

# Methylmercury Risk Analysis at Muskrat Falls

Webinar 1: Introduction and Comparison of Approaches

Ryan Calder, ScD

December 7<sup>th</sup>, 2017

Independent Expert Advisory Committee, Newfoundland and Labrador

# Ryan Calder

- **Postdoctoral Associate**  
Department of Civil and Environmental Engineering,  
Duke University Pratt School of Engineering
- **ScD, Environmental Health**  
Harvard T.H. Chan School of Public Health (in  
collaboration with the Harvard John A. Paulson School of  
Engineering and Applied Sciences)
- **MASc and BEng, Civil Engineering**  
Concordia University
- **Hydraulic Engineer, GHD, Montreal (2008-12)**
- **Analyst, Quebec Ministry of Environment (2007)**
- **Interests:** Human exposures to waterborne  
contaminants, environmental fluid mechanics, human  
health and environmental forecasting



# Goals

- Common baseline understanding of methylmercury toxicity, connection to hydropower and scientific gaps
- Familiarity with the MeHg environment and health studies commissioned by Nalcor (goals and limitations)
- Understanding of the goals of the Harvard studies and differences with respect to the Nalcor reports (scientific findings and implications for human health)



# Structure

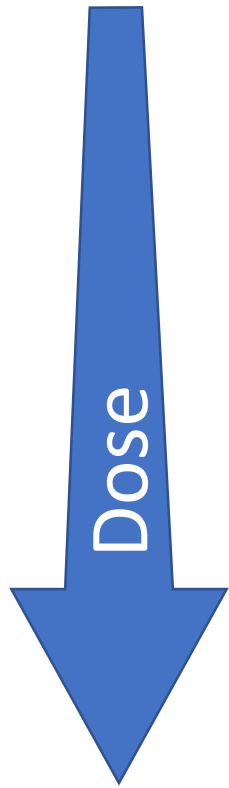
- Background: MeHg, health and hydropower
- Nalcor studies
  - Environmental Impact Statement (2009)
  - Joint Review Panel (2011) and since
- Harvard studies
  - Schartup et al. 2015; Calder et al. 2016
- Q&A + discussion
  - (Or feel free to ask questions throughout!)

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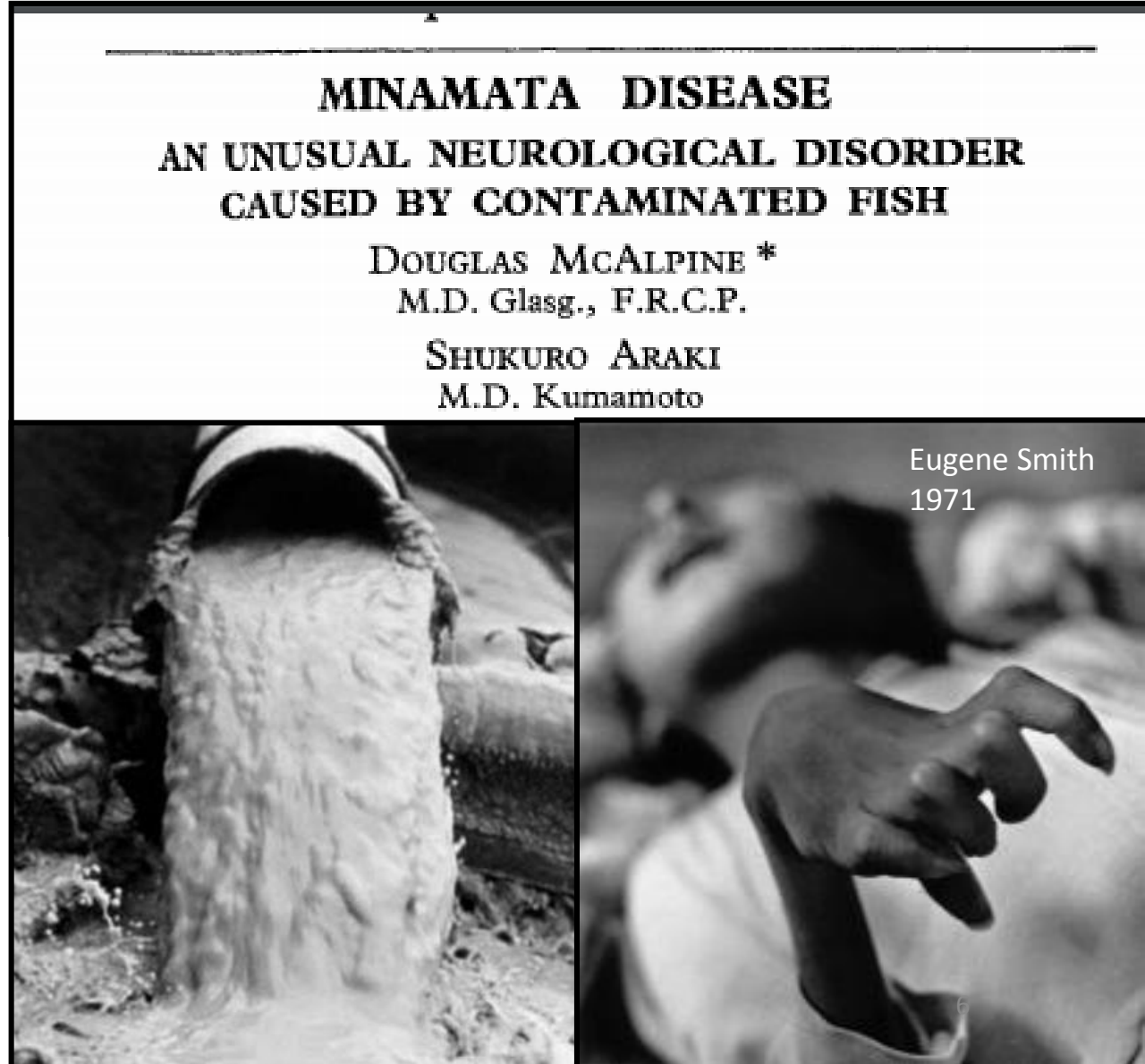
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# MeHg is a neurotoxin and cardiovascular stressor



