The background of the slide is a photograph of the Niagara Falls, showing the water cascading over the rocks. The water is a light blue-green color, and the surrounding area is misty and white with snow or ice.

# **Decision-Making Tools Employed in Niagara River Ice Management**

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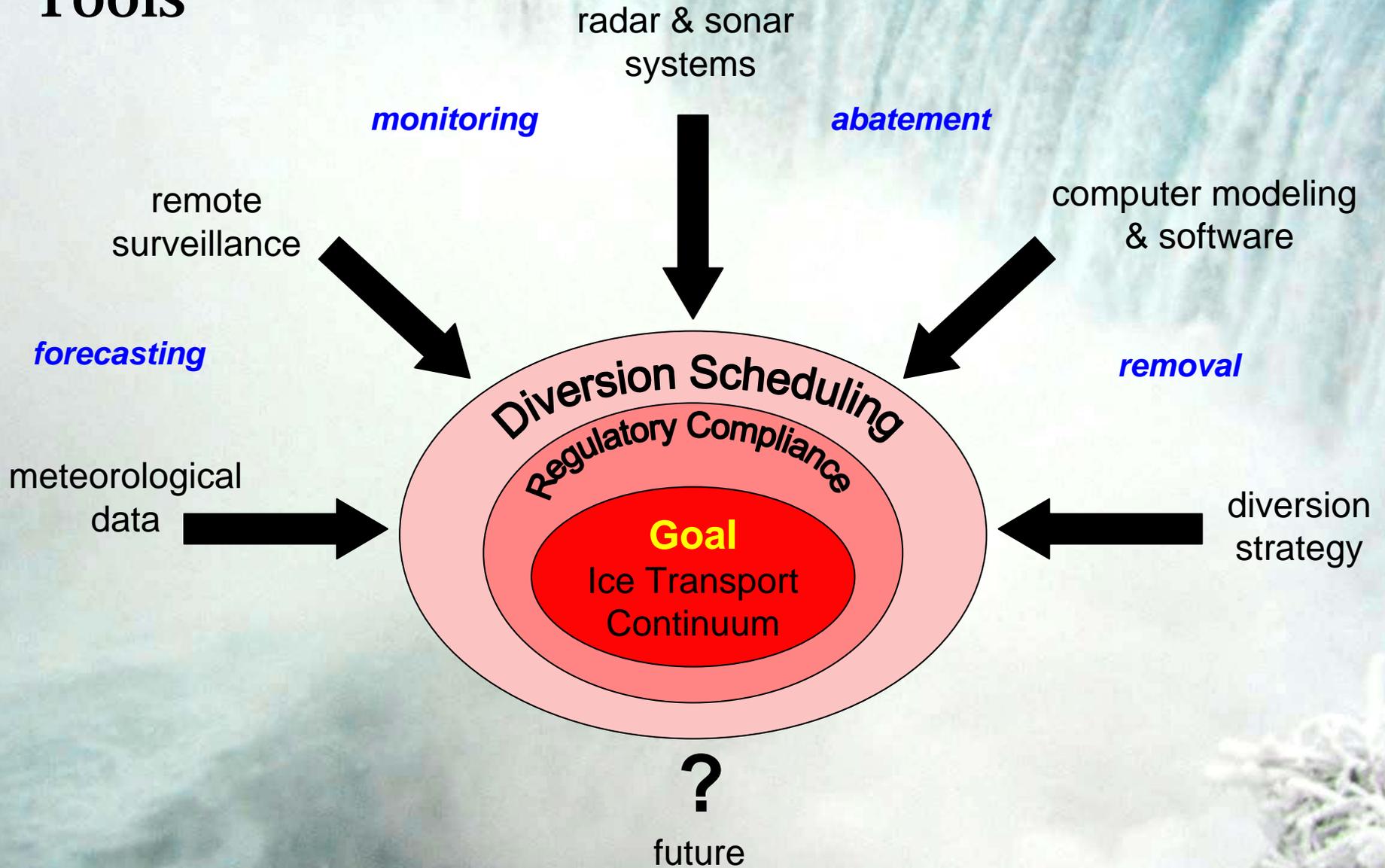
**Water Management Decision-Support Software  
WMIG Conference: November 16-17, 2005  
Niagara Falls, New York, U.S.A.**

**Peter Kowalski: Niagara River Control Supervisor**

# Objectives

1. Discuss tools & software employed in:
  - forecasting ice generation
  - monitoring ice transport / ice discharge
  - abatement of ice stoppage growth
  - removal of ice stoppages
2. Discuss winter operating strategies
3. Outline techniques used to mitigate ice impact
4. Suggest direction for further development of tools

# Tools



# Meteorological Data (water temperature)

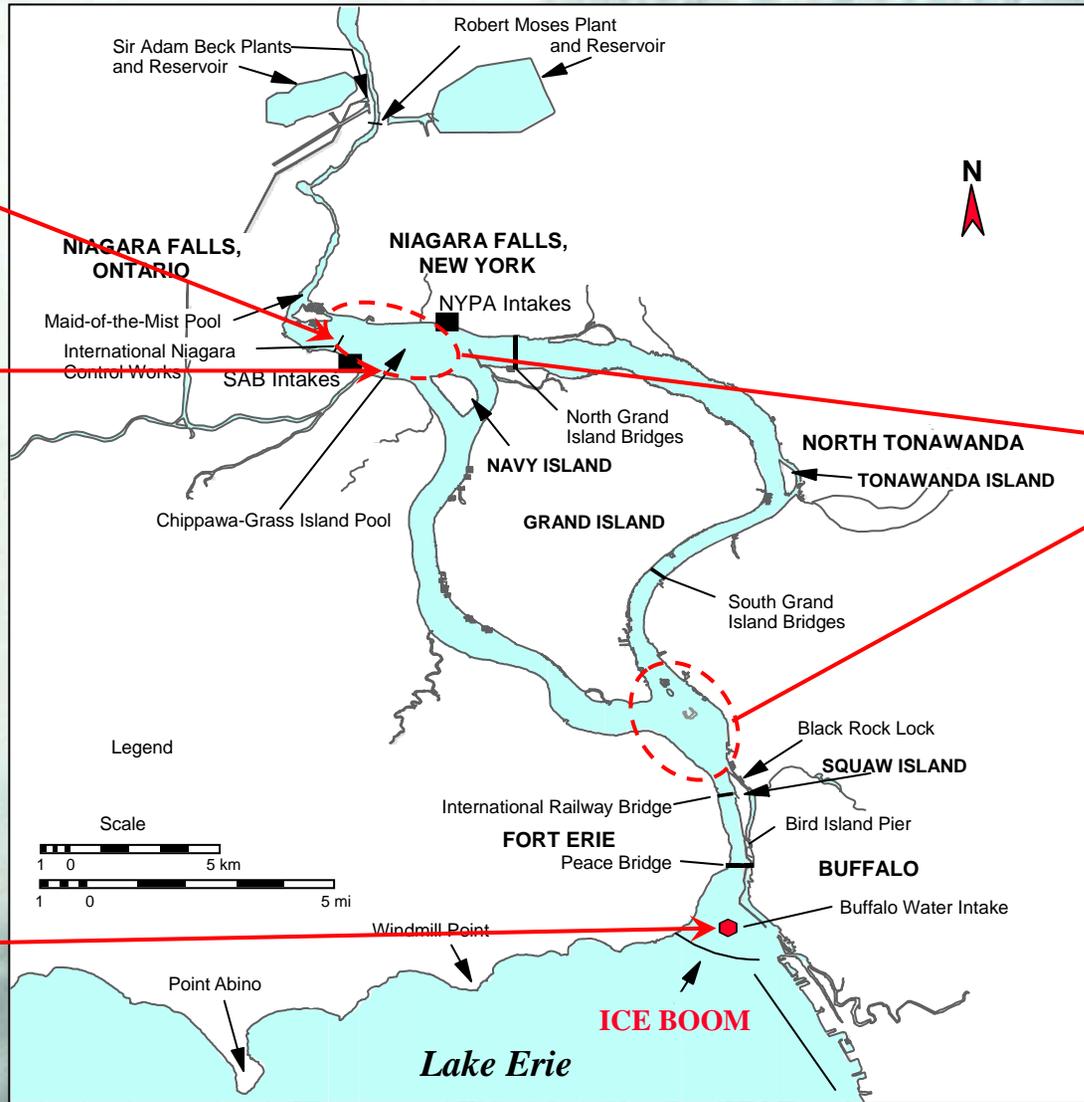
- Buffalo Water Intake (ice boom installation criteria)
- International Control Dam (coarse scale  $> 2.0^{\circ}\text{C}$ )
- Canadian Boat Dock (fine scale  $+2.0$  to  $-0.2^{\circ}\text{C}$ )
  
