# Scope Outline of Potential CAWS & Lake Michigan Hydrologic, Hydraulic, and Water Quality Investigations

## Overall Objective and Background

As noted in a January 2016 letter to the President and the Great Lakes and Mississippi River Congressional Delegation, the CAWS Advisory Committee (Advisory Committee) determined that further study was warranted to evaluate a system of possible control points as a long-term solution to AIS transfer through the CAWS. Specifically, the Advisory Committee identified further information is needed to design and select a long-term solution, including assessing the following in more detail:

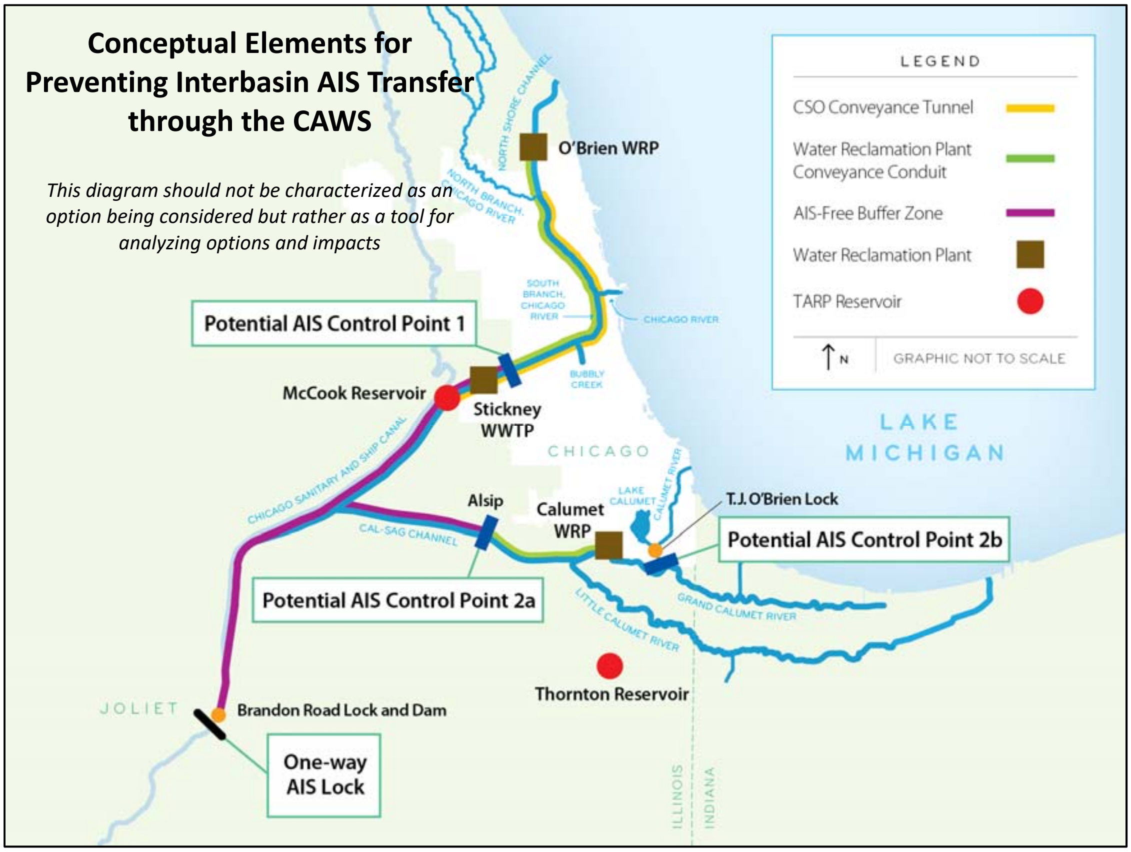
- Whether and how control points could be implemented consistent with mid-system locations identified in GLMRIS

Implications regarding flood risk management and water quality are critical components to the assessment of potential AIS control points, and evaluation of these implications will require additional hydrologic, hydraulic, and water quality investigations. As such, the Advisory Committee has identified hydrologic, hydraulic, and water quality investigations as one of the primary near term topic areas. In support of this near term focus, this document provides a scope outline and plan of activities to refine, enhance, and/or augment existing hydrologic, hydraulic, and water quality models and analyses to inform and evaluate the conceptual elements and components identified for discussion by the Advisory Committee.

Conceptual elements or possible components of a potential long term solution identified for investigation are illustrated in Figure 1. Potential control point locations were informed by previous study results and evolved through CAWS Advisory Committee discussions based on relationship with the working criteria involving AIS risk, flood risk, water quality, and transportation. These conceptual elements and control points were intended to serve as a tool for further evaluation of potential options, and do not necessarily reflect the position of the Advisory Committee or any of its members.

Through direct coordination with Resource Group stakeholders (City of Chicago, MWRDGC, Northwest Indiana Forum, USACE, USGS, and GLC), an initial scope outline document was drafted to identify a broad list of hydrologic, hydraulic, and water quality related tasks needed to further evaluate AIS control points. This draft scope outline was presented to the Advisory Committee for review and input, resulting in a revised draft outline that incorporated Advisory Committee input (Appendix A). The next steps were to develop additional detail and determine an estimated level of effort for performing the identified analyses, which this document and the associated appendices outline.

**Figure 1: Conceptual Elements of Potential Long Term Solution**




Graphic credit: Great Lakes Commission.

## Framework for Evaluations

While possible for some subsequent tasks to be performed in parallel, foundational tasks including establishing baseline water quality conditions and creation of a comprehensive set of linked hydrologic/hydraulic models that encompass the entire study area must be performed first. Effective and efficient development of these foundational investigative components requires coordination with regulators and stakeholders for determining metrics/measures/factors of importance and necessity, baseline conditions, and potential alternatives and associated mitigation strategies. Recognizing the State of Illinois' anti-degradation process for evaluating water quality implications also requires these elements for upfront coordination and strategy, the framework presented in the document for hydrologic, hydraulic, and water quality analyses was created in a complementary manner. While anti-degradation is focused on water quality, variations in water quality implications associated with potential AIS control points are directly related to factors influencing other water related issues (i.e. flood risk management, water supply, and navigation). Due this interdependence, the anti-degradation process provides a logical overarching framework for the extensive set of required water related analyses.

Major Tasks

The specific components of all of the water related analyses outlined in this scoping document can be summarized into 3 major tasks elements:

1) Anti-degradation Review – overarching framework for conducting analyses/modeling including:
    a. Coordination with regulators and stakeholders to determine:
        i. Parameters of concern
        ii. Baseline water quality conditions
        iii. Alternatives and mitigation measures
        iv. Factors of social and economic importance
    b. Evaluation of alternatives – evaluation of a range of non-degrading and less degrading practicable alternatives
    c. Demonstration of social and economic importance – demonstrate potential lowering of water quality is necessary (not an economic cost-benefit analysis)
2) CAWS Hydrologic/Hydraulic/Water Quality Analyses – primarily CAWS focused analyses evaluating a variety of water related issues:
    a. Flood risk management – overland and basement flooding
    b. CSO/TARP conveyance and storage
    c. CAWS water quality and sediment transport
    d. River/lake operational considerations – flood risk, navigation, recreation, and water supply related primarily to water/infrastructure elevations
    e. Water supply investigations – industrial/municipal water supply, navigation, recreation related primarily to volume
3) Lake Michigan Hydrologic/Hydraulic/Water Quality Analyses – primarily Lake Michigan focused analyses requiring linkage with CAWS models/analyses
    a. Develop refined near field hydrodynamic model for Chicago/NW Indiana vicinity and lower CAWS river reaches (assume data collection required for model development/calibration)
    b. Develop sediment transport and contaminant fate model connecting CAWS with Lake Michigan (links with CAWS sediment modeling and assumes additional data collection for model development/calibration)

Additional detail regarding these major tasks is provided in the appendices following this document:

- Appendix A: initial draft scope outline developed through Resource Group coordination and Advisory Committee feedback; subsequently, additional detailed scope documents were developed in support of this overview document and are included as other appendices

- Appendix B: Task Item #1 - Anti-degradation Review scope outline

- Appendix C: Task Item #2 - CAWS Hydrologic/Hydraulic/Water Quality Analyses scope outline
- Appendix D: Task Item #3 – Lake Michigan Hydrologic/Hydraulic/Water Quality Analyses scope outline

It is noted that since the initial draft scope outline was prepared and reviewed by the Advisory Committee, Resource Group and Advisory Committee member MWRDGC has contracted with the University of Illinois at Urbana-Champaign (UIUC) to independently perform a significant amount of hydrologic/hydraulic/water quality modeling of the CAWS as it relates to invasive species alternatives (see Appendix E). While the specific correlation and overlap of this MWRDGC scope with the Advisory Committee draft scope has yet to be determined, initial review of the MWRDGC scope indicates that it draws parallels with the vast majority of the originally identified Task Item #2 (CAWS Hydrologic/Hydraulic/Water Quality Analyses) elements. It is recommended that the Advisory Committee coordinate directly with MWRDGC to leverage the overlapping scope elements and potential coordination of resources for the benefit of all stakeholders.

For purposes of this scoping document, it was assumed that the majority of Task #2 items could be accomplished through coordination and supplementation of the MWRDGC scope. A few specific Task #2 items were identified as items outside of the MWRDGC scope that would require additional focus including:

- Evaluation of future conditions – land use and potential climate change effects
- Calumet System flood risk assessment – potential impacts and mitigation measures including impacts/modifications to USACE Little Calumet Flood Risk Management project
- River/lake operational considerations – navigation requirements, wave/wind effects on rivers when open to the lake, recreational area access/impacts, and industrial/commercial water supply needs (lakeside water elevations)
- Industrial and municipal water supply – industrial/municipal water supply, navigation, and recreation implications related primarily to water volume
- Sediment modeling – expand analyses to include longer duration simulation

<u>Timeframe and Budget</u>

These tasks are envisioned to utilize as much existing information, modeling, and analyses as possible to capitalize on previous efforts and expenditures including general acceptance of models by stakeholders. Nonetheless, considerable effort and evaluation is anticipated for refining and/or augmenting these analyses and models for purposes of evaluating a potential long-term AIS solution involving control points. An approximate timeframe and order of magnitude estimate of costs for conducting these analyses is outlined as below.

**Approximate Duration and Conceptual Costs for Potential Water Related Analyses**

| Task | Approximate Duration[1] | Conceptual Cost |
|---|---|---|
| 1) Anti-degradation Review | | |
| Coordination | 12-18 months | $100-$150k |
| Alternative Analysis | 12-18 months | $650-$850k |
| Social/Economic Importance | 6 months | $50-$75k |
| 2) CAWS Hydrologic/Hydraulic/Water Quality | | |
| MWRD Investigations (UIUC scope)[2] | 48 months | $975k |
| Supplemental Evaluations (beyond UIUC scope) | | |
| Calumet System Flood Risk Assessment | 6-12 months | $300-$400k |
| River/Lake Operational Considerations | 6-12 months | $100-$150k |
| Industrial/Municipal Water Supply Investigation | 6-12 months | $200-$300k |
| Sediment Modeling (Longer Duration) | 6-12 months | $400-$500k |
| 3) Lake Michigan Water Quality | | |
| Independent Review of CAWS H&H | 3-6 months | $75-$100k |
| Lake Michigan Water Quality Data Collection & Modeling | 18-24 months | $500-$750k |
| CAWS/Lake Michigan Sediment Data Collection & Modeling | 30-36 months | $750k-$1M |
| Total:<br>MWRD Investigation:<br>**Remaining Total:** | See Timeframe Table | $4M-$5.5M<br>($975k)<br>**$3M-$4.5M** |

Notes: 1) Approximate durations of individual task items; total duration of tasks will not equal the sum of all tasks as some task items can be performed in parallel

2) Based on UIUC scope dated August 15, 2016

While some of the individual task items may be performed in parallel, many of the tasks are dependent upon each other and must be performed in sequence. In particular, establishment of baseline water quality conditions/parameters and creation of a comprehensive set of linked hydrologic/hydraulic models that encompass the entire study area must be performed before conducting the various impact analyses and investigation of alternatives and mitigation strategies. However, some overlap must be incorporated to provide coordination between the sequential tasks and some cyclical analyses, which allows for some tightening of overall schedule.