- Neurodevelopmental: IQ deficits, ADHD
- Cardiovascular risks
- Ataxia, cognitive issues
- Dysarthria
- Deformities
- Death



# MeHg: no known safe dose

- Three large epi studies (Faroe Islands, Seychelles, New Zealand)
- Reference doses based on “benchmark dose” (lowest dose with observed risk)
  - Not the same thing as the dose at which we can be confident there is no risk
- No known mechanistic basis for threshold effect
- Therefore, any incremental increase → some incremental increase in risk

“...no evidence of a threshold arose for methylmercury-related neurotoxicity within the range of exposures in the Faroe Islands study.”

– US EPA 2001

“Data seem to indicate that there may not be an actual threshold for methylmercury toxicity...”

– Grandjean et al. 2010

# MeHg linked to hydropower in 1970s

- Observations that fish in hydro reservoirs have higher Hg levels than nearby systems
- Laboratory experiments demonstrated that flooding → MeHg production
- Too late for systematic monitoring of Churchill Falls

## **Mercury Accumulation by Largemouth Bass (*Micropterus salmoides*) in Recently Impounded Reservoirs**

A. Ray Abernathy<sup>1</sup> and Peter M. Cumbie<sup>2</sup>

1977

## INCREASES IN FISH MERCURY LEVELS IN LAKES FLOODED BY THE CHURCHILL RIVER DIVERSION, NORTHERN MANITOBA

R.A. Bodaly, R.E. Hecky and R.J.P. Fudge

1984

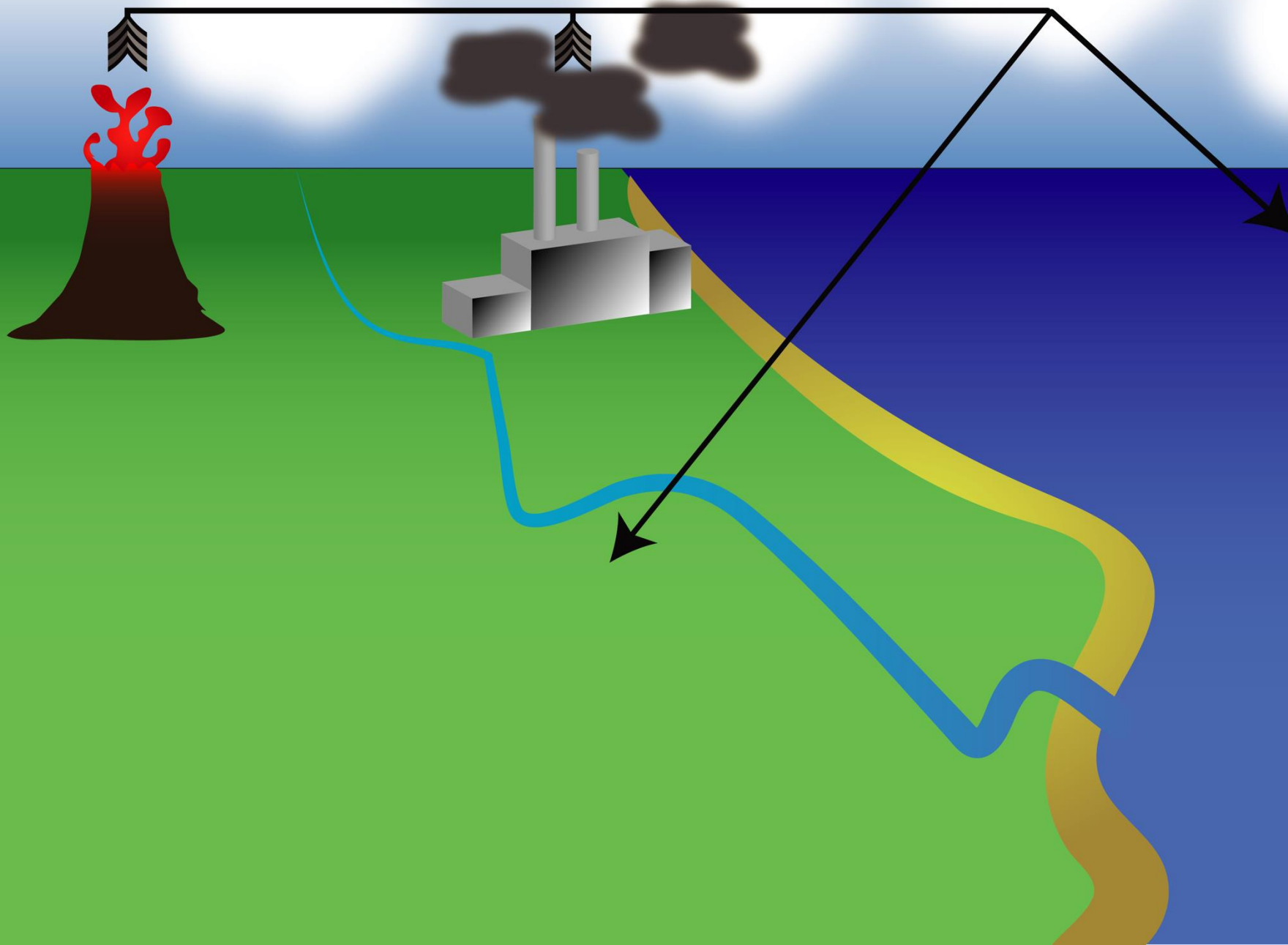
## Methylation and Demethylation of Mercury Under Controlled Redox, pH, and Salinity Conditions†