- Rate of decline to forecast “freeze-up” event
- Nightly indicator for frazil / anchor / river ice generation

# Meteorological Data (water temperature)

International Control Dam

Canadian Boat Dock

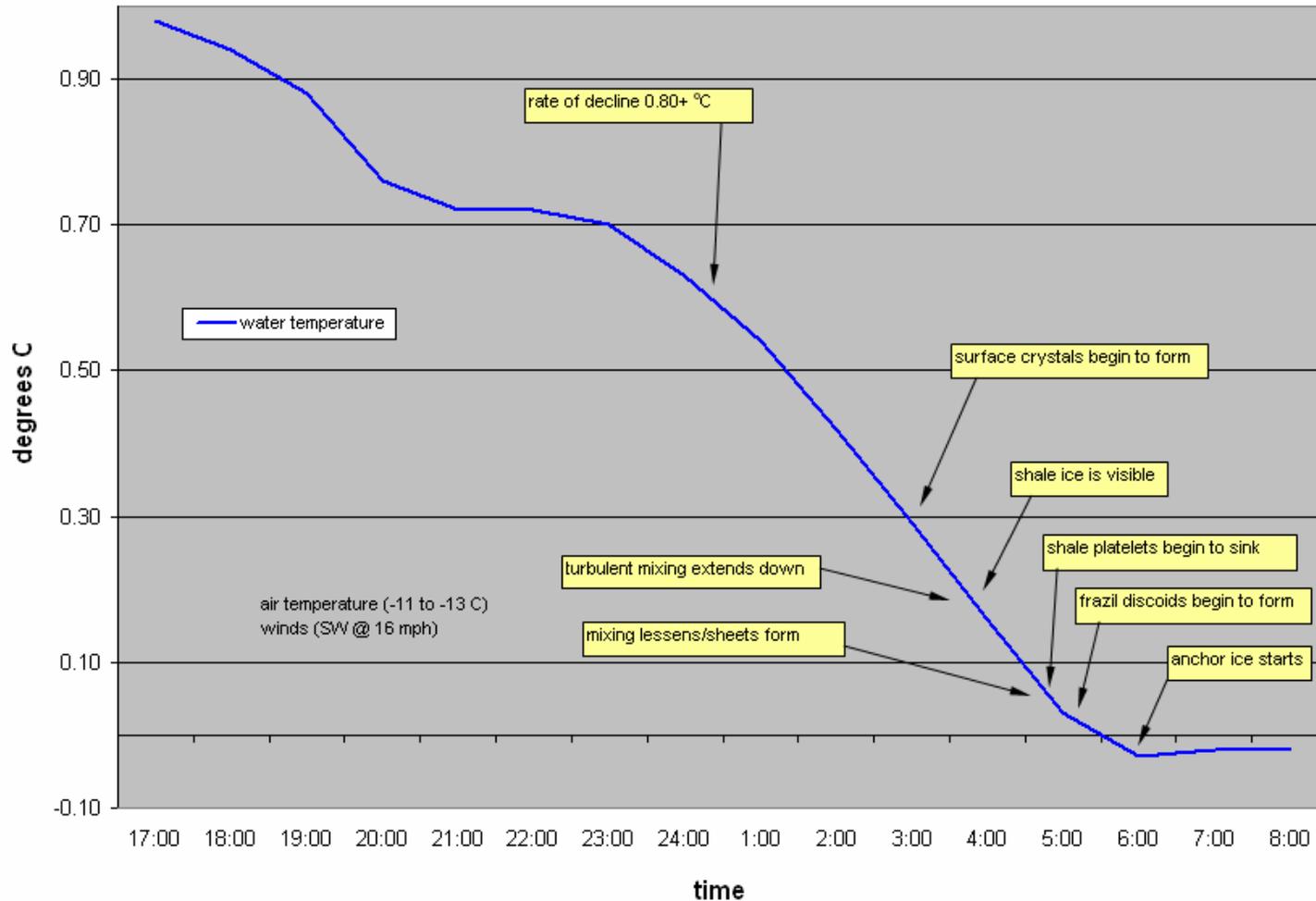
Buffalo Water Intake



Anchor Ice Impact Areas

# Meteorological Data (water temperature)

GIP Freeze-Up Event - December 12, 1995 (typical)



# Meteorological Data (radiation & wind conditions)

- Net pyrradiometer (solar + terrestrial + atmospheric radiation flux)
- Used to forecast anchor ice / nightly ice generation cycle
- US Coast Guard Buffalo anemometer (speed & direction)
- Strong SW winds can lead to higher flows ~ lake ice runs
- Strong NE winds lead to reduced flows ~ retarding ice runs
- ICD anemometer (speed & direction)
- Influence on surface ice in GIP (shale, slush)
- May lead to adjustment in diversions to overcome forces