The table below of approximate timeframes provides a broad level overview of the relation of individual task items to each other as well as the overall timeframe.

### Approximate Timeframe[1] for Potential Water Related Analyses

| Task | 2017 | | 2018 | | 2019 | | 2020 | | 2021 | | 2022 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) Anti-degradation Review | | | | | | | | | | | | |
| Coordination | | | | | | | | | | | | |
| Alternative Analysis | | | | | | | | | | | | |
| Social/Economic Importance | | | | | | | | | | | | |
| 2) CAWS Hydrologic/Hydraulic/Water Quality | | | | | | | | | | | | |
| MWRD Investigations (UIUC scope)[2] | | | | | | | | | | | | |
| Supplemental Evaluations (beyond UIUC scope) | | | | | | | | | | | | |
| Calumet System Flood Risk Assessment | | | | | | | | | | | | |
| River/Lake Operational Considerations | | | | | | | | | | | | |
| Industrial/Municipal Water Supply Investigation | | | | | | | | | | | | |
| Sediment Modeling (Longer Duration) | | | | | | | | | | | | |
| 3) Lake Michigan Water Quality | | | | | | | | | | | | |
| Independent Review of CAWS H&H | | | | | | | | | | | | |
| Lake Michigan Water Quality Data Collection & Modeling | | | | | | | | | | | | |
| CAWS/Lake Michigan Sediment Data Collection & Modeling | | | | | | | | | | | | |

Notes: 1) Relation of individual task item approximate timeframes are based on anticipated completion of Task #2 elements by MWRD and assume a start date of Task Item #1 in 2017

2) Based on UIUC scope dated August 15, 2016

# Appendix A: Initial Draft Scope Outline of Potential CAWS Hydrologic, Hydraulic, and Water Quality Investigations

<u>Overall Objective and Framework</u>

Refine/enhance existing hydrologic, hydraulic, and water quality models and analyses to inform and evaluate the conceptual elements and components identified for discussion by the CAWS Advisory Committee, specifically:

- Whether and how control points could be implemented consistent with mid-system locations identified in GLMRIS (variations of the GLMRIS Alternatives #6 and #7)
    1. Potential AIS Control Points near Stickney and Alsip
    2. Potential AIS Control Points near Stickney and O'Brien Lock along with control points on Grand and Little Calumet Rivers near basin divides

<u>CAWS Hydrology & Hydraulics</u>

Objective

- Revise/enhance existing hydrologic and hydraulic modeling to inform and evaluate the conceptual elements and system components identified for discussion by the CAWS Advisory Committee, specifically related to:
  - Revised CSO design event assumption and storage needs based on stormwater conveyance, potential pumping, treatment, and TARP reservoir optimization (Note: revised CSO assumptions also requires coordination with IEPA/IDEM regarding anti-degradation requirements)

Task Components

- Overall hydrologic and hydraulic modeling elements
  - Extend/combine existing models to incorporate North Branch Chicago River and Grand/Little Calumet reaches in Northwest Indiana to develop a single comprehensive set of models compassing the entire study area
- Hydrologic updates based on precipitation/design events
  - 2-yr (water quality loading) through 500-yr (flood risk) design events
  - Revised CSO design event and storage/conveyance assumptions (associated with CSO/TARP hydraulic evaluation)
  - Future conditions – land use projections and consideration of potential climate change effects through model sensitivity analyses
- Hydraulic Evaluations
  - CSO/TARP Conveyance and Storage Evaluation
    - Evaluate various scenarios for capturing Chicago River system CSO outfalls and/or Racine Avenue Pumping Station (RAPS) and impacts to CAWS water elevations
      - Identify pumping/storage needs and impacts to CAWS water elevations for scenarios:
        1) RAPS outfall routed to McCook
        2) North Shore Channel (NSC) CSO outfalls only routed to McCook (no reroute of RAPS)
      - Evaluate impact of McCook storage volume assumptions (no storage limit vs. 2029 storage) on CSO conveyance and CAWS water elevations
      - Need for high volume pumping/treatment and/or additional reservoir volume during extreme event and back-to-back storms
      - Need for additional conveyance to McCook from NSC and/or North Branch
      - Consider potential reductions in need for conveyance/storage that could result from green infrastructure.

- River/Lake Operational considerations
  - Frequency, duration, and impacts of varying lake levels
  - Impacts of wave effects (some existing evaluation) and wind setup conditions on lower rivers when open to lake
  - Evaluate need for maintaining Chicago and/or O'Brien Lock and/or lower CAWS elevations relative to Lake Michigan
    - Potential drawdown/pumping for storm events to mitigate increased flood elevations
    - Navigation and vessel clearance on the CAWS (non-storm conditions)
    - Recreation area (including City of Chicago Riverwalk) access and impacts (non-storm conditions)
    - Industrial/commercial water supply needs (water elevation)
- Calumet System flood elevation assessment
  - Evaluate potential impacts and identify required mitigation measures of control point scenarios based on overall objective assumptions (potential control point locations and CSO storage)
  - Includes impacts/modifications needed to USACE Little Calumet Flood Risk Management project
- City of Chicago Basement flooding
  - Evaluate potential impacts and identify required mitigation measures of control point scenarios based on overall objective assumptions (potential control point locations and CSO storage)
  - Determine potential impacts of revised CAWS water elevations on sewer conveyance and basement flooding
  - Consider effects of lake level variations, operational needs (maintaining CAWS elevations using locks), and potential reductions in basement flooding from green infrastructure

Potential Existing Resources/Models

- MWRD 2D/3D CAWS models and TARP tunnel modeling including Univ. of Illinois models
- USACE 1D/3D CAWS models from GLMRIS, etc.
- City of Chicago Infoworks Sewer Models

## Water Supply Investigations

### Objective

- Investigate potential water supply implications and mitigation measures that would inform and evaluate the conceptual elements and system components identified for discussion by the CAWS Advisory Committee, specifically related to:
    - Reduced baseflow and storm event discharges to the Mississippi River basin side of the CAWS downstream of potential ANS control point locations
    - Operational impacts of CAWS water elevations lakeside of ANS control points due to variations in Lake Michigan levels

### Task Components

- Navigation water depth requirements – determine potential impacts and mitigation needs, including operational controls, for maintaining navigation (Note: navigation requirement issues on the CAWS lakeside of potential ANS control points will be investigated as part of the CAWS hydraulic evaluations)
    - Focused riverside of the potential ANS control points and primarily downstream of Lockport Lock & Dam
    - Dry weather (non-storm) and storm event conditions (based on revised/new hydrologic/hydraulic models)
    - Evaluate for scenarios with MWRD WRP (O'Brien and Calumet) reroutes to downstream CAWS and without (WRPs discharge to Lake Michigan)
- Industrial and municipal water supply - determine potential impacts and mitigation needs, including operational controls, for maintaining water supply (Note: Industrial/commercial water supply users lakeside of potential ANS control points will be investigated using the revised/new CAWS hydraulic evaluations as water elevation is primarily an operations issue in this area)
    - Water supply evaluation focused riverside of the potential ANS control points and primarily downstream of Lockport Lock & Dam
        - Dry weather (non-storm) and storm event conditions (based on revised/new hydrologic/hydraulic models)
        - Evaluate for scenarios with MWRD WRP (O'Brien and Calumet) reroutes to downstream CAWS and without (WRPs discharge to Lake Michigan)

### Potential Existing Resources/Models

- USGS and MWRD stream gage information
- USACE – Illinois River UNET model and reservoir operations model (?)
- Revised CAWS hydrologic and hydraulic models

## CAWS Water Quality

Objective

- Investigate potential CAWS water quality implications and mitigation measures that would inform and evaluate the conceptual elements and system components identified for discussion by the CAWS Advisory Committee, specifically related to:
  - Anti-degradation requirements
    - Additional pollutant loadings and required mitigation measures from new continuous discharges to the CAWS lakeside of potential ANS control point locations
    - Potential for pollutant load reductions now entering North Branch, Little Calumet and Grand Calumet
    - Other changes anticipated in pollutant discharge points
  - Contaminated sediment – evaluating the potential for movement/transport of CAWS contaminated sediments and determining appropriate threshold levels

Task Components

- Anti-degradation requirements – extend existing DUFLOW model to include Little and Grand Calumet regions and add non-point/stormwater inflows
  - Determine pollutant loadings from new discharge locations (outfall relocations of existing discharges)
    - MWRD O'Brien and Calumet WRPs
    - Stormwater/non-point and non-MWRD point discharges
  - Evaluate various point source conditions
    - MWRD WRPs rerouted to Mississippi (with and without additional treatment)
    - MWRD WRPs discharged to Lake Michigan (with and without additional treatment)
    - Other upstream point sources that would be discharged to Lake Michigan or rerouted to Mississippi (with and without additional treatment)
  - Evaluate various operational conditions
    - Based on revised CAWS hydraulic modeling for evaluating control structure operational needs related to flooding, navigation, etc.
      - Maintain current Chicago and/or O'Brien Lock water level controls
      - Revised Chicago and/or O'Brien Lock water level controls
  - Assess flow augmentation needs
  - Determine conceptual level costs for mitigation measures required to meet anti-degradation rules (will require coordination w/ IEPA/IDEM and acknowledgement of some level of inherent degradation)

- Contaminated sediment modeling – enhance existing CAWS 3D model and/or develop new model for determining potential transport of contaminated sediments
    - Determine appropriate threshold levels for assessing human and aquatic health risks
    - Assess sediment volume/loadings based on pollutants and determine potential implications for water quality parameters
        - Single event and near term (months/year)
        - Long term (years/decades) transport and loadings/accumulation in the CAWS
    - Evaluate various operational conditions
        - Based on revised CAWS hydraulic modeling for evaluating control structure operational needs related to flooding, navigation, etc.
            - Maintain current Chicago and/or O'Brien Lock water level controls
            - Revised Chicago and/or O'Brien Lock water level controls
    - Determine potential areas of sediment deposits related to dredging needs
    - Determine potential implications related to the Bubbly Creek Superfund sites
- Flow augmentation
    - Identify potential stagnant areas both lakeside and riverside of potential control points requiring mitigation flow augmentation, increased wastewater treatment, or re-direction of current flows Conceptualize flow augmentation mitigation measures and costs (i.e. effluent from WRPs, Lake Michigan water, etc.)
    - Assess opportunities to improve water quality of discharges as part of the analysis of the need for augmentation

Potential Existing Resources/Models

- MWRD – DUFLOW all CAWS
- MWRD WRP data/loadings
- MWRD (or USACE?) CAWS 3D model (EFDC) with sediment transport
- US EPA and MWRD sediment data/studies

<u>Lake Michigan Water Quality</u>

Objective

- Investigate potential Lake Michigan water quality implications and mitigation measures that would inform and evaluate the conceptual elements and system components identified for discussion by the CAWS Advisory Committee, specifically related to:
  - Anti-degradation requirements – additional pollutant loadings and required mitigation measures from new continuous discharges to Lake Michigan
  - Determination of minimum amount of additional pollutant that must be necessarily allowed and potential effect of that increased loading on Lake.