G. COMPEAU AND R. BARTHA\*

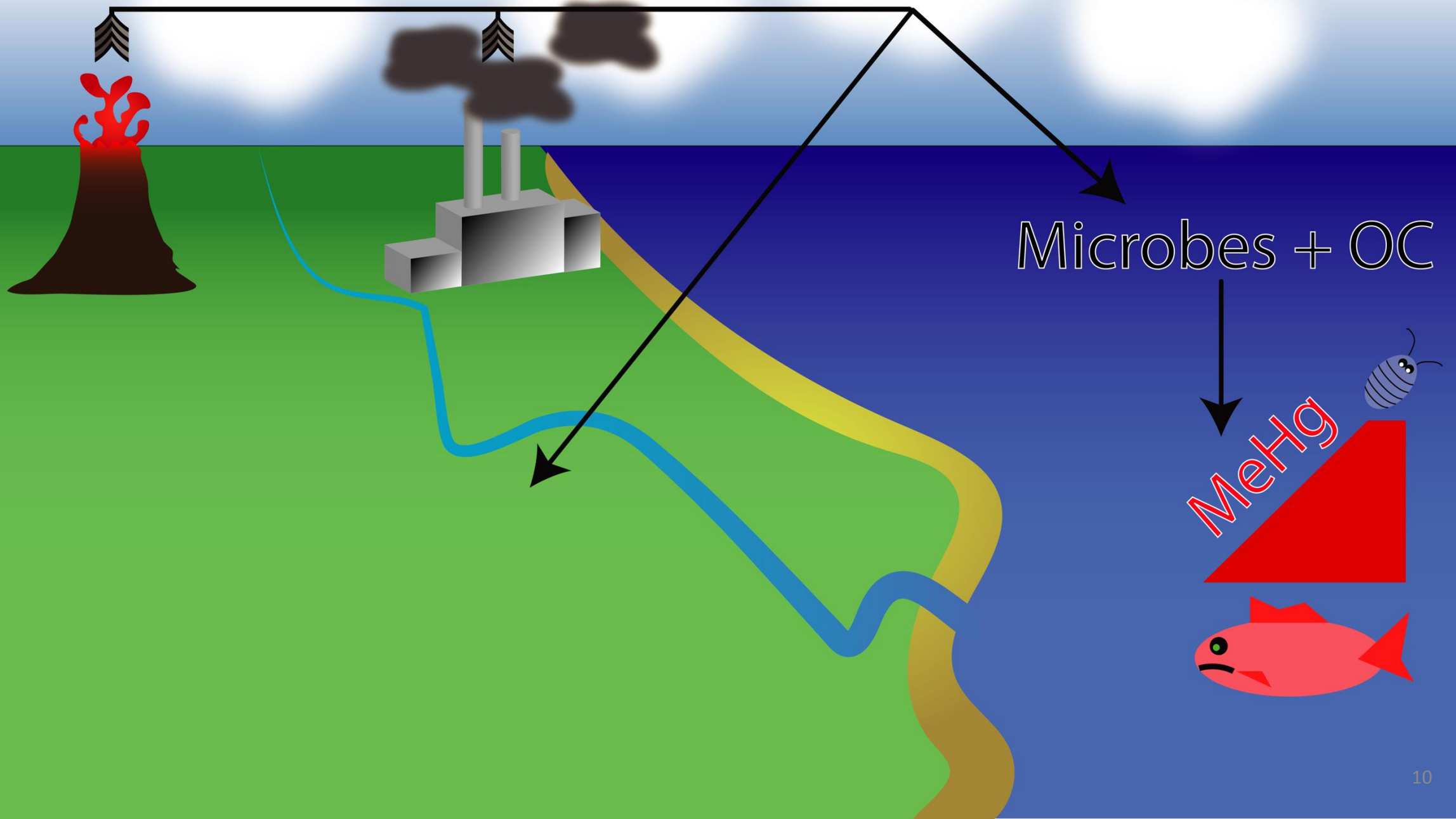
1984



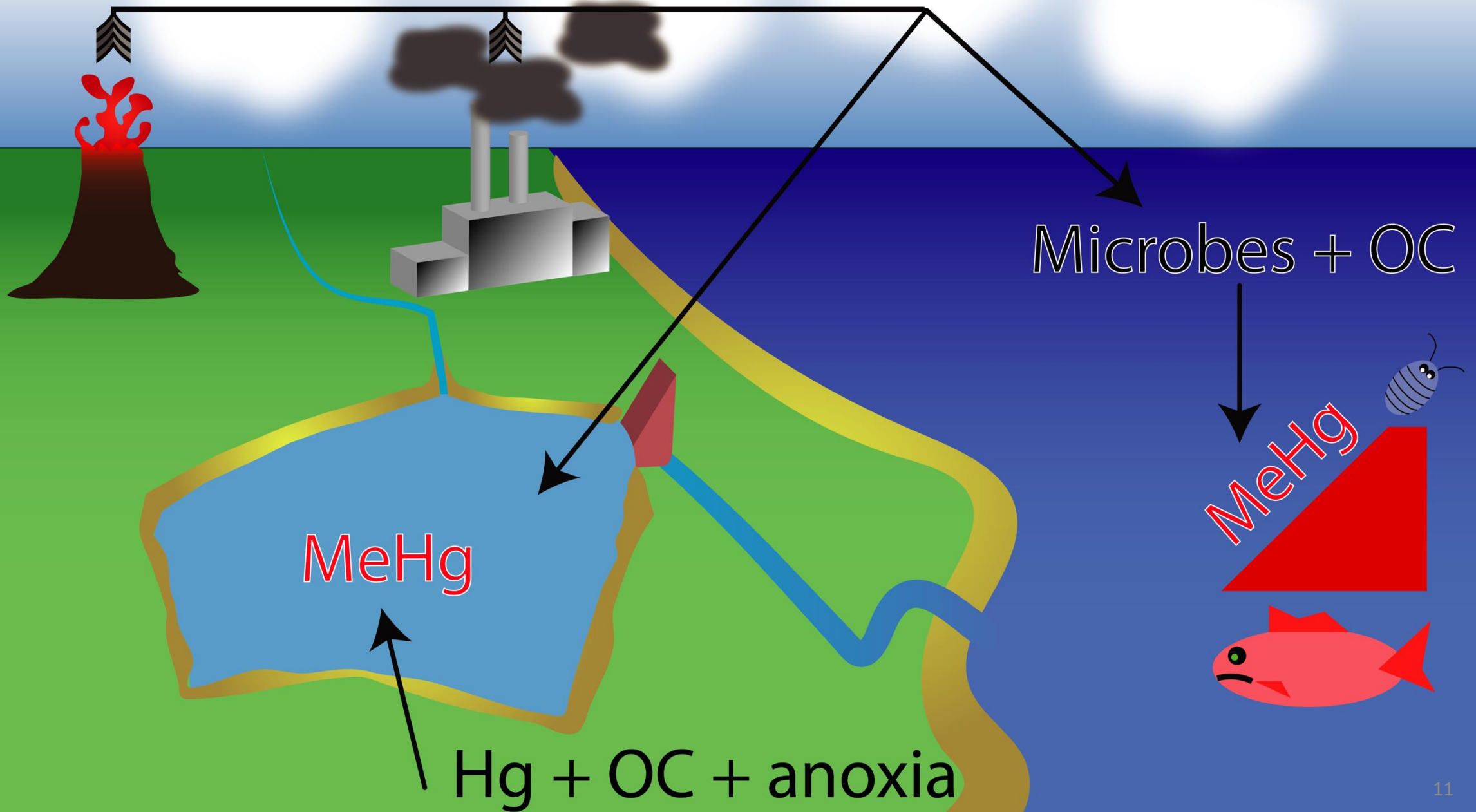
Hg(II), Hg(0)