# Meteorological Data (radiation & wind conditions)

## Wind effect on Lake Erie

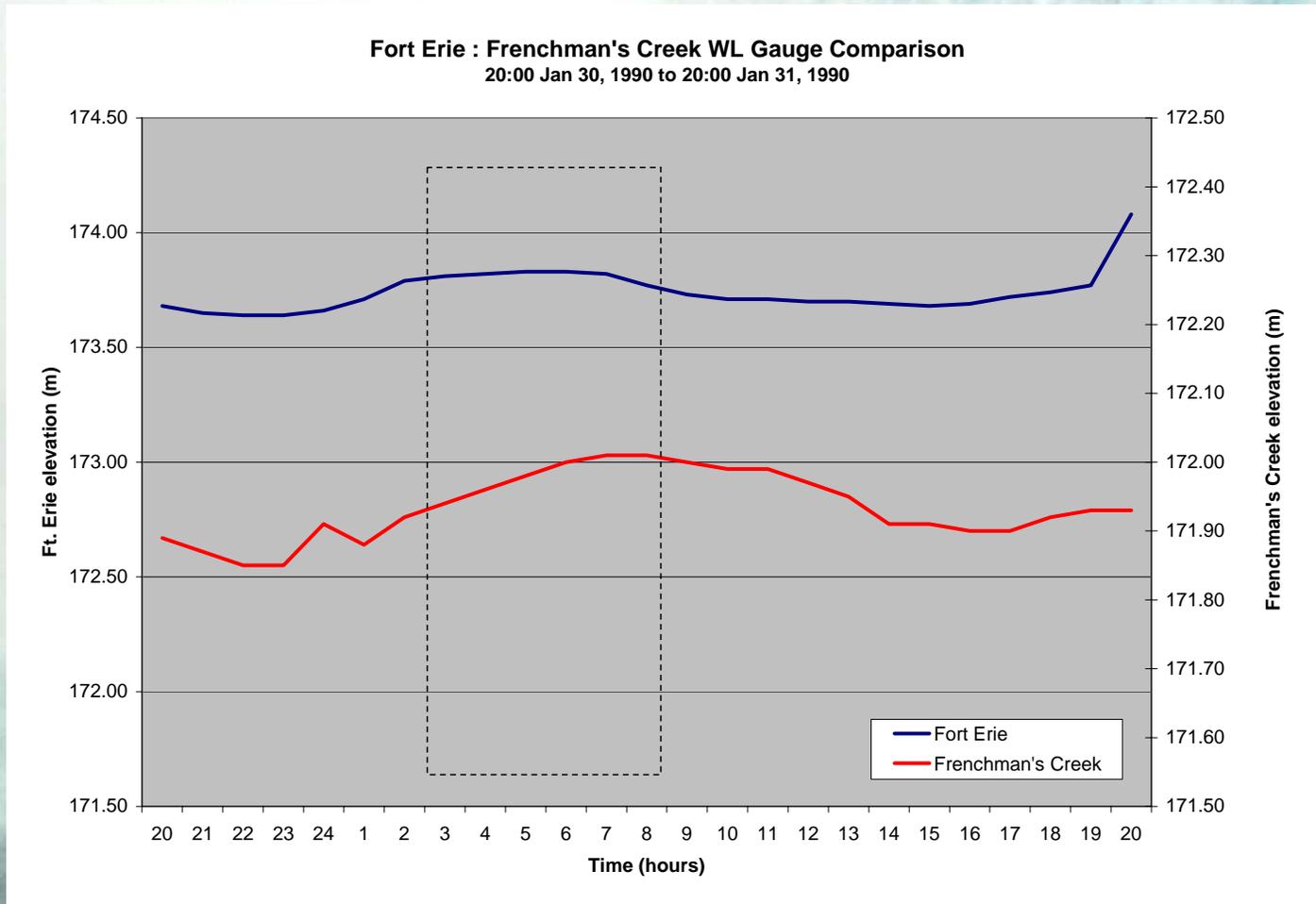


## Wind effect on Grass Island Pool



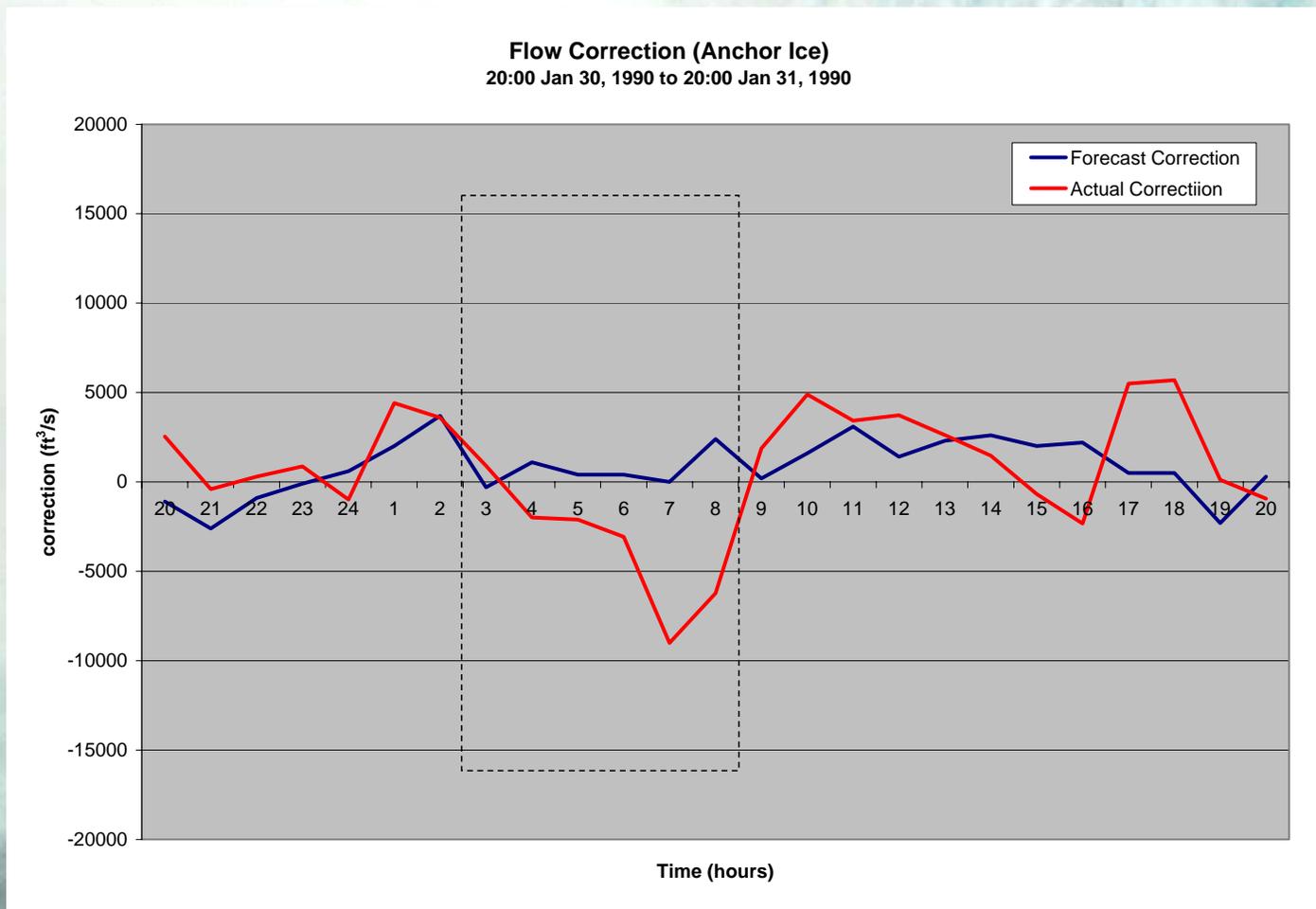
# Meteorological Data (water level gauge relationship)