Task Components

- Determine pollutant loadings (unavoidable and potentially mitigated) to Lake Michigan from new discharges – building off of USACE FVCOM model, develop continuous long term model and revised event based model
  - Loading sources
    - MWRD O'Brien and Calumet WRPs
    - Stormwater/non-point and non-MWRD point discharges
    - Contaminated sediment
    - Existing shoreline sources (e.g., direct runoff, stormwater, water fowl) as they impact bacteria levels and contribute to beach closures
  - Evaluate various point source conditions
    - MWRD WRPs rerouted to Mississippi (with and without additional treatment)
    - MWRD WRPs discharged to Lake Michigan (with and without additional treatment)
    - Include upstream point sources discharges in evaluation
  - Evaluate various operational conditions
    - Based on revised CAWS hydraulic modeling for evaluating control structure operational needs related to flooding, navigation, etc.
      - Maintain current Chicago and/or O'Brien Lock water level controls
      - Revised Chicago and/or O'Brien Lock water level controls
  - Determine potential implications for water quality (i.e. beach closures, source water quality, drinking water treatment modifications)
    - Single event and near term (months/year)
    - Long term (years/decades) loadings/accumulation in Lake Michigan
    - Implications and potential mitigation for City of Chicago (and other Lake Michigan water users) drinking source water and/or treatment needs
- Develop new sediment transport and water quality model (or build off of CAWS EFDC and USACE FVCOM)
  - Assess sediment volume/loadings based on pollutants
  - Determine potential areas of sediment deposits related to dredging needs

- Determine conceptual level costs for mitigation measures required to meet anti-degradation rules (will require coordination w/ IEPA/IDEM and acknowledgement of some level of inherent degradation)

Potential Existing Resources/Models

- CAWS EFDC model
- USACE – FVCOM model

## Appendix B: Task Item #1 – Anti-Degradation Review Scope Outline

Objective

- Determine whether potential CAWS water quality implications and mitigation measures meet all antidegradation requirements. Compliance with antidegradation requirements will be based on an evaluation of necessity and importance, which will be informed by the following:
  - Coordination with regulators and stakeholders
  - Evaluation of alternatives
  - Demonstration of social and economic importance

Task Components

- Coordination with regulators and stakeholders
  - Effective use of the CAWS and Lake Michigan models for evaluating mitigation alternatives requires: development of water quality baseline conditions for short and long term modeling time periods; assessment parameters of concern; compliance points for assessment; and parameter magnitude, frequency and duration targets. This is important from the perspective of developing a stakeholder agreed upon set of the water quality metrics that can be used to assess the pros and cons of the different mitigation alternatives. This effort should be completed early in the overall effort so that the CAWS and Lake Michigan models are capable of accurately addressing the water quality metrics for decision making purposes.
  - Coordination with regulators and stakeholders to determine key components and measures for determining necessity and importance, with emphasis on the following:
    - Parameters of concern (POC) – Once identified, POCs will form the basis for pollutant loading calculations and impact assessments.
    - Baseline water quality – Baseline, or existing, water quality will be used to assess changes in water quality. Coordination is needed to reach a mutual understanding for how baseline water quality for each POC will be determined including, statistical analyses and spatial endpoints.
    - Alternatives and mitigation measures
    - Factors of social and economic importance
  - Estimated timeframe: 12-18 months
  - Estimated cost: $100,000-$150,000

- Evaluation of Alternatives
  - An alternatives analysis must evaluate a range of non-degrading and less degrading practicable alternatives, which is defined at §131.3(n) as "technologically possible, able to be put into practice, and economically viable." Depending on the outcome of the coordination task, the evaluation will:
    - Determine baseline conditions for all POCs
    - Determine pollutant loadings from new discharge locations (outfall relocations of existing discharges)
      - MWRD O'Brien and Calumet WRPs
      - Stormwater/non-point and non-MWRD point discharges
      - Combined sewer discharges at various levels of control
    - Evaluate various point source conditions
      - MWRD WRPs rerouted to Mississippi (with and without additional treatment)
      - MWRD WRPs discharged to Lake Michigan (with and without additional treatment)
      - Other upstream point sources that would be discharged to Lake Michigan or rerouted to Mississippi (with and without additional treatment)
      - Combined sewer discharges to Lake Michigan and CAWS at various levels of control
    - Evaluate various operational conditions
      - Based on revised CAWS hydraulic modeling for evaluating control structure operational needs related to flooding, navigation, etc.
        - Maintain current Chicago and/or O'Brien Lock water level controls
        - Revised Chicago and/or O'Brien Lock water level controls
    - Assess flow augmentation needs
      - Identify potential stagnant areas both lakeside and riverside of potential control points requiring mitigation flow augmentation, increased wastewater treatment, or re-direction of current flows Conceptualize flow augmentation mitigation measures and costs (i.e. effluent from WRPs, Lake Michigan water, etc.)
      - Assess opportunities to improve water quality of discharges as part of the analysis of the need for augmentation

        - Model sediment contamination - enhance existing CAWS 3D model and/or develop new model for determining potential transport of contaminated sediments
            - Determine appropriate threshold levels for assessing human and aquatic health risks
            - Assess sediment volume/loadings based on pollutants and determine potential implications for water quality parameters
                - Single event and near term (months/year)
                - Long term (years/decades) transport and loadings/accumulation in the CAWS
            - Evaluate various operational conditions
                - Based on revised CAWS hydraulic modeling for evaluating control structure operational needs related to flooding, navigation, etc.
                    - Maintain current Chicago and/or O'Brien Lock water level controls
                    - Revised Chicago and/or O'Brien Lock water level controls
            - Determine conceptual level costs for alternatives and mitigation measures
            - Determine potential implications related to the Bubbly Creek Superfund sites
    - Estimated timeframe: 12-18 months
    - Estimated cost: $650,000-$850,000

- Demonstration of social and economic importance
    - Regulations at §131.12(a)(2)(ii) provides that before allowing a lowering of water quality, states must find, after an analysis of alternatives, that such a lowering in necessary to accommodate important economic or social development in the area in which the waters are located. A determination of social and economic importance will be made based on those factors agreed upon during the coordination task. Depending on what factors are used, model analyses and existing evaluations from the GLMRIS report may be utilized to demonstrate importance.
    - This task is not an economic cost-benefit analysis, but rather a technical narrative based on alternative analyses demonstrating the social and economic importance
    - Estimated timeframe: 6 months
    - Estimated cost: $50,000-$75,000

# Appendix C: Task Item #2 – CAWS Hydrologic/Hydraulic/Water Quality Analyses Scope Outline

MWRDGC has contracted with the University of Illinois at Urbana-Champaign (UIUC) to independently perform a significant amount of hydrologic/hydraulic/water quality modeling of the CAWS as it relates to invasive species alternatives (Appendix E). While the specific correlation and overlap of this MWRDGC scope with the Advisory Committee draft scope has yet to be determined, initial review of the MWRDGC scope indicates that it draws parallels with the vast majority of the originally identified CAWS Hydrologic/Hydraulic/Water Quality Analyses elements described in the initial draft scope outline (Appendix A). Therefore, for purposes of this scoping document, it was assumed that the majority of Task #2 items could be accomplished through coordination and supplementation of the MWRDGC scope. It is also recommended that the Advisory Committee coordinate directly with MWRDGC to leverage the overlapping scope elements and potential coordination of resources for the benefit of all stakeholders.

A few specific Task #2 items were identified as items outside of the MWRDGC scope that would require additional focus and could be performed as supplemental evaluations to the MWRDGC scope including:

- Evaluation of future conditions
    - consideration of hydrologic conditions representing future land use and potential climate change effects through model sensitivity analyses
    - Estimated timeframe and conceptual cost are assumed to be absorbed into UIUC efforts with minimal impact through use of sensitivity analyses
- Calumet System flood risk assessment
    - Evaluate potential impacts and identify required mitigation measures of control point scenarios based on potential control point locations and CSO storage
    - Includes impacts/modifications needed to USACE Little Calumet Flood Risk Management project
    - Assumes use of existing USACE models and/or models to be developed through MWRDGC evaluations (by UIUC)
    - Estimated timeframe: 6-12 months
    - Estimated cost: $300,000-$400,000
- River/lake operational considerations
    - Impacts of wave effects (some existing evaluation) and wind setup conditions on lower rivers when open to lake
    - Evaluate need for maintaining Chicago and/or O'Brien Lock and/or lower CAWS elevations relative to Lake Michigan
        - Potential drawdown/pumping for storm events to mitigate increased flood elevations
        - Navigation and vessel clearance on the CAWS (non-storm conditions)
        - Recreation area (including City of Chicago Riverwalk) access and impacts (non-storm conditions)
        - Industrial/commercial water supply needs (water elevation)

    - Assumes use of models to be developed through MWRDGC evaluations (by UIUC)
    - Estimated timeframe: 6-12 months
    - Estimated cost: $100,000-$150,000
- Industrial and municipal water supply
    - Determine potential impacts and mitigation needs, including operational controls, for maintaining water supply (Note: Industrial/commercial water supply users lakeside of potential ANS control points will be investigated using the revised/new CAWS hydraulic evaluations as water elevation is primarily an operations issue in this area)
    - Water supply evaluation focused riverside of the potential ANS control points and primarily downstream of Lockport Lock & Dam
        - Dry weather (non-storm) and storm event conditions (based on revised/new hydrologic/hydraulic models)
        - Evaluate for scenarios with MWRD WRP (O'Brien and Calumet) reroutes to downstream CAWS and without (WRPs discharge to Lake Michigan)
    - Assumes use of models to be developed through MWRDGC evaluations (by UIUC)
    - Estimated timeframe: 6-12 months
    - Estimated cost: $200,000-$300,000
- Sediment modeling
    - Expand MWRDGC analyses (by UIUC) of CAWS to include longer duration simulation
        - Sediment oxygen demand (SOD) effects on CAWS water quality has been identified as a concern associated with ANS mitigation alternatives. SOD issues are best addressed with inclusion of a sediment diagenesis model (Di Toro, 1985) in the water quality model. It is not clear if the versions of WASP7 used in the existing CAWS modeling framework has a sediment diagenesis submodel capable of calculating SOD. In addition, the application of a water quality model with a sediment diagenesis submodel requires multiple year simulations because decay of particulate organic matter (POM) in the sediment is on the order of a few years. These long term simulations may require long computer run times with the very fine model segmentation used in the CAWS models.
        - Once the CAWS modeling time periods are clarified with UIUC, it may be necessary to increase the modeling time period to at least an annual period to correlate changes to POM loads to the sediment to the resulting SOD and impact on dissolved oxygen levels. It is assumed that this would be completed by UIUC.
    - Assumes use of models to be developed through MWRDGC evaluations (by UIUC) and expanded modeling is performed by UIUC
    - Estimated timeframe: 6-12 months.
    - Estimated cost: $400,000-$500,000.

# Appendix D: Task Item #3 – Lake Michigan Hydrologic/Hydraulic/Water Quality Analyses Scope Outline

### Summary of CAWS & Lake Michigan Water Quality Modeling

As part of the Great Lakes and Mississippi River Inter Basin Study (GLMRIS), the USACE contracted the USGS and Marquette University to model the effects of hydrologic separation on water quality in the Chicago Area Waterways System (CAWS). Marquette University used the DUFLOW model jointly developed by universities in the Netherlands. DUFLOW is a 1D unsteady hydrodynamic model and was used to evaluate the changes in water elevation and velocity throughout the CAWS with various proposed control and mitigation alternatives intended to prevent the exchange of aquatic nuisance species (ANS) between the Great Lakes and Mississippi Basins. Marquette University linked the EPA WASP5 water quality model to the DUFLOW model to evaluate changes in CAWS water quality associated with various ANS mitigation alternatives. The USACE also contracted with the USGS and Michigan State University (MSU) to model the effects of hydrological separation on water quality in Lake Michigan. The 3D, time-variable Finite Volume Coastal Ocean Model (FVCOM) linked to the WASP5 water quality model was used for the Lake Michigan water quality analysis. The DUFLOW model was used to compute the time-variable pollutant loads from the CAWS to Lake Michigan.

The University of Illinois at Urbana-Champagne (UIUC) has also developed a suite of hydrologic, hydraulic, hydrodynamic and water quality models of the CAWS for MWRDGC over the last ten years. UIUC has developed a 1D hydraulic model (HEC-RAS) of the CAWS that is linked to the hydrologic/hydraulic TARP model (MetroFlow) and they have linked the HEC-RAS model to the EPA WASP7 water quality model to compute water quality changes within the CAWS associated with ANS mitigation alternatives. UIUC has also developed a 3D Environmental Fluid Dynamics Code (EFDC) model of the CAWS that is also linked with the WASP7 water quality model. Use and further development of these models by UIUC for the MWRDGC is planned during 2016-2020 to evaluate mitigation alternatives and their effect on water quality in the CAWS. The 1D HEC-RAS/WASP7 model is not as computationally burdensome as the 3D EFDC/WASP7 model and would be used for water quality model calibration of the CAWS, whereas the more complex 3D EFDC/WASP7 model would be used to evaluate specific mitigation alternatives. It is unknown if UIUC has a Lake Michigan model or intends to extend their EFDC model into Lake Michigan.