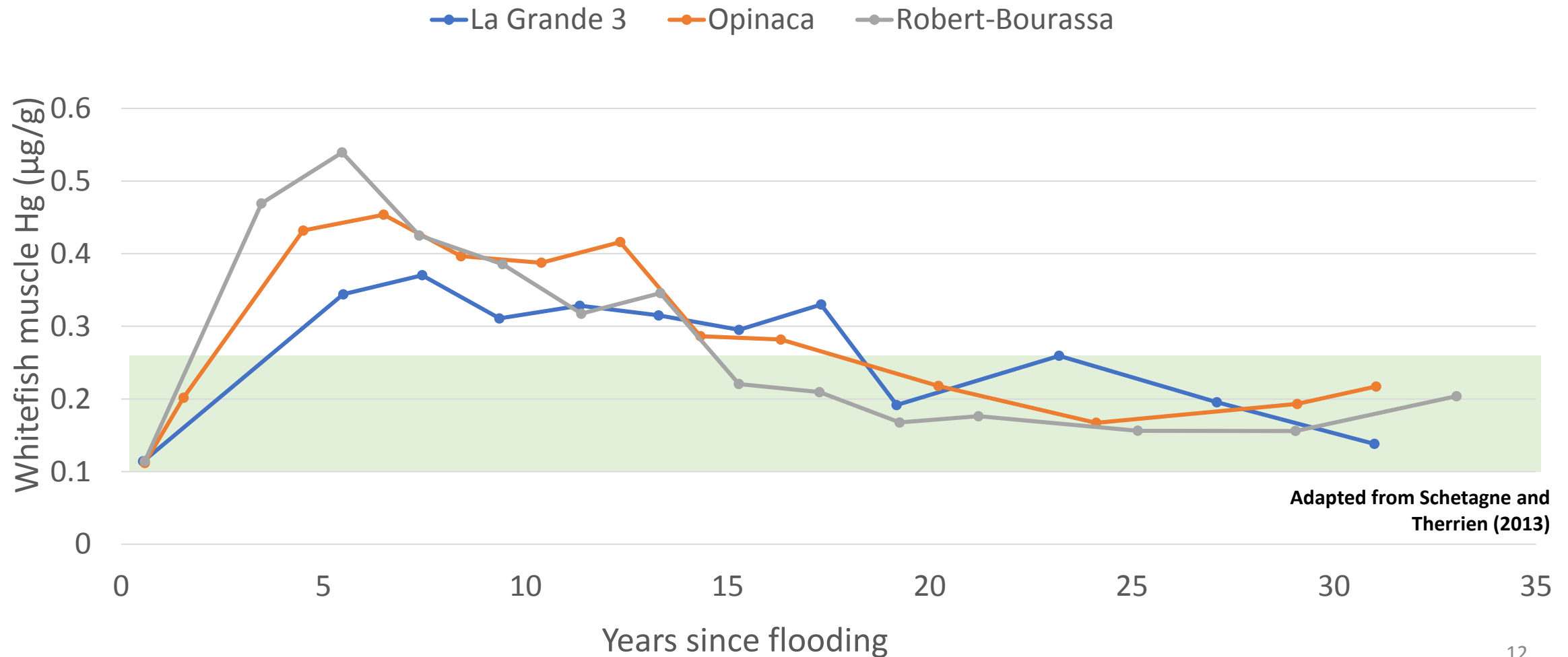
Hg(II), Hg(0)



Hg(II), Hg(0)



# Longitudinal data from Hydro-Québec



# Scientific uncertainties before Muskrat Falls

- Physicochemical
  - Persistence of MeHg in downstream environment
  - Importance of physical variables in magnitude of pulse (carbon, reservoir size, etc.)
- Human MeHg exposures
  - Attributable MeHg exposures never calculated from previous projects (inadequate baseline data, changing diets, etc.)
  - Highly heterogeneous diets (among indigenous and also non-indigenous vs. indigenous)

“We do not predict that creation of the Muskrat Falls reservoir will heighten risk to people in Lake Melville.”

