task 1 of the framework includes developing a long list of potential water quality options for the CAWs. The list of potential options for Bubbly Creek contained in TM-7WQ should be considered in Task 1.

Task 3 of the framework includes a review of the capabilities of the various models including the Marquette and University of Illinois Models and other models available to the MWRDGC. Thus, this task should include a review of the potential enhancements needed for the Marquette Model required for developing the integrated strategy and a study of how the University of Illinois Models (both the TARP and Water Quality Models) might be used alone or in combination with the Marquette Model. TM-7WQ contains a discussion of potential enhancements to the Marquette Model and a summary of the University of Illinois modeling objectives.

The studies in TM-1WQ and TM-3WQ through TM-6WQ are a good start on the road to developing an integrated strategy for the CAWs. But there is considerable effort remaining in order to determine what water quality management options and/or combinations of options will produce the greatest benefit for the CAWs at the lowest cost.

TM-7WQ includes the framework for developing this integrated strategy.