Provide indication of anchor ice formation/severity

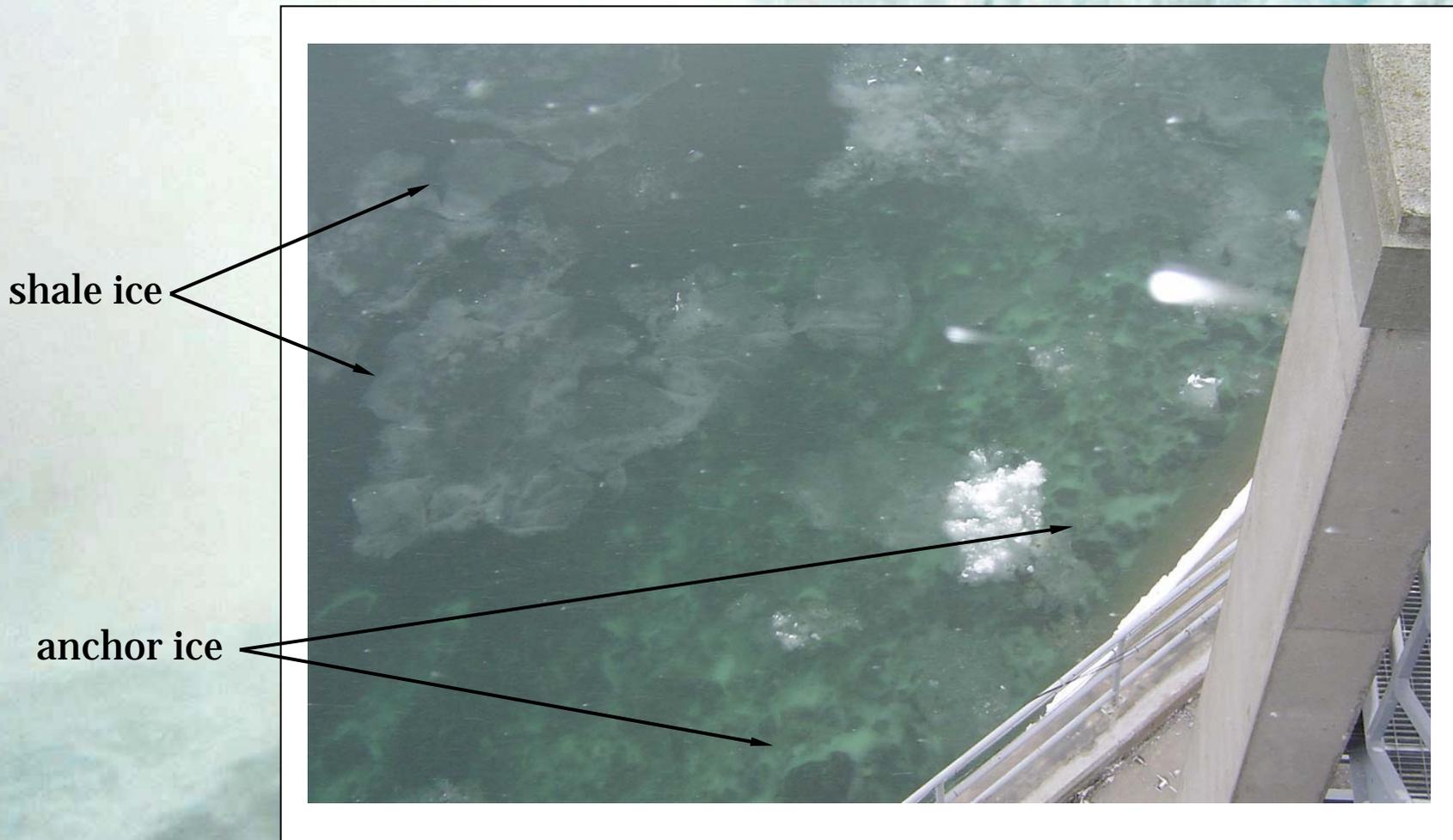


# Meteorological Data (water level gauge relationship)

Provide indication of anchor ice formation/severity

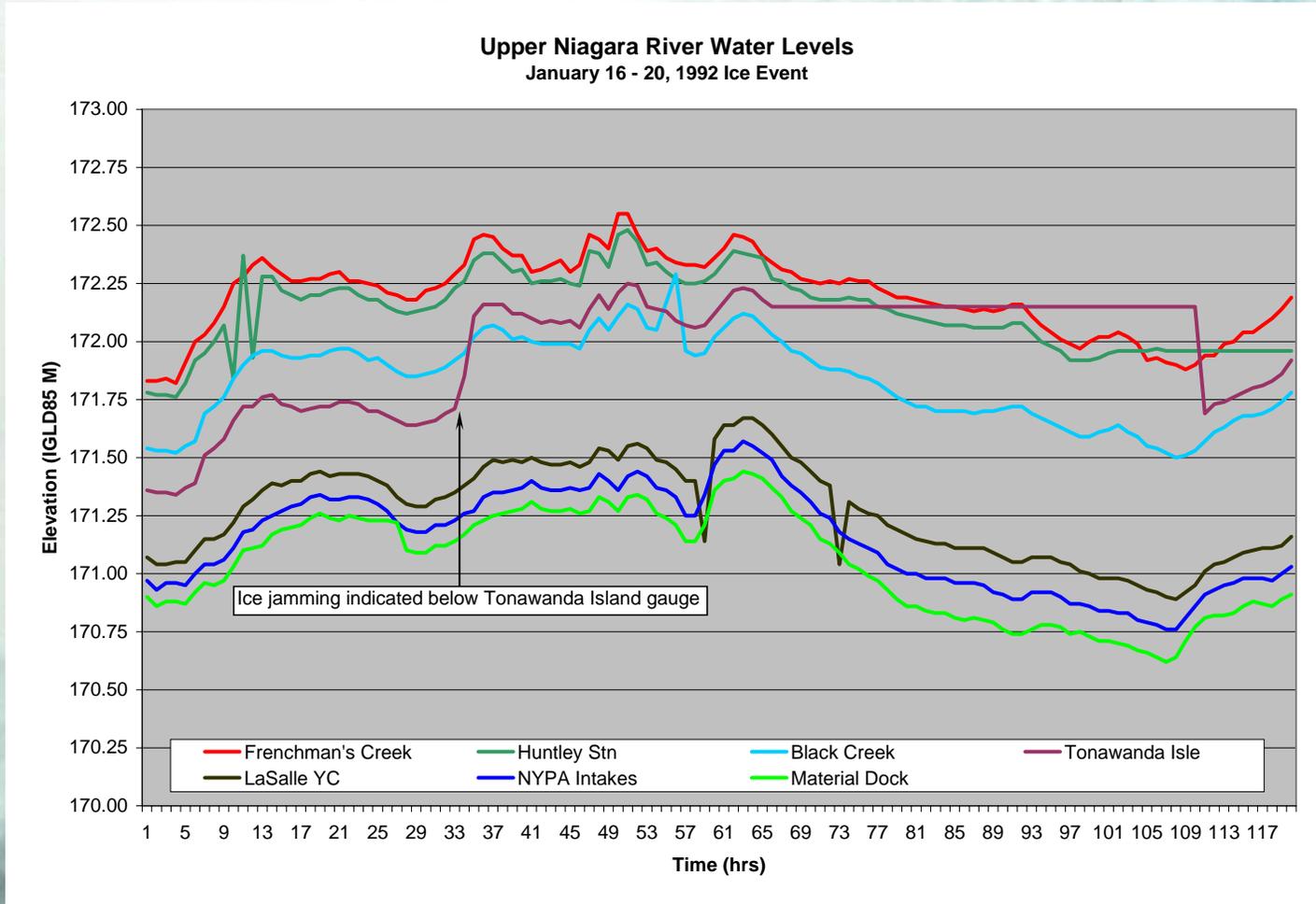


# Meteorological Data (water level gauge relationship)



# Meteorological Data (water level gauge relationship)

Provide indication of ice stoppages and/or jamming



# Remote Surveillance (camera systems)

Remote monitoring of ice formation and transport:

- Lake Erie – Niagara River Ice Boom
- Upper Niagara River @ Peace Bridge

web site: [www.iceboom.nypa.gov](http://www.iceboom.nypa.gov)

Ice Boom Camera



Peace Bridge Camera



# Remote Surveillance (camera systems)

## Remote monitoring of ice transport at NYPA Intakes

- 2 x 3-camera arrays each with independent remote PTZ
- colour day camera + image-intensified low light camera + infrared camera
- 22x optical zoom + 10x digital zoom capability

NYPA Intakes arrays



Viewing downstream



# Remote Surveillance (camera systems)

## Monitoring of ice transport in U.S. Ice Escape Channel

- B&W day camera with digitized low light capability
- Remote PTZ and adjustable shutter sensitivity

Tower Island camera



Viewing U.S. Ice Escape channel



# Remote Surveillance (camera systems)

## Remote monitoring of ice transport at SAB Intakes

- B&W day camera with digitized low light capability (present)
- Single 3-camera array with remote PTZ
- colour day camera + image-intensified low light camera + infrared camera
- 22x optical zoom + 10x digital zoom capability

SAB Intake camera



Viewing upstream



# Remote Surveillance (human reconnaissance)

## Monitoring of ice build up at various locations

- As required along upper Niagara River
- Weekly digital pictures Maid-of-the-Mist Pool
- As required in lower Niagara River

MOMP Ice Bridge



Lower Niagara River (NOTL)