– Gilbert Bennett,  
Executive Vice  
President, Nalcor  
Energy, 2016

“... there is no reasonable possibility that the Project would have an adverse environmental effect on the Labrador Inuit Settlement Area”

– Project Planning and  
Description, 2009

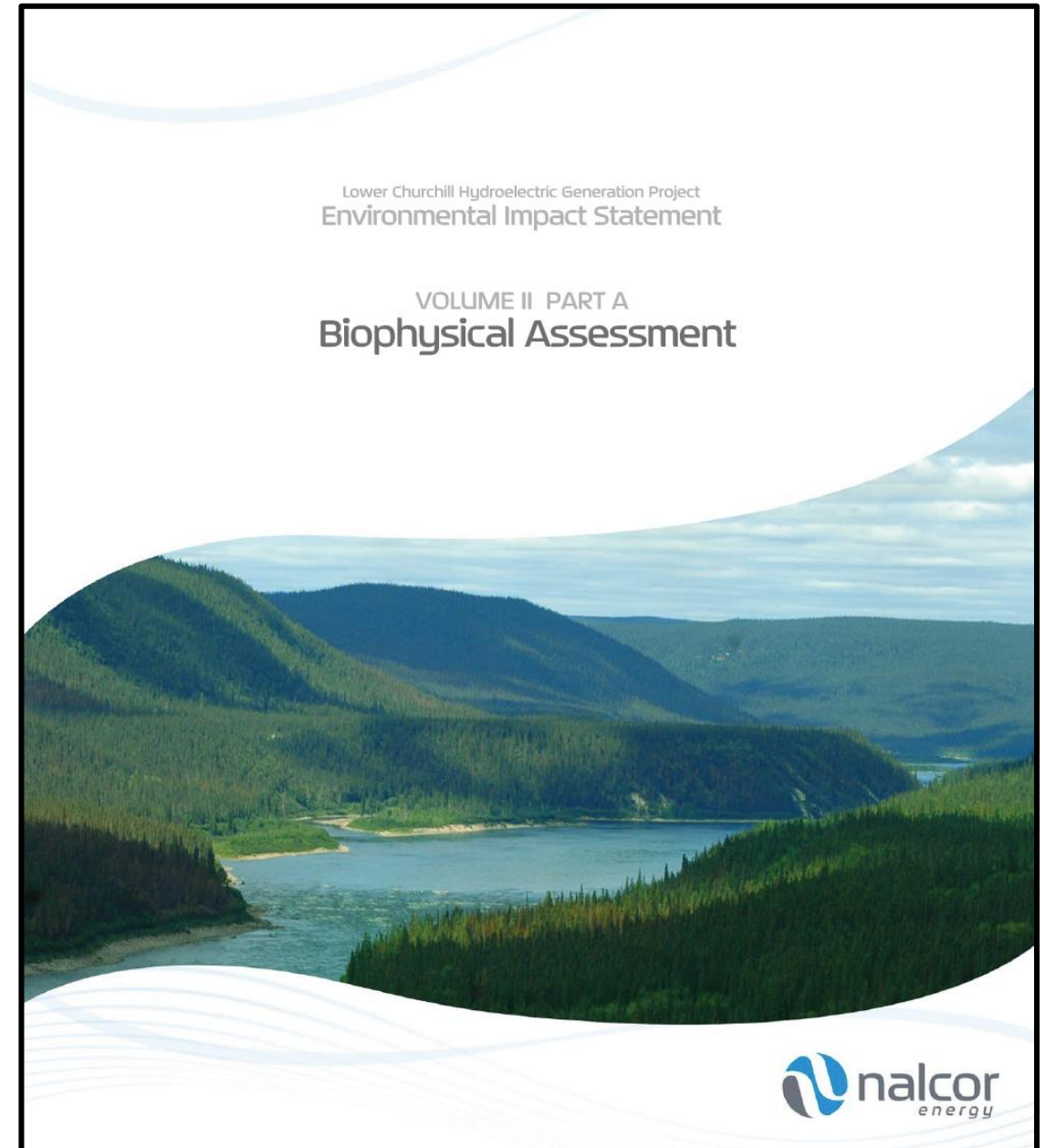
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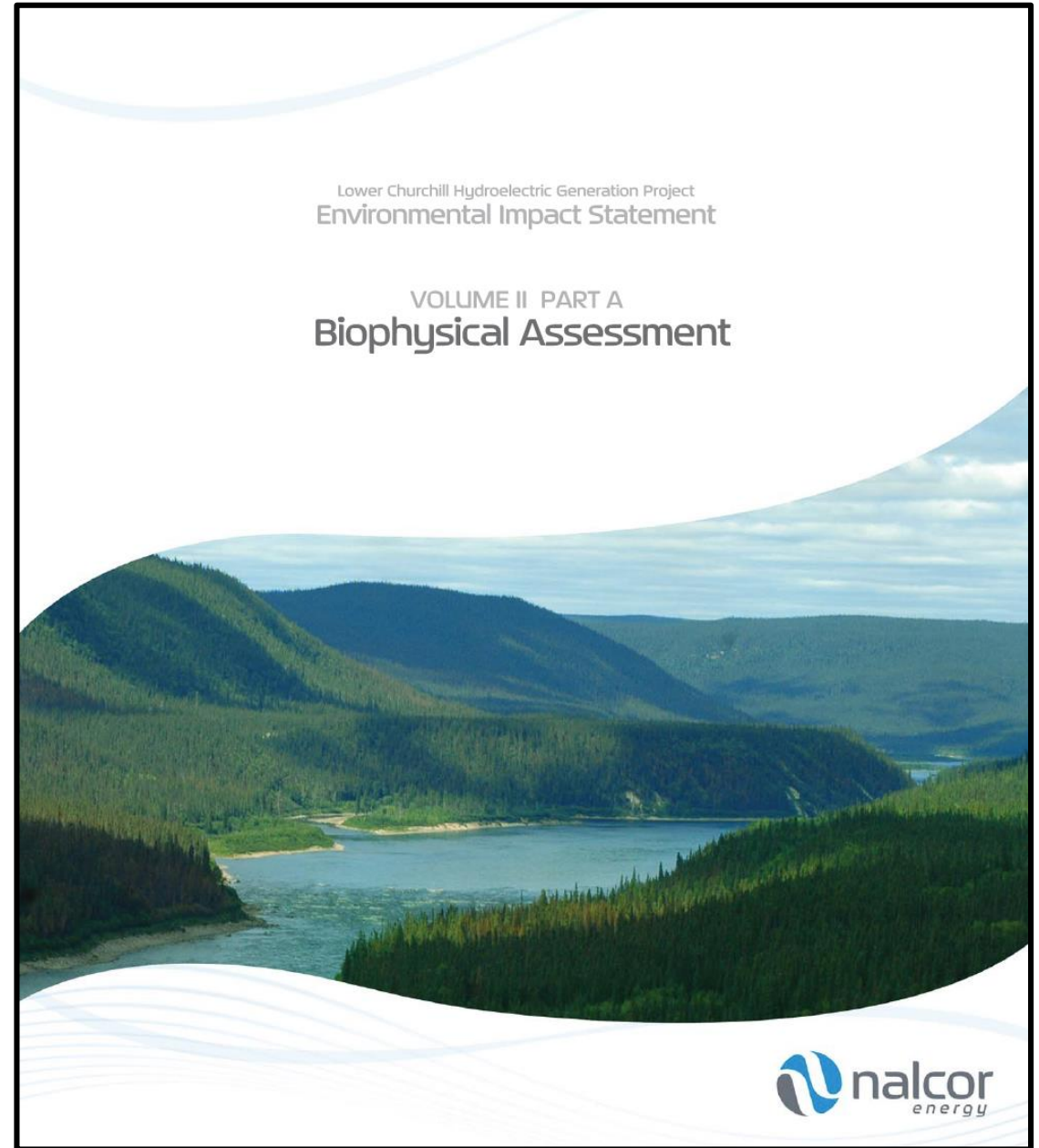
# Nalcor Environmental Impact Statement