The WASP5/7 water quality models to be used in the CAWS and used in Lake Michigan are capable of analyzing the following parameters: organic nitrogen; ammonia nitrogen; nitrite+nitrate nitrogen; organic phosphorus; orthophosphate; BOD; dissolved oxygen; phytoplankton; conservative tracer; bacteria; sediments; pH; various types of toxic chemicals; and temperature. Based on the UIUC planned CAWS modeling efforts for MWRDGC, it is not clear what level of water quality modeling is to be completed (i.e., simple BOD-DO modeling or eutrophication modeling). In addition depending on the WASP7 version used, the sediment diagenesis submodel that calculates sediment oxygen demand (SOD) and nutrient fluxes may or may not be implemented yet. It is assumed that the CAWS water quality modeling will provide sufficient detail for assessing parameters of concern.

The CAWS modeling time periods are unclear at this time but appear to include existing conditions and various storm event modeling. As discussed below, long term modeling simulations may be required to evaluate SOD changes in the CAWS but also to evaluate different longer term hydrologic regimes.

The hydraulic/hydrodynamic models of both universities (UIUC and MSU) have been calibrated, although only the MSU FVCOM Lake Michigan model calibration has been initially reviewed for scoping purposes.

The calibration of lake velocity and temperature for a summer period seems reasonable although there may be some issues with the lake temperature calibration. The only water quality model calibration available and reviewed to date was the WASP5 model of Lake Michigan for a one month period (August 2012) at one water quality station near Burns Ditch (southeast of Chicago).

**Recommended Improvements/Changes to Existing Models**

Based on this cursory review of the available models for the CAWS and Lake Michigan, the following potential efforts have been identified to build upon the existing modeling efforts by UIUC and MSU.

- Independent Review of CAWS Hydrologic/Hydraulic Modeling
  a. The calibration of the hydrologic/hydraulic, hydrodynamic, and water quality models selected for CAWS ANS mitigation alternative evaluation should be critically reviewed prior to any model application to assess management strategies.
     i. Independent review of the CAWS hydrologic/hydraulic, hydrodynamic and water quality models should be completed to ensure the level of calibration is acceptable for completing evaluation of management alternatives. This should include: model-data comparison and statistical goodness of fit measures review; review of model coefficients and parameters to ensure consistency with typical literature ranges and/or field studies designed to estimate important model rates; review of sediment diagenesis model revisions proposed and results calibration. One component of this review should also consider whether the modeling time period(s) used are sufficient for assessing management alternatives (e.g., short term for bacteria assessment; and long term for dissolved oxygen, nutrient and contaminated sediment assessment). This should include obtaining and reviewing all model files (not just documentation) and reproducing model results.
     ii. Estimated timeframe: 3-6 months after CAWS models are finalized or approximately 1 month after each CAWS model is completed (i.e., hydrologic/hydraulic, hydrodynamic; and water quality).
     iii. Estimated cost: $75,000-$100,000

- Lake Michigan Water Quality Data Collection & Modeling

  The Lake Michigan FVCOM hydrodynamic and water quality model should be calibrated against a much more extensive water quality dataset than the one station near Burns Ditch used for calibration of the FVCOM/WASP5 model before being used to evaluate mitigation alternatives. In addition, there does not appear to be a linked (coupled) CAWS/Lake Michigan modeling framework that can properly represent the potential effect of colder Lake Michigan water intruding inland to any of the rivers that may be opened to free exchange with Lake Michigan as part of an ANS mitigation alternative. UIUC has identified the potential flushing of Chicago River water with clean Lake Michigan water as a potential benefit to CAWS. A possible approach in addressing this issue could be the direct inclusion of rivers opened to free exchange with Lake Michigan into the Lake Michigan FVCOM/WASP5 modeling framework. This is important from the perspective of the potential for stagnant zones in the lower river reaches that are opened to free exchange with the lake that can cause water quality impacts such as depressed dissolved oxygen levels.

The current FVCOM/WASP5 model includes all of Lake Michigan with tens of thousands of model segments and may not be well suited for addressing local water quality concerns or many multiple year model simulations associated with phosphorus (e.g., excessive phytoplankton and *Cladophora* growth), bacteria and dissolved oxygen. A more practical modeling approach may be to use the large Lake Michigan FVCOM model to develop hydrodynamic boundary conditions for a smaller regional hydrodynamic/water quality model that has acceptable solution times for multiple year model simulations and is more spatially focused on the area of concern. This model could also include the lower reaches of the rivers that will freely exchange with lake water for the mitigation alternatives to be analyzed.

Additional data collection is assumed to be required to inform and calibrate the smaller regional hydrodynamic/water quality model proposed for use in long term simulations. This data collection would include field sampling of water quality parameters periodically during one calendar year in order to obtain inputs over a wide range of temperature and flow conditions.

i. Estimated timeframe: 18-24 months total (assumes 6 months overlap of data collection and modeling); 12 months for data collection and 12-18 months after model dataset obtained for an approximate annual modeling time period.
ii. Estimated cost: $500,000-$750,000

- CAWS/Lake Michigan Sediment Data Collection & Modeling

It is not clear if either the DUFLOW/WASP5 or 3D EFDC/WASP7 modeling frameworks to be developed by UIUC will address the potential resuspension and transport of legacy contaminated sediments from CAWS to Lake Michigan. The UIUC modeling approach intends to develop a sediment transport module within EFDC but the emphasis is on resuspension of benthic organic matter and its effect on overlying water dissolved oxygen in CAWS through enhancing SOD. Any modeling framework for the evaluation of ANS mitigation alternatives should contain a contaminated fate and transport module to define the resuspension of contaminated sediments within the CAWS and subsequent transport of these contaminated sediments to Lake Michigan. Given the complex nature of sediment transport and contaminant fate modeling, it is recommended to first determine critical bottom stresses for different CAWS flow regimes to determine whether bottom sediments have the potential to mobilize and be transported to Lake Michigan. This initial screening effort can help guide the level of modeling needed or whether other less complicated assessment approaches may be acceptable.

Additional data collection is assumed to be required to inform and calibrate sediment transport and contaminant fate models proposed. This data collection would include field sampling of sediment parameters periodically during an 18 month period in order to obtain inputs over a wide range of temperature and flow conditions.

i. Estimated timeframe: 30-36 months total (assumes 6 months overlap of data collection and modeling); 18 months for data collection and 18-24 months for developing CAWS/Lake Michigan sediment transport and contaminant fate model.
ii. Estimated cost: $750,000-$1,00,000

## Appendix E: MWRDGC Statement of Work by UIUC (under separate cover) – Invasive Species Mitigation Alternatives Impacts on the CAWS as it Relates to Flooding, Water Quality, and Navigation

**Statement of Work**

# Invasive Species Mitigation Alternatives Impacts on the CAWS as it Relates to Flooding, Water Quality and Navigation

**Submitted to**
**Dr. Thomas Granato**
**Director, Monitoring & Research Department**
**METROPOLITAN WATER RECLAMATION DISTRICT**
**OF GREATER CHICAGO (MWRDGC)**

**By**
**Prof. Marcelo H. Garcia**
**Ven Te Chow Hydrosystems Laboratory**
**Department of Civil and Environmental Engineering**
**University of Illinois at Urbana-Champaign**

**Estimated Total Duration: 48 months**

**Estimated Total Cost: $975,320**

| | | |
|---|---|---|
| **2016:** | **$50,320** | **(4 months: September – December: $12.6k/month)** |
| **2017:** | **$250,000** | **(12 months: January – December: $21k a month)** |
| **2018:** | **$250,000** | **(12 months: January – December: $21k a month)** |
| **2019:** | **$250,000** | **(12 months: January – December: $21k a month)** |
| **2020:** | **$175,000** | **(8 months: January August: $22k a month)** |

**Proposed Starting: September, 2016**

**August 15, 2016**

## Motivation for Proposed Work

A number of mitigation alternatives are being considered to prevent the movement of aquatic nuisance species (ANS), particularly Asian Carp, between the Great Lakes and the Mississippi River Basins. Invasive species mitigation alternatives can be expected to have an important impact on drainage, flooding, water quality and navigation in the Chicago area as indicated in a recent study conducted by the US Army Corps of Engineers known as GLMRIS.

GLMRIS is the Great Lakes and Mississippi River Interbasin Study conducted by the United States Army Corps of Engineers (USACE) as authorized by the United States Congress. USACE conducted the study in consultation with other federal agencies, Native American tribes, state agencies, local governments, and non-governmental organizations (USCOE, 2014). The goal of GLMRIS was to present a range of options and technologies to prevent the transfer of ANS between the Great Lakes and Mississippi River basins through aquatic pathways.

One of the mitigation alternatives considered by GLMRIS, known as the Mid-System Hydrologic Alternative, is focused on preventing the mixing of water between the Great Lakes and Mississippi River basins using different aquatic invasive species control (AIS) technologies. Such control points would be placed upstream of MWRD's Stickney WRP and at Alsip along the subcontinental divide. Since different invasive species mitigation (ISM) alternatives could reduce the amount of water draining towards the South Branch of the Chicago River (SBCR) and then into the Chicago Sanitary and Ship Canal (CSSC), it is of paramount importance to assess the hydraulic and water quality conditions along the North Branch of the Chicago River (NBCR) during normal weather conditions as well as the hydraulic capacity of the CAWS to convey the storm water runoff and combined sewer overflows (CSO) resulting from extreme rainfall events having different intensity, durations and frequencies. Also of interest would be to study the interaction of the Chicago River with Lake Michigan at both Wilmette and at the lake front (CRCW) in the presence of different mitigation alternatives. The impact of varying lake water levels will have to be assessed as well as the need for maintaining Chicago and/or O'Brien Lock and/or lower CAWS elevations relative to Lake Michigan. For instance, the impact of water levels on recreation areas, including City of Chicago Riverwalk, will have to be determined. Water levels will also have an impact on navigation and vessel clearance on the Chicago River and the rest of the CAWS.

Mitigation measures to be placed on the Cal-Sag near Alsip could reduce the amount of water flowing towards the junction with the CSSC. The water quality along the Cal-Sag will also be affected and the use of additional SEPA stations, for instance, to maintain DO levels would have to be considered. Sediments along the CAWS are known to have elevated sediment oxygen demand (SOD) so it will be important to characterize the role played by sediments on water quality in the CAWS, and determine under what flooding conditions the sediments could be re-suspended and transported further into Lake Michigan during storms. Another important question is with regards to the flow discharge that will have to be maintained in Bubbly Creek to ensure acceptable water levels and water quality conditions along the SBCR, which in the presence of some potential mitigation measures will flow north towards Lake Michigan. An "ecological flow discharge' will have to be maintained in Bubbly Creek to prevent stagnant water conditions.

The main objective of the proposed multi-year effort will be to study with the help of MetroFlow, a suite of hydrologic/hydraulic/water quality models developed by UIUC for the MWRD, the impact of invasive species control alternatives on the hydraulics, water quality, sedimentation, and navigation conditions on the CAWS as well as the potential impacts on sewer conveyance and basement flooding taking into account mitigation measures such as green infrastructure and

McCook reservoir storage capacity (no storage limit vs. 2029 storage) on CSO conveyance and CAWS water elevations.

**Impact of invasive species mitigation alternatives in the CAWS: Motivation for Hydraulic, Water Quality and Sedimentation Modeling**

Over the last decade, there has been a growing interest in controlling the potential migration of invasive species from and towards the Great Lakes from the Mississippi River watershed. Different mitigation technologies have been considered as an alternative to prevent the migration of invasive species. Preventing the migration of invasive species by means of different control technologies in the waterways implies that the urban drainage and navigation systems will have to operate under a very different set of conditions so having a model for the whole system could prove very useful. The University of Illinois has worked towards the development of an urban hydrologic model which includes the TARP system and is coupled with 1D and 3D hydraulic and water quality models of the CAWS. This suite of models known as MetroFlow was prepared with the support of the MWRD. The potential use of such models to assess the impact of mitigation measures to prevent the movement of invasive species on flooding and water quality in the CAWS provides the motivation for this proposal.