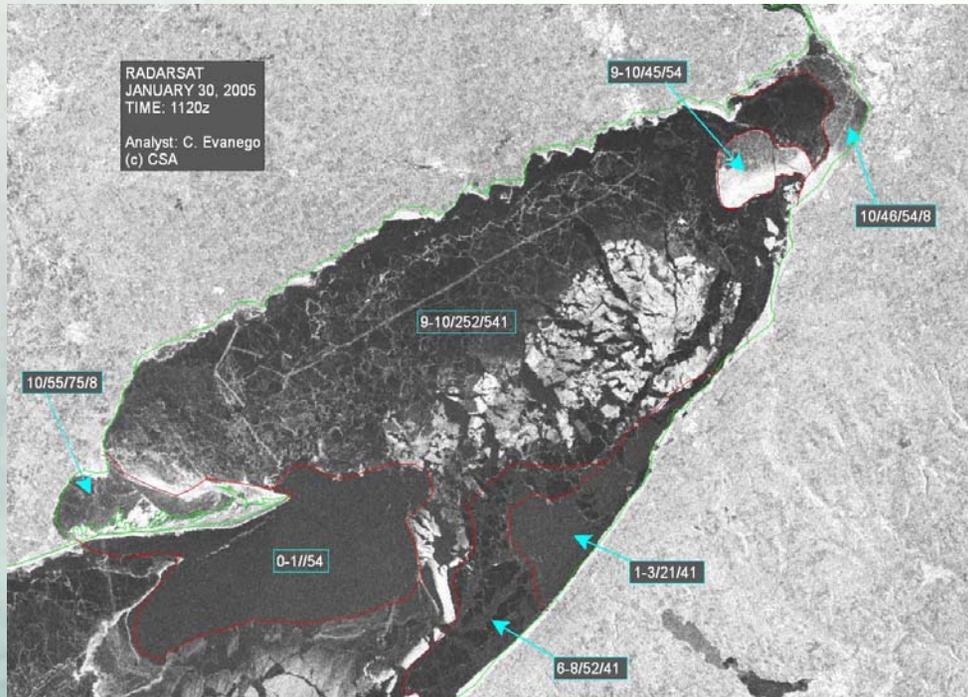
# Radar & Sonar Systems (satellite imagery)

## National Ice Centre

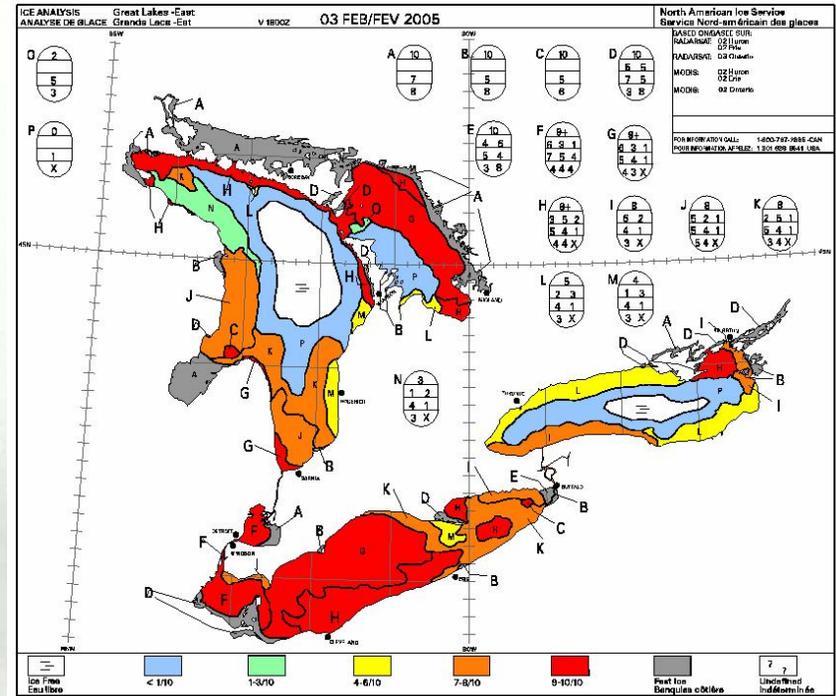
- Established in 1976 / re-organized in 1995
- Includes NOAA, U.S. Navy and U.S. Coast Guard
- Partnership with Environment Canada (CIS and CMC)
- Provides satellite imagery and ice analysis on Great Lakes
  
- Used to monitor extent of Lake Erie ice cover
- Regulatory support for ice boom installation/removal
- Gauge severity / ice impact of each winter season

# Radar & Sonar Systems (satellite imagery)

## RadarSat imagery



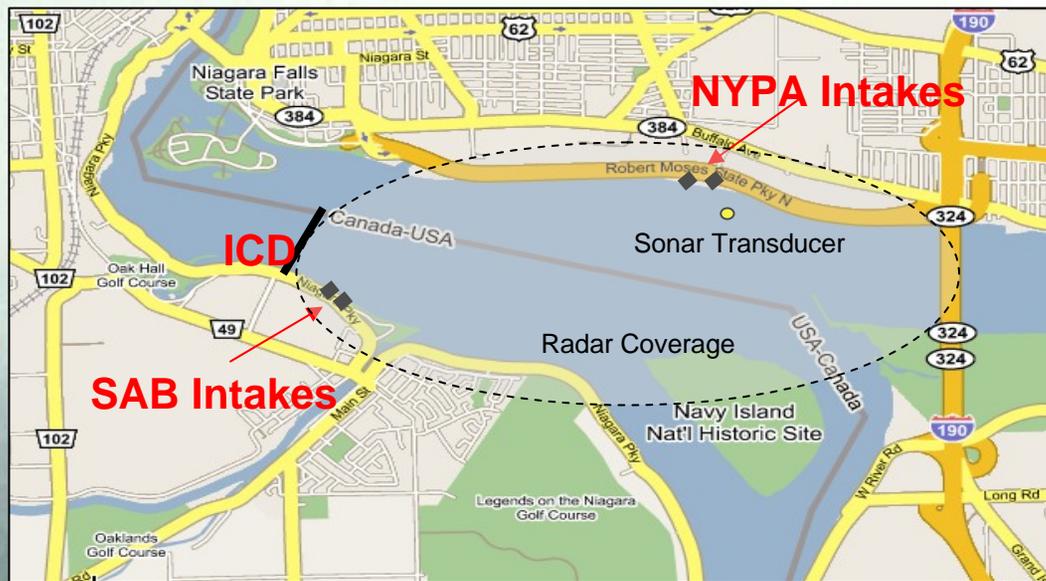
## NIC ice analysis



# Radar & Sonar Systems (marine radar & upward-looking sonar)

## NYPA Intakes

- Prototype system in-service for evaluation in 1994-95
- Useful in determining:
  - ice flow distribution / discharge through U.S. EC
  - ice thickness / volume characteristics at Intake
- Real-time production system under development (2006)