- Estimates of future Hg levels in key fish species based on statistical analyses from MB, QC (Harris and Hutchinson 2008)
- Calculation of intake scenarios to respect Health Canada pTDI ( $0.2 \mu\text{g kg}^{-1} \text{ day}^{-1}$  for women of childbearing age and children;  $0.47 \mu\text{g kg}^{-1} \text{ day}^{-1}$  for everyone else) (Minaskuat Inc. 2008)



# Nalcor Environmental Impact Statement

- “Lake Melville is not included within the Assessment Area as there will be no [...] physical disturbance beyond the mouth of the Churchill River from this Project.”
  - Impacts not evaluated because there are no impacts.
- No calculation of exposure impacts



# Harris and Hutchinson 2008

- Application of semi-mechanistic statistical relationship
  - Fish Hg vs. flooded area, flow, etc.
  - Regression constants from other sites
- Post-hoc adjustment for possible higher increases among certain size fractions
- Muskrat Falls: **1.8–4.7x** increase factor for riverine species

Harris, R. and D. Hutchinson (2008). "Assessment of the Potential for Increased Mercury Concentrations." Lower Churchill Hydroelectric Generation Project Environmental Impact Statement. St. John's, NL: Nalcor Energy.

## Lower Churchill Hydroelectric Generation Project Environmental Baseline Report:

### Assessment of the Potential for Increased Mercury Concentrations



Proposed Gull Island GS

Prepared by  
Reed Harris and David Hutchinson  
Tetra Tech Inc.  
Oakville, Ontario

In association with  
AMEC Americas, Earth & Environmental  
St. John's, Newfoundland

March 4, 2008

# Harris and Hutchinson 2008

- Statistical relationships calibrated in other environments and exclude relevant predictors (e.g., soil carbon)
- Unknown predictive power for Muskrat Falls (model coefficients calibrated to fit baseline data)
- Basis for consumption scenarios to respect pTDIs (Minaskuat 2008)