One of the alternatives considered by GLMRIS, known as the Mid-System Hydrologic Alternative (i.e. Alternative Plan 6 in USCOE, 2014), is focused on preventing the mixing of untreated water between the Great Lakes and Mississippi River basins by controlling the movement of invasive species between the two basins with the help of different technologies (Figure 1). This alternative was developed with the goal of having minimal increased flood risk created by the mitigation alternatives. This alternative includes both structural measures, such as control structures, as well as nonstructural mitigation measures. Examples of nonstructural control measures include removal (e.g., netting), chemical control (e.g., use of herbicides), controlled waterway use (e.g., inspection and cleaning of watercraft before or after entry to a water body), and educational programs.

Stagnant conditions and other water quality impacts could be expected in the CAWS depending on the mitigation measures that are implemented. Therefore, the Mid System mitigation alternative includes ANS treatment plants located at Stickney and Alsip that would take flow from the Lake Michigan side of the ecological control points, treat it, and discharge it into the CAWS to improve water movement and water quality. Navigation could also be affected depending on the control measures taken and this should be analyzed as well. Another potential impact of Alternative Plan 6 could be on Lake Michigan water quality. Treated discharges from the O'Brien and Calumet WRPs, hundreds of combined sewer overflows (CSOs), dozens of storm sewers, and discharges from five CSO pumping stations could be directed towards Lake Michigan as a result of this alternative. Urban stormwater runoff and contaminated sediments could also contribute to impacts on Lake Michigan; therefore, the dynamics of sediment in the system has to be well understood.

This proposal focuses on evaluating the impact of different invasive species mitigation measures on the hydraulic performance of the CAWS as well as on the water quality, sediment dynamics, and navigation (both recreational and commercial) during normal flow conditions and extreme rainfall events. The assessment will be based on a combined used of multi-dimensional models. First a 1D hydraulic numerical model of the entire CAWS using the package HEC-RAS with a water quality model (WASP7) will be coupled with a Hydrologic/Hydraulic TARP model (MetroFlow) developed with support from the MWRDGC at the University of Illinois. Once boundary conditions are obtained from the 1D modeling, they will be used to conduct 3D Environmental Fluid Dynamics (EFDC) modeling with a recently developed hydrodynamic and water quality model of the CAWS also implemented with support from the MWRDGC (Figure 2). There is also a clear need to have a data base for the CAWS, in particular in the Calumet area, so that all the computational models can be run more effectively and this is also included as part of this proposal.

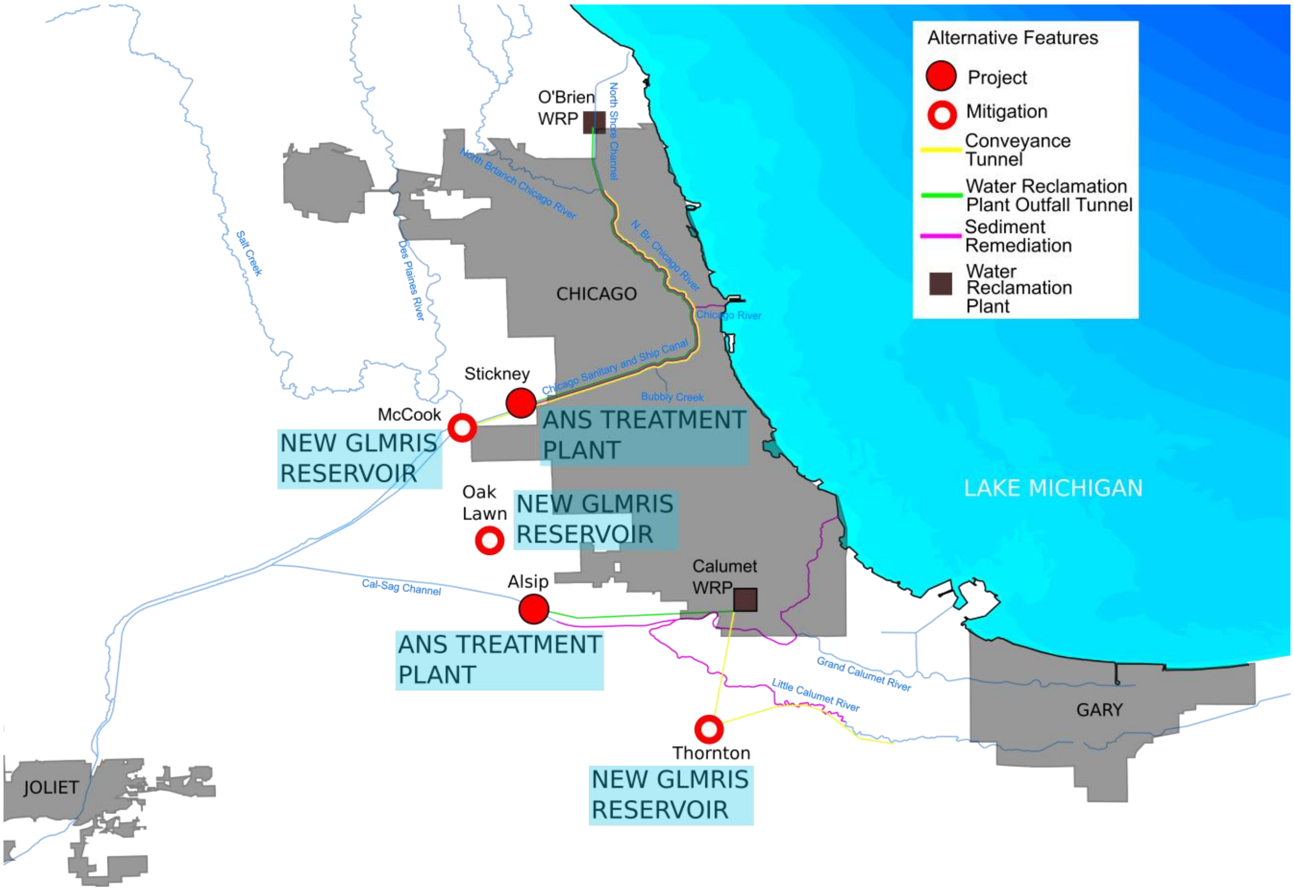



**Figure1. Mid-System Invasive Species Mitigation Alternatives proposed by the GLMRIS study (USCOE, 2014)**

## Main Objectives of Proposed Work

The main objective of the proposed multi-year effort will be to study the impact of the invasive species mitigation measures on the hydraulics, water quality, sedimentation, and navigation conditions on the CAWS and on Lake Michigan. Since the presence of ANS control points could alter the amount and quality of water draining towards the South Branch of the Chicago River (SBCR) and then into the Chicago Sanitary and Ship canal (CSSC), it is of paramount importance to assess the hydraulic and water quality conditions along the North Branch of the Chicago River (NBCR) during normal weather conditions as well as the hydraulic capacity of the CAWS to convey the storm water runoff and combined sewer overflows (CSO) resulting from extreme rainfall events having different intensity, durations and frequencies. Also a second ANS control section will be placed on the Cal-Sag near Alsip, thus changing the navigation conditions and reducing the amount of water flowing towards the junction with the CSSC. The water quality along the Cal-Sag will also be affected and the use of the SEPA stations, for instance, to maintain DO levels would have to be considered. Sediments along the CAWS are known to have elevated sediment oxygen demand (SOD) so as part of this effort it will be important to characterize the role played by sediments on water quality in the CAWS, and determine under what conditions the sediments could be re-suspended and transported further into Lake Michigan during storms. Another important question is with regards to the flow discharge that will have to be maintained in Bubbly Creek to ensure acceptable water levels along the SBCR.

To simulate the water quality in the CAWS in the presence of mitigation measures, the water quality model WASP7 will be coupled with hydrodynamic models that have been validated previously in CAWS. The two hydrodynamic models (i) HEC-RAS in one dimension and (ii) EFDC in three dimensions are both coupled with WASP as part of a previous project conducted for the MWRD (Quijano et al., 2015). The validation and performance of these hydrodynamic models have been presented before in previous studies (Zhu et al., 2014; Santacruz and Garcia, 2014).

Initially, we would like to determine the impact of different extreme rainfall events (10-yr, 50-yr, 100-yr and 500-yr return periods) on the hydraulic performance of the CAWS, in the presence of different ANS mitigation measures along the South Branch of the Chicago River and the Calumet River. In particular, the September 13-15, 2008 storm and the storm of April 17-18, 2013, which resulted in 5 inches of rain in 24 hours (100-yr return period), will be used for the modeling of the CAWS. This storm also indicates that the impact of antecedent conditions and back to back storms should be accounted for in the analysis of different mitigation scenarios. Figure 2 shows the 1D and 3D models to be used as part of the proposed effort.

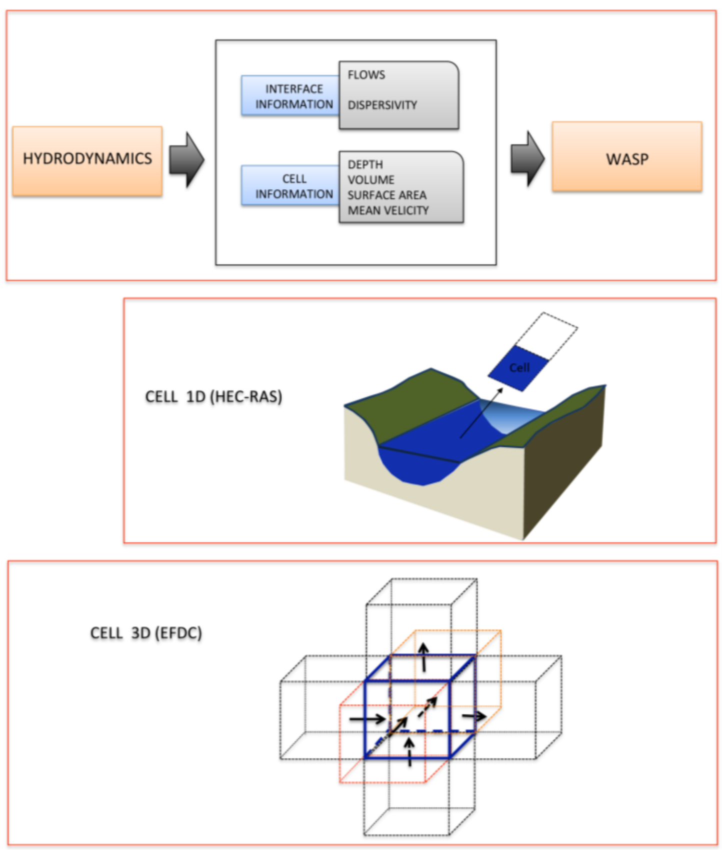


**Figure 2. Schematic representation of the coupling between the hydrodynamics and the water quality models at different dimensions. The hydrodynamic model and the grid structure changes from the model in one and three dimensions. However, the same water quality formulation is implemented in both dimensions.**

## Proposed Methodology

### 1D Hydraulic (HEC-RAS) and Water Quality (WASP) Modeling of the CAWS in the Presence of Invasive Species Mitigation Measures

Water levels for extreme rainfall events on CAWS will be estimated using an existing one-dimensional (1D) HEC-RAS Hydraulic Model coupled with the EPA-supported WASP model for water quality recently implemented by the University of Illinois. The computational domain will include the North Shore Canal from Wilmette controlling works, the North, Main, and South Branches of the Chicago River, the Chicago Sanitary and Ship Canal (CSSC) to Lockport dam and locks, Cal-Sag Canal, and Calumet River downstream the O'Brien Lock and Dam. More information is needed regarding the Calumet River as well as the Grand and Little Calumet River Flows. TARP Calumet model is now complete and can be used to estimate CSOs during storms to the Grand and Little Calumet Rivers having Thornton Reservoir on line. Rating curves developed with a computational fluid dynamics (CFD) model for the gates and locks at CRCW, with support from the US Army Corps of Engineers, will be used to provide boundary conditions at the lake front. UIUC will need to develop rating curves for Lockport with the help of CFD modeling as part of this effort. The geometrical schematization will be based on the 2008 bathymetry surveyed jointly by the USGS and the University of Illinois. The cross-sections are to be exported into HEC-RAS using HEC-GeoRAS for ArcGIS 10. The Hydraulic Performance Graph Method, developed at the University of Illinois, will be coupled with the HEC-RAS model to do a conveyance analysis of the waterways. A calibration and validation process involving input parameters and model outputs will be conducted for different conditions in the waterways using the data base to be developed as part of this project (see below).