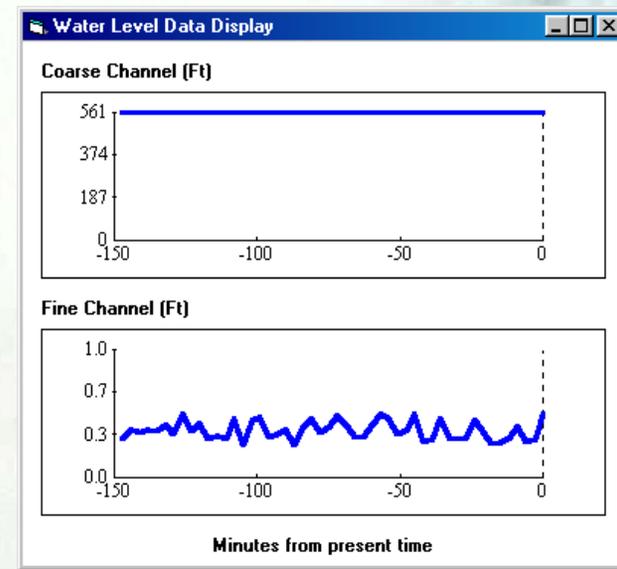
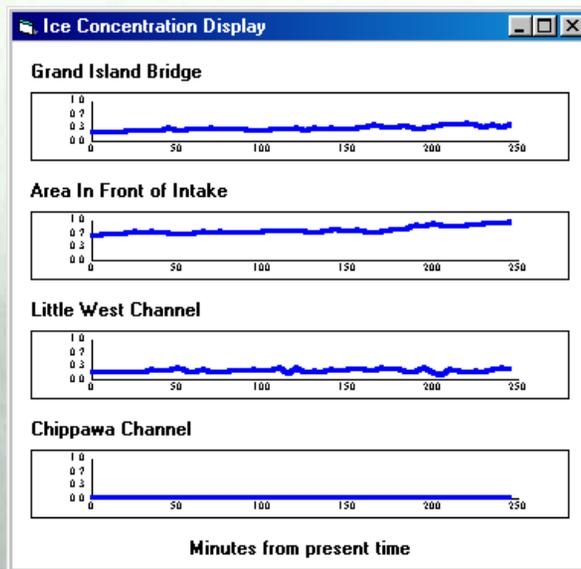
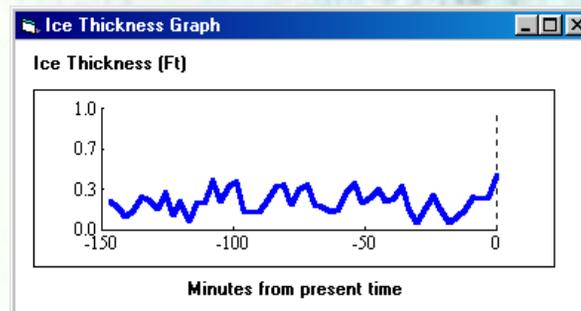
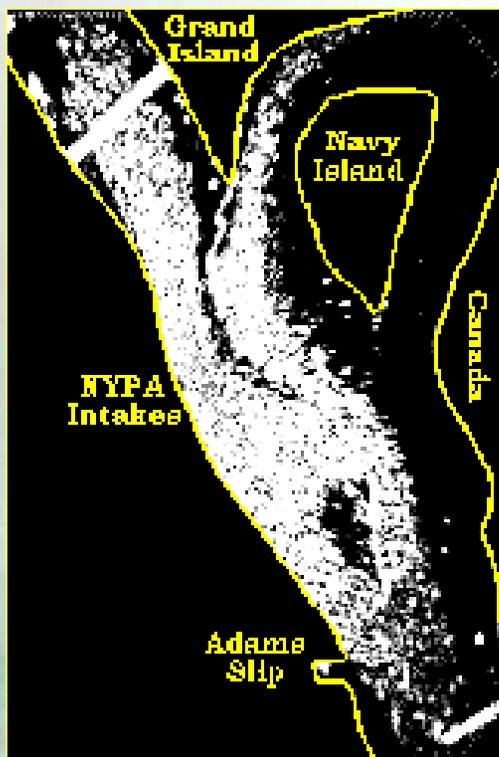


# Radar & Sonar Systems (marine radar & upward-looking sonar)

## Sonar Products

### Radar Product

Jan 16, 1997 @ 20:00



# Computer Modeling & Software (Physical models)

Simulate presence of ice / effect on flows & diversions  
Determine best location for new facilities / remedial work

- **OPG models**

  - Falls crest engineering work – early 1950's

  - Ontario Hydro Research Dept – (Flow Systems Lab) Toronto, ON

  - Tunnel intakes - 1985

  - Ontario Hydro Research Dept – (Flow Systems Lab) Toronto, ON

- **NYPA model**

  - To support FERC License Amendment

  - Alden Research Laboratory (ARL) – Holden, MA

  - US Army Cold Regions R & E Laboratory (CRREL) – Hanover, NH

# Computer Modeling & Software (Numerical models)

Simulations for alternative operating procedures  
Simulations for varying meteorological conditions  
Determine best location for new facilities

- **OPG models (to support plant operation)**

- Niagara Optimal Dispatch (NOD)

- Beck Maximum Output Program (BMOP)

- Niagara Incremental Economy Factor (NIEF)

- Niagara Utilization Model (NUM)

- **NYPA model (to support FERC License Amendment)**

- Dr. H.T. Shen – Clarkson University – Potsdam, NY

# Computer Modeling & Software (Operational software)

Realtime analysis of current conditions

Provide level monitoring / out-of-limits annunciation

Aid in determining most effective / efficient strategy

- **Niagara River Routing Model (NRRM)**

- One-dimensional hydrodynamic model

- Employs automatic calibration and filtering

- Routes flows on upper NR into GIP through 36 cross-sections

- Middle stage in 'forecast-routing-utilization' software suite

- Output to OEWS (TC regression calculation/open water estimate)

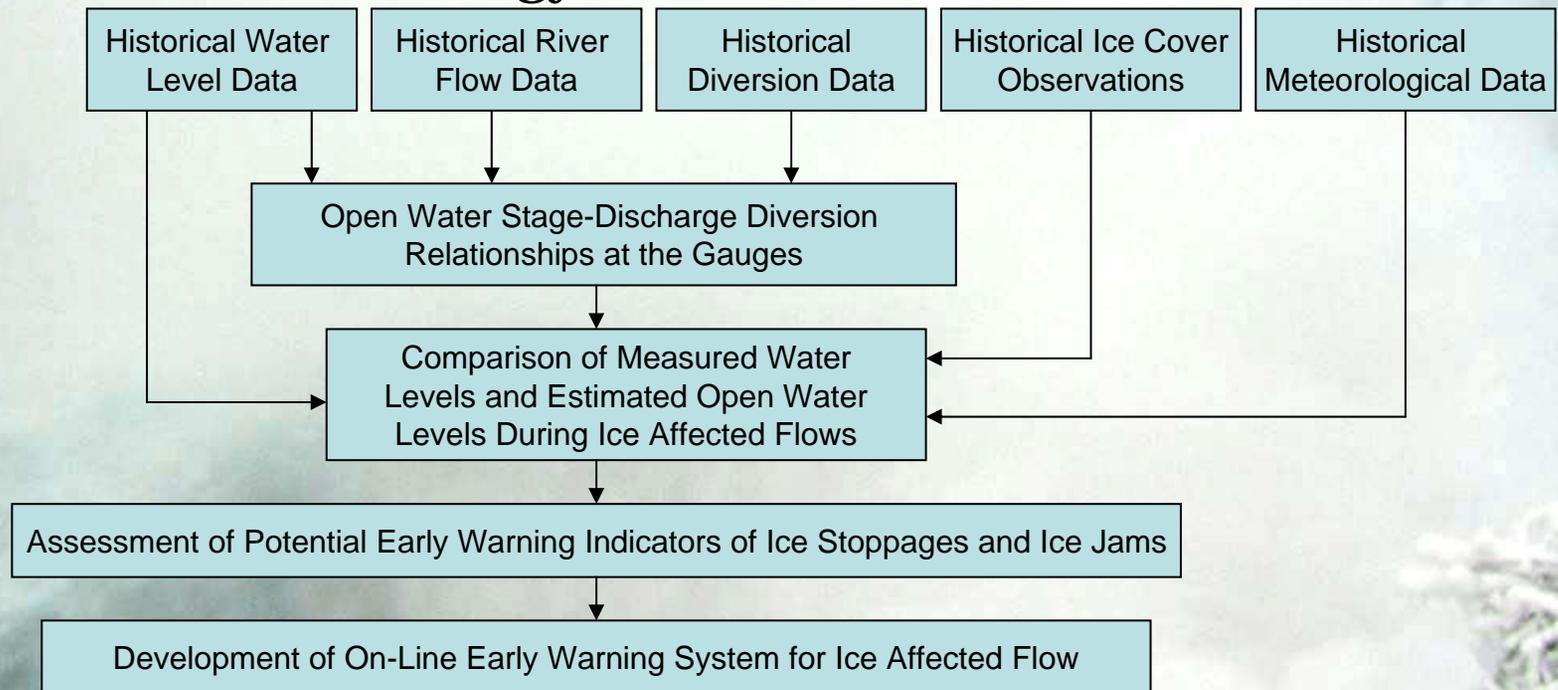
- Future plans: conversion and enhancement to re-develop GUI

# Computer Modeling & Software (Operational software)

- **Online Early Warning System (OEWS)**

Provides real-time and early warning information on ice conditions  
Used as notification tool for public safety (ice-affected flooding)  
Helps to avoid generation losses caused by ice

- **OEWS Methodology**



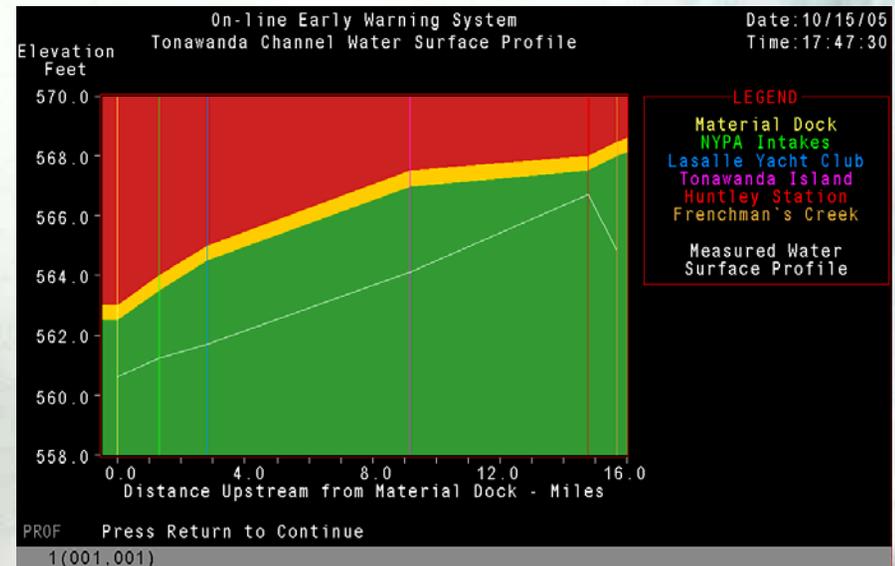
# Computer Modeling & Software (Operational software)

- OEWS Early Warning Indicators

- 1) Duration of ice-affected flow (> 30 hrs increases risk)
- 2) Maximum super-elevation due to ice (>0.5 ft increases risk)
- 3) Rate of change (drop) in river flow (>5,000 ft<sup>3</sup>/s per hour)

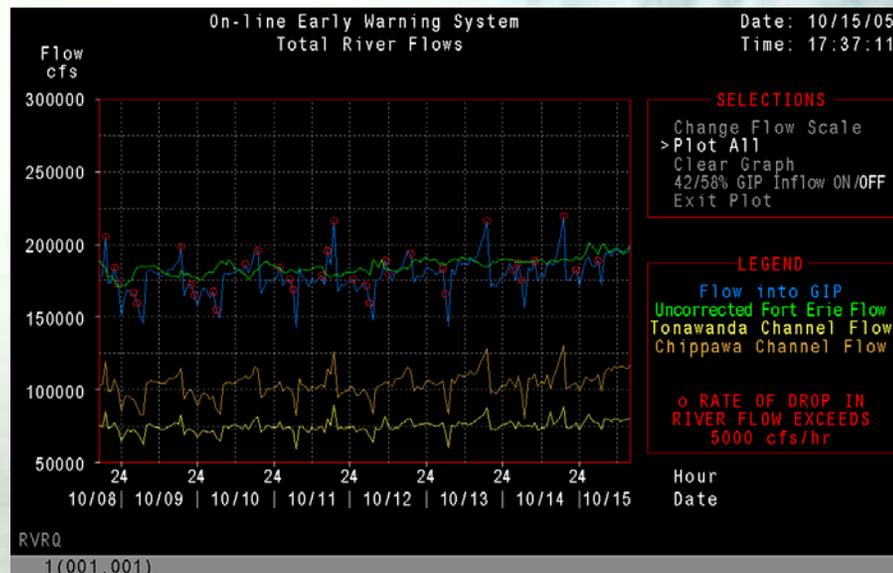
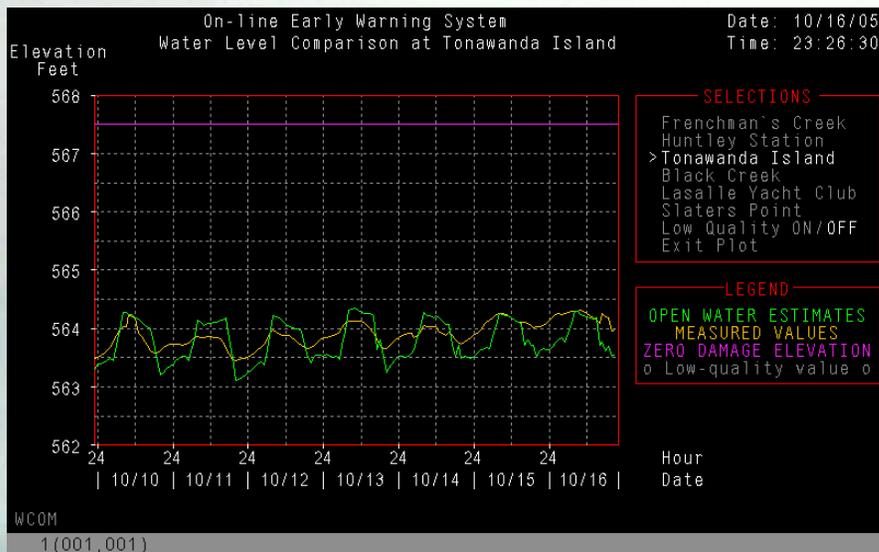
OEWS: Status of Early Warning Indicators				
		Date: 10/15/05	Time: 17:45:30	
Early Warning Indicator	Threshold Value	Actual Value	Status	
Duration of Ice-Affected Flow (hours):	30.0	167.0	██████████	
Maximum Water Level Difference (feet):	0.5	6.0	██████████	
at: <b>Huntley Station</b>				
Rate of Change in River Flow (cfs/hr):	-5000	3884	██████████	
TC Flow = 0.42*(Uncorrected FE Flow)+Correction		79760. cfs.		
TC Flow = Regression Calculation		79230. cfs.		
Location	Zero Damage Elevation	Actual Elevation	Difference	Status
Material Dock	563.00	560.64	-2.36	██████████
NYPA Intakes	564.00	561.24	-2.76	██████████
Lasalle Expressway	564.50	561.72	-2.78	██████████
Lasalle Yacht Club	565.00	561.72	-3.28	██████████
Tonawanda Island	567.50	564.12	-3.38	██████████
Huntley Station	568.00	571.72	3.72	██████████