The intensity, duration, and spatial distribution of the rainfall will define the hydrological scenarios to be evaluated, and the distribution of the inflows into the system. Inflows to be included are: local flow discharges through pumping stations (RAPS, NBPS, etc.), effluents from all the water reclamation plants belonging to the Metropolitan Water Reclamation of Greater Chicago (MWRDGC), and combined sewer outfalls draining into the CAWS. The MetroFlow model developed for the MWRDGC will be used to estimate the magnitude of CSOs resulting from different storms at different locations along the CAWS. The TARP Calumet model is complete and the TARP Main Stream/Des Plains Model has also been completed. Eventually the storm event on September 13 – 18th 2008, or other historical extreme event such as the very recent April 18, 2013 storm could be used for this purpose. The results from multiple simulations will be provided. The exact location of the alternative mitigation measures will be discussed with the MWRD and other interested agencies.

Hydrodynamic simulations performed with HEC-RAS will be used to simulate the water quality in one dimension with WASP and in the presence of mitigation measures. This formulation is less computational expensive than simulations performed in three dimensions, and therefore, this approach represents an important alternative to understand, and calibrate the water quality model in the Chicago Area Waterway System (CAWS) to analyze the Mid-System hydrologic control scenario.

For both the 1D and 3D models, the simulated scenarios will be built cumulatively upon each other as follows:

1) Without project (existing) condition – includes fully functional TARP (year 2029) and current waterway operations (gates/locks default closed until backflows triggered),
2) Mid-System Alternative with different structural mitigation alternatives without non-structural mitigation elements,
3) Mid-System Alternative with different structural mitigation alternatives in place and with additional mitigation elements.

The simulated scenarios are to be defined considering the following assumptions:

- All phases of TARP are completed and operational (year 2029).
- A control structure is located at the South Branch to top of bank, at some point downstream of Bubbly Creek, but upstream of Stickney Water reclamation Plant.
- All controlling works (locks and gates) at Wilmette and Chicago River will be used as boundary conditions to the model. For scenarios with alternative mitigation measures the initial condition is assumed to be 'full open' to Lake Michigan.
- Foster Avenue tunnel has been built and is fully functional.
- Initial water elevation at the Lake will be 0.00 ft CCD; other scenarios will be presented assuming a water level of +3.00 and -3.00 ft at Lake Michigan.
- Assumptions for Mid-System Alternative mitigation include:
    - TARP inflows will be simulated using MetroFlow for at least three scenarios:
        1) TARP completed with McCook Reservoir on line,
        2) With additional tunnel from RAPS to McCook Reservoir and reduced inflows by 5 - 10% as result of modifications on the watershed response due to best management practices for storm and surface water management, for instance, development of green infrastructure.
    - Floodplain storage in North Branch Chicago River watershed estimated with IUHM Hydrologic model developed at UIUC. However, the storm of April 2013 indicated that floodplain storage is limited.
- Little and Grand Calumet River inflows to CAWS will be simulated for 'control structure' scenario to account for proposed mitigation measures on Little and Grand Calumet included in Mid-System Mitigation Alternative. While flow reductions will be estimated, modeled reaches will include Grand and Little Calumet. TARP-Calumet model developed by UIUC can be used to estimate contributions during storms.

Other scenarios may be considered as new ideas arise from discussions with the MWRDGC. For instance, an additional control structure at the Calumet River could be considered. Floods events will occur due to overflow of the channel banks and/or flow reversals through runoff and CSO pipes discharging directly into the waterways. Therefore, the bank-full levels and an inventory of the location and elevation of those outfalls constitute basic information for this study. Preliminary flooding risk maps of Chicago will be plotted by overlapping water surface elevations computed with the model and topographic maps. Thus, it is also desirable to have a validated digital elevation model (DEM) of the area. A simpler alternative would be to limit the analysis to a comparison between the elevation of the ground or basements and the water levels estimated with the model along the Chicago River and the rest of the waterways. Before proceeding, this will be discussed further with MWRDGC.

**3D EDFC & WASP Modeling of Invasive Species Mitigation Measures in the CAWS**
Our group has recently completed a three-dimensional (3D) hydrodynamic (EFDC) model for the CAWS, including all CSO outfalls that are linked to the District TARP systems and major storm water outfalls. The hydrologic/hydraulic model has been calibrated with the existing data from MWRDGC's gauging network and USGS flow and stage gauging stations, incorporation of boundary condition algorithms (i.e. hydraulic structures such as lock and gates) at Chicago River Control Works (CRCW) and Lockport, respectively.

The 3D CAWS hydrodynamic model has been linked to the TARP Hydrologic Model (MetroFlow) to create a functional tool for estimating the magnitude and frequency of CSOs and stormwater into the CAWS, flow reversals into Lake Michigan as well as the effectiveness of the TARP System in reducing CSOs and local flooding during extreme hydrologic events. Of particular relevance to this effort, is the linked 3D CAWS water quality model (WASP) which has been calibrated with water quality observations made by MWRDGC.

In the proposed effort, the 3D CAWS-WASP &TARP set of models will be used to assess the impact of mitigation and control measures on the waterways. Of particular interest is also the impact of CSOs on water quality (e.g. dissolved oxygen) as well as the impact of sediment resuspension and benthic oxygen demand on water quality. One important aspect is the potential remobilization of historically deposited sediment having a legacy of contamination that could potentially be re-suspended and transported towards Lake Michigan and other areas along the CAWS.

As mentioned earlier, stagnant conditions and other water quality impacts are expected in the CAWS if control structures are placed. Therefore, the USCOE (2014) plan for the mid-system mitigation strategy includes ANS treatment plants located at Stickney and Alsip that would take flow from the Lake Michigan side of the control structures, treat it, and discharge it into the CAWS to improve water movement and water quality. Such mitigation measures will be analyzed with the help of the 3D EFDC-WASP model of the CAWS. The model will also be used to assess the impact of other mitigation measures such as the maintenance of an 'ecological flow discharge" in Bubbly Creek and along the Cal-Sag in order to maintain acceptable dissolved oxygen levels for the preservation of the ecosystem. An important parameter to be included in the water quality modeling effort is a thermal model of the CAWS to predict both vertical and longitudinal temperature distributions in the CAWS. Temperature affects to a large measure water density, and if the Lake Michigan water is colder than CAWS water it is quite possible that density currents could flow into the Chicago River if there are no gates controlling the flow and depending on lake water levels and this could have a positive effect on water quality.

Other water quality mitigation measures to be analyzed with the set of models includes the potential effect of reducing DO levels in a portion of the CAWS to stop ANS migration as well as the impact of constructing a tunnel to convey the outflow from the O'Brien Water Reclamation Plant towards Stickney so that the effluent does not go towards lake Michigan if the North Shore Channel at Wilmette is freely connected to the lake. Most likely there will be other mitigation measures that can be analyzed with the help of the models. For instance where to locate the discharge from the Calumet WRP to maintain flow and water quality conditions east of the AlsipANS control structure?

**Calumet-TARP-CAWS Data Repository Development**

Within the Calumet-TARP and associated waterways, there is a need for a comprehensive dataset collection, curation, and access system to complement the comprehensive CAWS modeling framework proposed herein. Currently, it is tedious and time-consuming to process and prepare all the required rainfall, hydraulic, and water quality data for use by hydraulic models (MetroFlow or other modeling packages). While MetroFlow eases the interaction and flow of data within and between models, there is limited ability to import data from external sources. The proposed comprehensive data repository for the Calumet region would provide MWRD and affiliated engineers and consultants with a centralized and standardized data repository. In addition to benefiting the MetroFlow-based modeling of TARP and CAWS, this repository would also benefit current efforts with HEC-RAS, EFDC, WASP and InfoWorks. For these stand-alone models, developed data import/export utilities and data connectors would allow UIUC as well as MWRD's engineers and consultants to rapidly query and extract data from the Repository (via both a simple user interface and APIs) for other modeling projects. In particular, other MWRD collaborative efforts such as the current Microbiome Project with Argonne could greatly benefit from this type of centralized and standardized data repository.

The data repository we propose to implement as part of this effort will be designed in such a way that future projects can be built upon it. For example, this system could be customized to serve not only as a repository for modeling and related tasks, but also for a data storage system to replace spreadsheets and other non-standardized data (such as lock/gate opening records, treatment plant effluent, recorded water quality, etc.). In a future project, the database system could be utilized to generate real-time information for informing operational decisions/rules to avoid flooding (e.g. backflow gate controls, the impact of rain distribution on water level rises). Another example project could use the database to model water quality and associated metrics during and after storm events for the purpose of providing information on the suitability of where, when, and how the public can recreate in the CAWS.

To date, the modeling efforts have relied on disparate and limited historical datasets. For example, a complete run of the MetroFlow system requires the following inputs:

- Rainfall data from one of the following:
    - historical storm from Cook County Precipitation Network (CCPN),
    - a design storm (user can specific design storms in MetroFlow),
- USGS flow data, from tributary streams,
- HEC-HMS simulation results for stormwater runoff,
- MWRD flow data, from pumping station records including RAPS,
- Calumet, Stickney, and O'Brien Treatment plant effluent,
- MWRD gate operation records at Wilmette, CRCW and O'Brien Lock and Dam,
- USACE Lockport Dam stage records,
- Water quality input parameter files

Many of these data are in non-standardized spreadsheet or other document formats, requiring manual reformatting of the data into a format acceptable for use by MetroFlow or other models. An improved current data access workflow would allow MWRD users, engineers, researchers, and consultants to focus on simulation and modeling, rather than data gathering, import, and management.

The Calumet-TARP-CAWS Data Repository will be developed using a collection of open technologies such as MySQL, HDF5, Python, and Java and will be accessible through MetroFlow and a simple lightweight, stand-alone graphical interface as well as by application programming interfaces (APIs) by which other software such as MetroFlow, internal MWRD applications, and external models can automate data retrieval. This data repository will be crucial for the success of the proposed project analyzing the impact of mitigation measures. Benchmarking of CAWS water quality conditions post-Thornton and pre- and post-control measures will be greatly facilitated by the data repository schematized below in
Figure

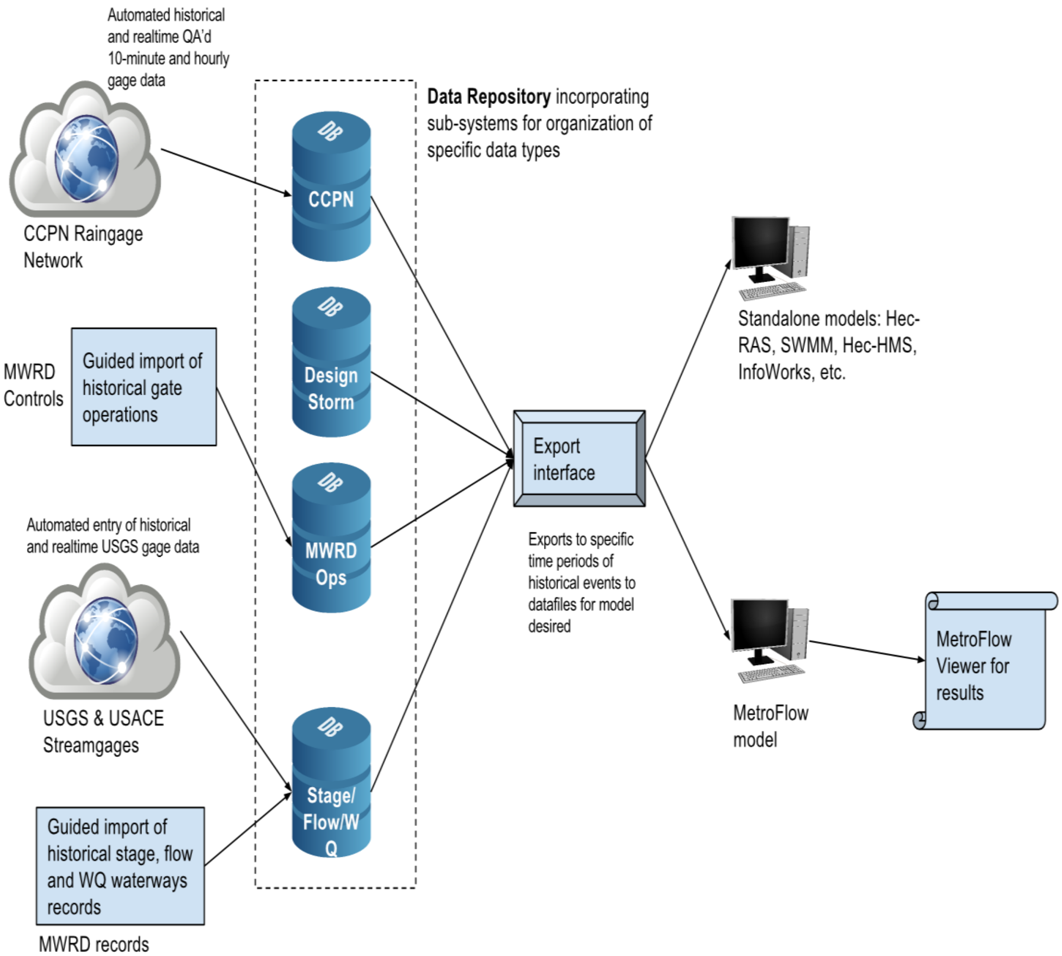



Figure 3 Schematic of Calumet-TARP-CAWS Data Repository

**Scope of Work**

For the purpose of this project the CAWS will be divided into three subsystems as follows:

- CAWS NB-CR: this includes the North Branch of the Chicago River, the North Shore Channel and the main stem of the Chicago River, Bubbly Creek and the South Branch of the Chicago River all the way till the ANS control section.
- CAWS CSSC-CalSag-Lockport: this includes the CSSC south from the control structure, located between Stickney and the turning basin at Bubbly Creek, all the way to Lockport Lock and Dam as well as the Calumet-Sag Channel up to the ANS control structure located at Alsip.
- CAWS Calumet: this extends east of the Alsip mitigation measure and includes both the Little and Grand Calumet Rivers all the way into northern Indiana, and the Calumet River before and after O'Brien Lock and Dam, all the way into Lake Michigan.

This partition of the CAWS is expected to facilitate the computational modeling and make it easier to assess the impact of the ANS mitigation measures.

The project duration is estimated to be 48 months and the following tasks are envisioned for the Mid-System Invasive Species Mitigation study:

**Task 1:** Implementation of control measures in the 1D Hydraulic (HEC-RAS) and Water Quality (WASP) models of the CAWS, and evaluation of the hydraulic conditions in the CAWS with control structures, including potential impact on water quality, sediment resuspension, transport and fate, and water levels with respect to local flooding potential during extreme hydrologic events. The impact of Lake Michigan water levels on conveyance in the CAWS NB-CR and CAWS CSSC-CalSag-Lockport will be analyzed with the help of the 1D model. This model will be coupled with the TARP Hydrologic model (MetroFlow) to estimate how much what will be discharged into Lake Michigan. For evaluations, both historical and design storms (e.g., based on a critical duration analysis using Bulletin 70 with Huff Quartiles using the 2-yr, 10-yr, and 100-yr storms) will be used. This model will be used for long term production runs and will provide guidance for the 3D modeling effort. Estimated duration: 12 months.

**Task 2:** Implementation of ANS mitigation measures in 3D CAWS hydrodynamic model linked to the TARP Hydrologic Model (MetroFlow) to create a functional tool for estimating the CSOs and stormwater into the CAWS will increase flow discharge into Lake Michigan as well as the effectiveness of both the current and completed TARP System in reducing CSOs and local flooding during extreme hydrologic events. The linked model will be used for specific simulations defined by MWRDGC including a critical duration analysis and impact of diverting flow from O'Brien WRP and Calumet WRP to mitigate impact of control measures on water quality. Estimated duration: 12 months.

**Task 3:** Implementation of mitigation measures in the linked 3D CAWS hydrodynamic (EFDC) and water quality model (WASP), recently implemented by UIUC, and using the model with water quality observations made by MWRDGC for existing conditions to assess the impact the mitigation measuress will have on the water quality of the CAWS and to explore mitigation measures that could be taken to reduce the potential for eutrophication in the CAWS due to stagnant water conditions. Estimated Duration: 12 months

**Task 4:** Development of Sediment Transport Model in 3D EFDC Hydrodynamic Model, including a sediment diagenesis submodel (Di Toro, 1985) so that impact of sediment oxygen demand (SOD) on water quality as well as potential sediment entrainment and transport in the CAWS can be assessed and mitigation measures can be taken Estimated Duration: 12 months.

**Task 5:** Performing in situ measurements of sediment erosion, resuspension and oxygen demand in the CAWS. In this task, we plan to conduct field experiments using an inverted flume constructed at the Ven Te Chow Hydrosystems Laboratory (VTCHL) shown in Fig. 4. This device has been used to study sediment resuspension and oxygen demand in Bubbly Creek, Chicago (Waterman et al., 2011). We plan to use the Illinois Sediment Erosion Sampler (ISES) to obtain an empirical relation between bottom shear stress and the volume of sediment eroded and re-suspended, with the goal of incorporating such an empirical equation into the sediment transport and contaminant fate models. The same tests will be used to develop a map of SOD for the ways that could be used to assess water quality conditions as well as areas with low-dissolved oxygen. Before going to the field for testing, laboratory experiments will be conducted to develop and test the performance of the Illinois Sediment Erosion Sampler (ISES). The field work will be conducted in the summer of 2017. Estimated Duration: 4 months

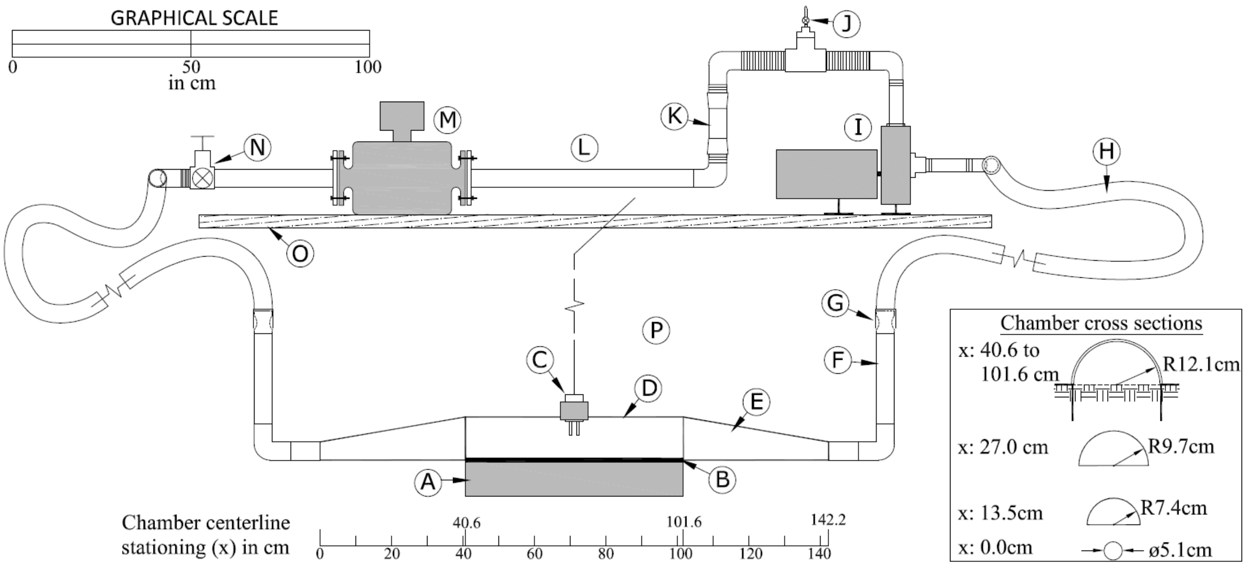



Figure 4. Illinois Sediment Erosion Sampler (ISES) (Waterman et al., 2011).

**Task 6:** Development of the Calumet-TARP-CAWS Data Repository. We propose to develop a Data Repository for the modeling of the CAWS that achieves the following objectives:

- Retention of historical records for
  - Cook County Precipitation Network (CCPN) raingage data,
  - MWRD raingage data,
  - USGS stage and flow records at sites influential to the Calumet waterways,
  - pumping records,
  - WRP effluent and other flow records,
  - MWRD water quality data,
  - gate operations at Lockport Dam and the O'Brien Lock and Dam,
  - Lake Michigan lake levels, and
  - USACE stage records at Lockport Dam.
- Automated acquisition of
  - CCPN raingage data,
  - USGS stage and flow records, and
  - USACE stage records.
- Workflows and processes (via both graphical user interfaces and command line options) to import non-automatable data such as pumping records and gate operations.
- Creation of connectors (APIs) to support MetroFlow and other external models, such as HEC-RAS, EPA SWMM, and InfoWorks.
- Modification of MetroFlow to allow visualization and import of data from the database.

Estimated duration: 12 months

**Task 7:** Evaluation of the impact that different mitigation measures will have on navigation, hydropower and the hydrologic regime of the Illinois River. Once the set of CAWS-TARP models with control structures are implemented and tested, they will be used to determine the navigation conditions that could be expected to exist in the CAWS when the Mid-System mitigation strategy goes into effect. For instance, Navigation and vessel clearance on the CAWS (non-storm conditions) in the Chicago River with respect the Lake Michigan levels will be analyzed. In particular navigation flow depths in the CAWS as well as locations where a multimodal system of transportation could be implemented. For instance, a bypass could be built by the Alsip control structure to transfer loads from barges and other vessels without the need to have a navigation lock. This task will also include an analysis of hydropower generation at Lockport with reduced flows as well as the impact that the mitigation measures will have on the hydrologic regime of the Illinois River. Estimated duration: 8 months.

The final CAWS-TARP set of models implemented to assess the Mid-Systems Mitigation Measures alternative will also be useful to study the options for flood relieving (such as starting lake reversal at various elevations; adding addition conveyance capacity, etc.); to optimize the operation of the TARP System, to assess the impact of CSOs on water quality (e.g. dissolved oxygen) as well as the impact of sediment resuspension and benthic oxygen demand on water quality. It will also be possible to couple the 3D CAWS model with the sources obtained by the CAWS Microbiome Project (CMP) currently being conducted by researchers from Argonne National Laboratory.

**Expected Products**

The modeling results will document the effectiveness of the proposed mitigation strategies in reducing flooding. It will further verify the peak flooding volume required to be managed to avoid flooding with the construction of the Mid-System Alternative flow control structures. Therefore, the expected products in order of priority include:

- Monthly reports documenting incremental model simulation results and identification of areas with high risk of flooding (water levels, volumes, discharges, etc.) and marginal water quality conditions

- Annual reports to the MWRDGC including methodology, modeled scenarios, configuration of the model, simulation results (profiles of water levels, velocities, volumes and discharges along the systems, among others), water quality, sediment dynamics and flooding maps or a simpler identification of areas with high risk of flooding, and conclusions and recommendation

- A video showing the interaction between the Urban Hydrology, the Chicago River and the TARP System via connecting structures will be also prepared for educational purposes showing the transformation the system will undergo if the Mid-System ANS mitigation strategy is followed.

Stagnant conditions and other water quality impacts are expected in the CAWS if control structures are placed. Therefore, this alternative includes ANS treatment plants located at Stickney and Alsip that would take flow from the Lake Michigan side of the mitigation measures, treat it, and discharge it into the CAWS to improve water movement and water quality. One of the greatest impacts of invasive mitigation alternatives could be on Lake Michigan water quality. Treated discharges from the O'Brien and Calumet WRPs, hundreds of combined sewer overflows (CSOs), dozens of storm sewers, and discharges from five CSO pumping stations would be directed towards Lake Michigan on a continuous basis as a result of this alternative. The set of models implemented in the proposed effort will make it possible to assess the impact of the Mid-System mitigation strategy envisioned in the GLMRIS study.

As a part of this project the graphical user interface for the TARP Coupled Models (TCM) program will be coupled to the 3D CAWS Model using Environmental Fluid Dynamics Code (EFDC). This will provide the MWRDGC with the ability to run the CAWS Model with outputs from the TARP models. It will also allow a user to interact with the TARP and CAWS Model data via a map interface and produce visualization of the results that could be used for waterways management as well as for public information and education.

The proposed coupled CAWS-TARP models with mitigation measures, including the graphic-user-interface (GUI), will be used to estimate the frequency and magnitude of CSOs into the CAWS and flow and sediment discharge into Lake Michigan as well as the effectiveness of the completed TARP System in reducing CSOs during extreme hydrologic events. The CAWS-TARP models will also be useful to analyze the mixing of CSOs with river water as well as the impact of several supplemental aeration stations (SEPA) on the levels of dissolved oxygen, to assess the effect of disinfection by tracking the transport and mixing of treated effluents as well as the impact of sediment resuspension and benthic oxygen demand on water quality.

**Deliverables**

At the end of each task, a summary report or summary presentation capturing the accomplishments of the task will be delivered, as follows:

**Task 1:** Summary report about results obtained with 1D Hydraulic (HEC-RAS) and Water Quality (WASP) models of the CAWS with the presence of mitigation measures. There will be one report for each portion of the CAWS: NB-CR, CSSC-CalSag-Lockport, and Calumet, respectively

**Task 2:** Summary report on 3D CAWS hydrodynamic model linked to the TARP Hydrologic Model (MetroFlow) on findings with respect to the impact of mitigation measures in the CAWS on the local flooding potentials in the selected areas during extreme hydrologic events. There will be one report for each portion of the CAWS: NB-CR, CSSC-CalSag-Lockport, and Calumet, respectively.

**Task 3:** Summary report on 3D CAWS hydrodynamic (EFDC) and water quality model (WASP) results regarding the impact of mitigation measures on the water quality of CAWS in the presence of control structures. There will be one report for each portion of the CAWS: NB-CR, CSSC-CalSag-Lockport, and Calumet, respectively.

**Task 4:** Summary report on sediment transport modeling results obtained with the 3D EFDC Hydrodynamic Model, including risk of sediment resuspension and effect of sediment oxygen demand (SOD) on water quality in the CAWS with the presence of mitigation measures. There will be one report for each portion of the CAWS: NB-CR, CSSC-CalSag-Lockport, and Calumet, respectively.

**Task 5:** Summary report on the field measurements obtained with the Illinois Sediment Erosion Sampler (ISES) regarding critical flow velocities needed to erode and entrain bottom sediments into suspension as well as distribution of SOD throughout the CAWS. A set of empirical relations and coefficients will be obtained to estimate rates of sediment entrainment and sediment oxygen demand with the numerical models of the CAWS.

**Task 6:** Calumet-TARP-CAWS Data Repository will be presented to the MWRD. It will be accessible through MetroFlow and a simple lightweight, stand-alone graphical interface as well as by application programming interfaces (APIs) by which other software such as MetroFlow, internal MWRD applications, and external models can automate data retrieval.

**Task 7:** Summary reports with finding regarding the impact of ANS mitigation measures, such as control structures, on navigation conditions and potential recommendations that could be implemented to reduce the economic impact associate with the elimination of barge traffic during to mitigation measures. Results about the impact of reduced flows on hydropower generation at Lockport and on flooding conditions on the Illinois River will be also included in this report.

In general, the main product of this effort will be the development of a set of calibrated and validated environmental flow models for the CAWS to assess the impact of different mitigation measures on flooding, water quality, sedimentation and navigation in the. The model will also be useful to assess the impact on hydropower generation by the MWRD at Lockport as well as on the hydrologic regime of the Illinois River. This effort could provide the foundation for the development of the Chicago Area Waterways Decision Support System (CAWDSS) that could be used to estimate the frequency, magnitude and mixing of CSOs into the CAWS and their impact on water quality (e.g. dissolved oxygen) as well as the effectiveness of the MWRDGC's Tunnel and Reservoir Plan (TARP) for extreme hydrologic events.

An important product to be delivered as part of this project will be consist of the graphical user interface for the TARP Coupled Models (TCM) program coupled to the 3D CAWS River Model (EFDC-WASP) with and withoutmitigation measures.

The models of the deliverable will be able to run on a Xeon workstation running 64-bit Windows XP (and/or later) operating system with minimum of 16 GB of RAM. MWRD personnel will be trained to use the CAWS-TARP Models with the help of the graphic-user-interface (GUI) to be developed as part of the project.

**Personnel:**

Personnel with experience in a variety of topics such as ecological, biological, surface-water, and hydrodynamic modeling techniques, stream gaging, bathymetric and velocity surveys, and water-quality monitoring will participate in this project. These personnel at the University of Illinois include Prof. Marcelo Garcia who will serve as the Principal Investigator. Dr. Garcia is a faculty member in the Department of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign who has led the development of the 3D CAWS model and TARP system models (MetroFlow). Additional team members will consist of: Dr. Blake Landry, Research Associate, Research Engineer Andrew Waratuke, and several Graduate Research Assistants. The USGS Illinois Water Science Center will participate through ongoing collaborations with Dr. P. Ryan Jackson and Mr. James J. Duncker, while the MWRDGC will provide technical support to the project.

**Proposed Schedule**

This timeline assumes project initiation of September 1, 2016, and a total duration of 48 months to complete the project. Monthly progress reports will be presented and reports for each task will be submitted to MWRD as tasks are completed. The following timeline is envisioned for the proposed effort:

Table- Estimated timeline completion of CAWS-TARP System Models Calumet TARP (Please note that some tasks will occur coincidentally so that the total project duration will not match the sum of the individual task durations)

| TASK | Time for completion of task in months | TASK (see scope of work for description) |
|---|---|---|
| 1 | 12 | Analysis of impact of ANS mitigation measures on flooding and water quality with 1D Hydraulic (HEC-RAS) and Water Quality (WASP) models of the CAWS |
| 2 | 12 | Analysis of impact of ANS mitigation measures on flooding, transport and mixing with 3D CAWS hydrodynamic model linked to the TARP Hydrologic Model (MetroFlow) |
| 3 | 12 | Analysis of impact of mitigation measures on water quality with linked 3D CAWS hydrodynamic (EFDC) and water quality model (WASP) |
| 4 | 12 | Development of Sediment Transport Model in 3D EFDC Hydrodynamic Model and linking to water quality via sediment oxygen demand (SOD) |
| 5 | 4 | Performing in situ measurements of sediment erosion, resuspension and oxygen demand in the CAWS |
| 6 | 12 | Development of the Calumet-TARP-CAWS Data Repository |
| 7 | 8 | Evaluation of the impact that different mitigation measures will have on navigation, both commercial and recreational, in the CSSC and Cal-Sag, hydropower at Lockport and the hydrologic regime in the Illinois River |

**Budget**

The 48-month long project will commence in September 1, 2016 and end on August 30, 2020. The totals estimated cost for the 48-month long project amounts to $975,320, with an allocation of $50,320 for the end of calendar year 2016 (4 months), $250,000 for calendar years 2017, 2018 and 2019 (36 months, total), and $175,000 for calendar year 2020 (8 months). Funding is requested for to support all the personnel mentioned above, purchase of a water quality probe, reconditioning of in-situ sediment testing flume, software licenses and travel for meetings to MWRDGC. A detailed budget can be found in the next page.

**Collaboration, Partnerships, and Overarching Plans**

This project is collaboration among the University of Illinois at Urbana (UIUC) and the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC). Since 2003, MWRDGC has funded the University of Illinois to develop hydrologic and hydraulic models of the Tunnel and Reservoir Plan (TARP) with the goal of having a better understanding of the Deep Tunnel Systems and allow for the optimization of the operation of TARP with the goal of minimizing flooding and preventing pollution of the waterways and Lake Michigan during extreme storm events. In 2001, UIUC advanced theories and models to explain observations of bidirectional flows (i.e. density currents) made the USGS in the Chicago River as part of the Lake Michigan water diversion studies. In 2007, MWRD commissioned a study of the waterways, combining modeling by UIUC and observations by the USGS, with an emphasis on quantifying the water quality dynamics in Bubbly Creek and the impact of the operation of the Racine Avenue Pumping Station (RAPS). One of the major findings of this work was the dependence of benthic sediment oxygen demand on hydrodynamic conditions in Bubbly Creek.

| Project Period: 9/1/2016 - 8/31/2020 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Budget** | | | | | | | | | | | | |
| | | | | | | | 4 months | 12 months | 12 months | 12 months | 8 months | All months |
| *A. Senior Personnel* | | | | | | | | | | | | |
| Marcelo H. Garcia | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | mos. | $ - | $ 24,928 | $ 25,675 | $ 26,446 | $ 26,446 | $ 103,494 |
| | | | | | | | | | | | | - |
| *B. Other Personnel* | | | | | | | | | | | | |
| Research Associate - Blake Landry | 0.8 | 1.7 | 1.7 | 1.8 | 2.8 | mos. | 5,493 | 12,266 | 12,634 | 13,113 | 20,474 | 63,980 |
| Research Engineer - Andrew Waratuke | 1.7 | 5.5 | 6.0 | 5.5 | 2.6 | mos. | 8,943 | 29,801 | 33,485 | 31,616 | 15,069 | 118,914 |
| Post Doctoral Research Associate | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | mos. | - | - | - | - | - | - |
| Research Assistant - Post BS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | mos. | - | - | - | - | - | - |
| Research Assistant - Post MS | 6.5 | 22.0 | 23.1 | 22.0 | 8.3 | mos. | 13,780 | 48,039 | 51,995 | 50,965 | 19,209 | 183,988 |
| Research Assistant - Post Prelim | 0.0 | 22.0 | 22.0 | 22.0 | 14.0 | mos. | - | 53,523 | 55,129 | 56,782 | 36,134 | 201,568 |
| Hourly | 23.0 | 458.0 | 425.0 | 425.0 | 425.0 | hours | 230 | 4,580 | 4,250 | 4,250 | 4,250 | 17,560 |
| Total Salary and Wages | | | | | | | 28,446 | 173,136 | 183,168 | 183,171 | 121,582 | 689,504 |
| *C. Fringe* | | | | | | | | | | | | |
| Academic 44.77%, RA 6.19%, Hourly 7.79% | | | | | | | 7,334 | 36,637 | 39,104 | 38,865 | 31,509 | 153,450 |
| Total Personnel | | | | | | | 35,780 | 209,773 | 222,273 | 222,037 | 153,091 | 842,954 |
| *D. Equipment* | | | | | | | | | | | | |
| Multi-parameter Water Quality Sonde | | | | | | | 9,965 | | | | | 9,965 |
| *E. Travel* | | | | | | | | | | | | - |
| Domestic | | | | | | | | 900 | 1,000 | 1,000 | 2,000 | 4,900 |
| Foreign | | | | | | | | - | - | - | - | - |
| | | | | | | | | | | | | - |
| *G. Other Direct Costs* | | | | | | | | | | | | - |
| Materials and Supplies | | | | | | | | 5,000 | | | | 5,000 |
| Software | | | | | | | | 4,000 | 4,000 | 4,236 | 4,000 | 16,236 |
| Services | | | | | | | | 7,600 | | | | 7,600 |
| Sub Contract - | | | | | | | - | - | - | - | - | - |
| Tuition -- 64% of RA Salary N/A | | | | | | | - | - | - | - | - | - |
| Total Other Direct Costs | | | | | | | - | 16,600 | 4,000 | 4,236 | 4,000 | 28,836 |
| *Total Direct Costs* | | | | | | | 45,745 | 227,273 | 227,273 | 227,273 | 159,091 | 886,655 |
| *I. Indirect Costs* | | | | | | | | | | | | |
| Facilities and Admin. 10% of UIUC TDC | | | | | | | 4,575 | 22,727 | 22,727 | 22,727 | 15,909 | 88,665 |
| Total Project Cost | | | | | | | $ 50,320 | $ 250,000 | $ 250,000 | $ 250,000 | $ 175,000 | $ 975,320 |

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