STAT Press Return to Continue



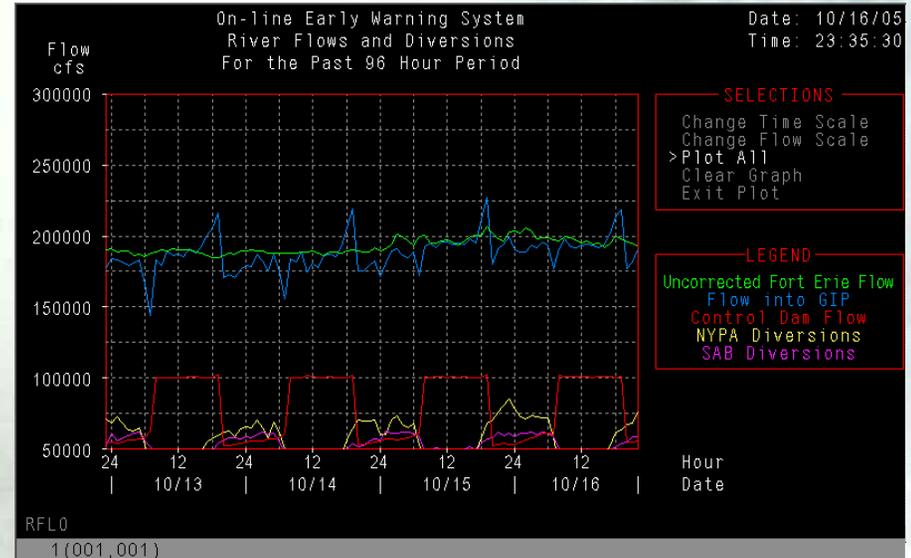
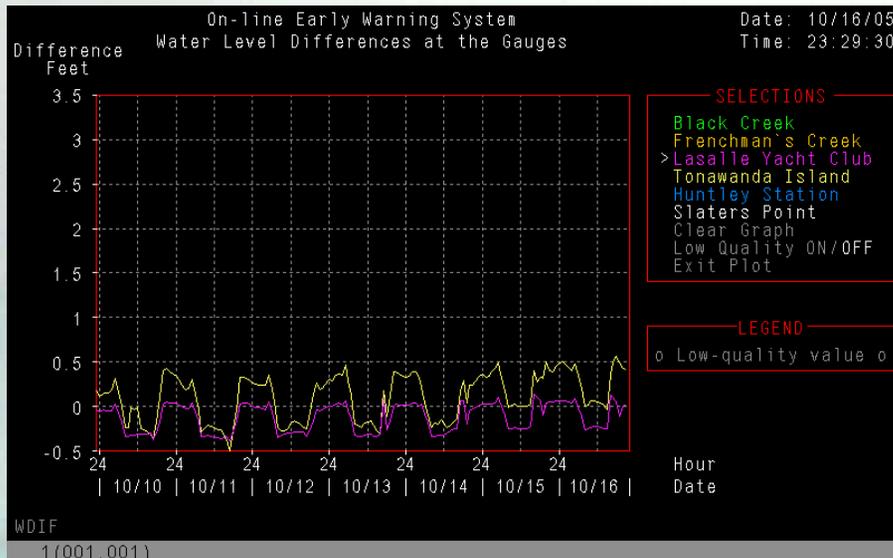
# Computer Modeling & Software (Operational software)

## Online Early Warning System (OEWS)



# Computer Modeling & Software (Operational software)

## Online Early Warning System (OEWS)



# Diversion Strategy/Mitigation Techniques

## Monitoring

- Use available tools to forecast ice arrival
- Assess conditions for ice type / magnitude

## Proactive Diversion Adjustments

- To combat slow ice transport & mitigate stoppages
- Consider market dynamics

## Post-Stoppage Ice Management

- To prevent stoppage growth / promote removal
- Prepare for next ice generation period

# Future Improvements

## Monitoring Tools

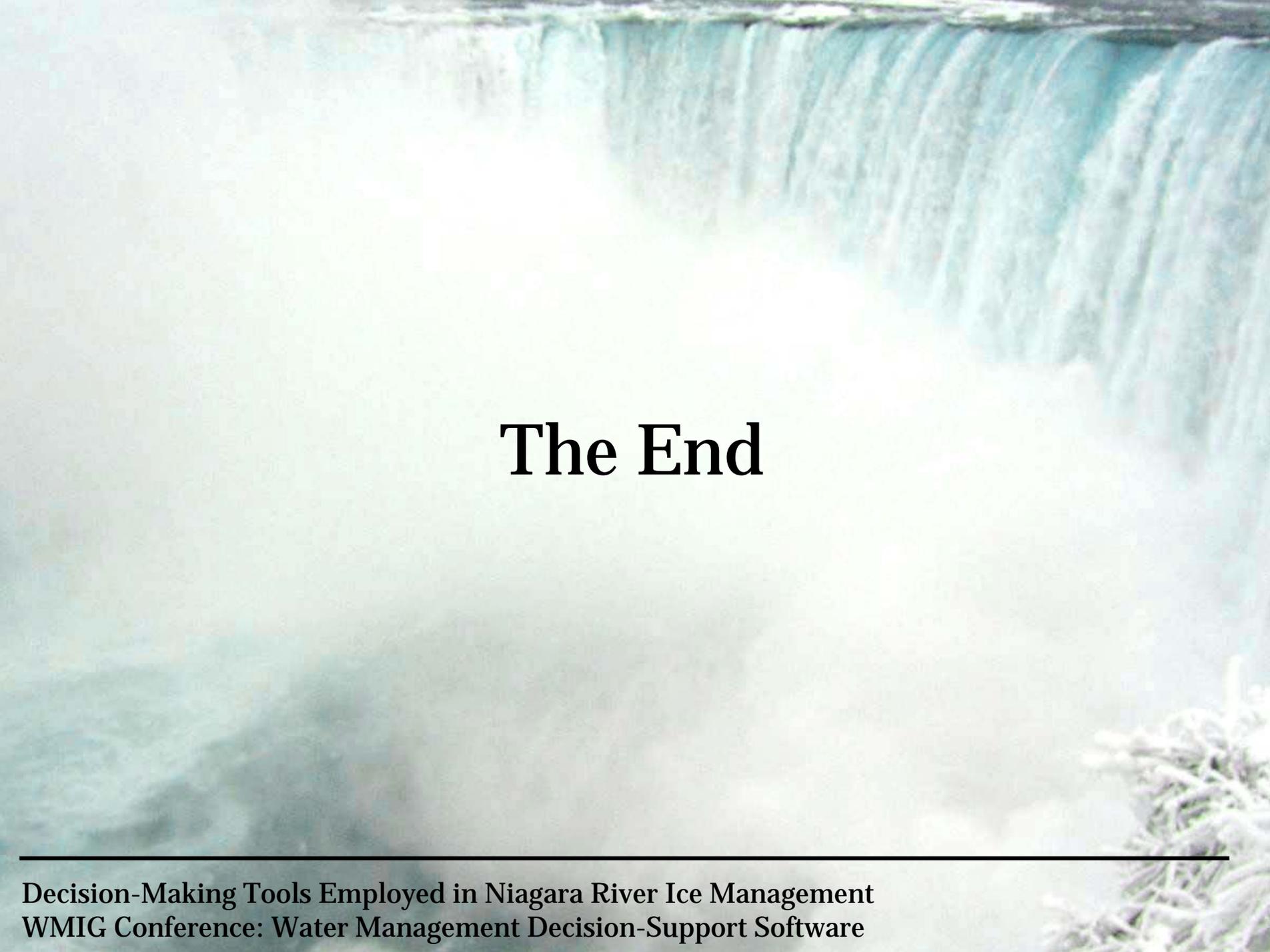
- Enhance suite of meteorological data
- Modify GUI to improve data handling / presentation

## Frazil Detector / Ice Forecaster

- Improve accuracy of anchor / frazil ice generation

## Software Applications

- Complete conversion and enhancements as planned
- Incorporate experiential knowledge

A photograph of Niagara Falls, showing the water cascading over the edge. The scene is slightly blurred, giving a sense of motion and power. The water is a deep blue-green color, and the surrounding area is hazy and misty.

# The End