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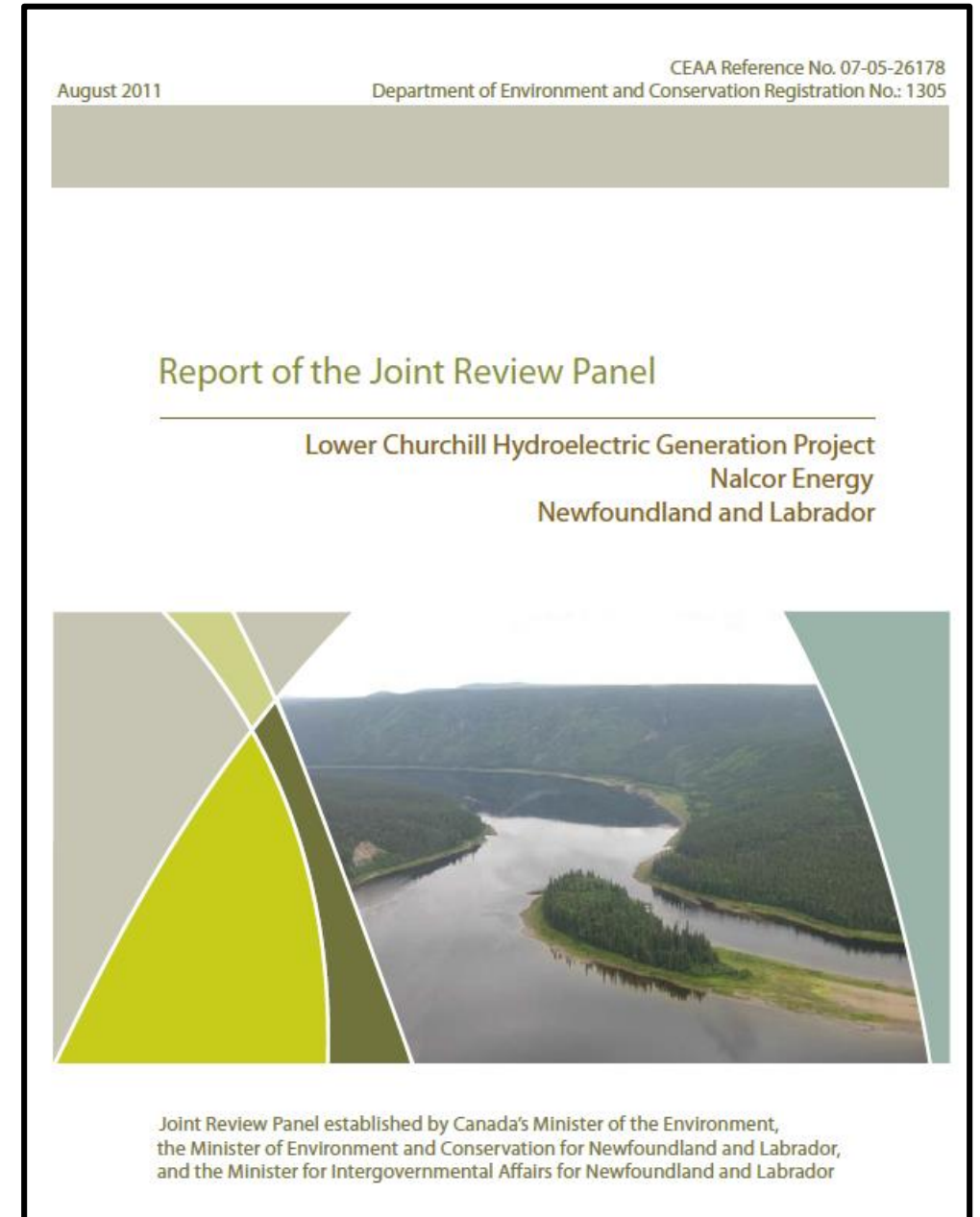
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March 4, 2008



# Joint Review Panel

- Requested studies to evaluate downstream impacts (JRP.166)
- Harris et al. 2010 (RESMERC) model carried out
- Results used in subsequent exposure assessments



# Harris et al. 2010

- Mechanistic model for MeHg production in flooded soils
- Based on fluxes observed in Experimental Lakes Area
  - Lower organic carbon
  - Slower flux due to less shear on sediment-water interface?
- Limited baseline measurements available at time of modeling

Harris, R., D. Hutchinson and D. Beals (2010). "Application of a Mechanistic Mercury Model to the Proposed Lower Churchill Reservoirs." Responses to Information Requests from the Joint Review Panel. St. John's, NL: Nalcor Energy.

## Application of a Mechanistic Mercury Model to the Proposed Lower Churchill Reservoirs:

Technical Memorandum in support of the Nalcor response to IR# JRP.166

Prepared for Nalcor

Prepared by.

Reed Harris and David Hutchinson  
Reed Harris Environmental Ltd.

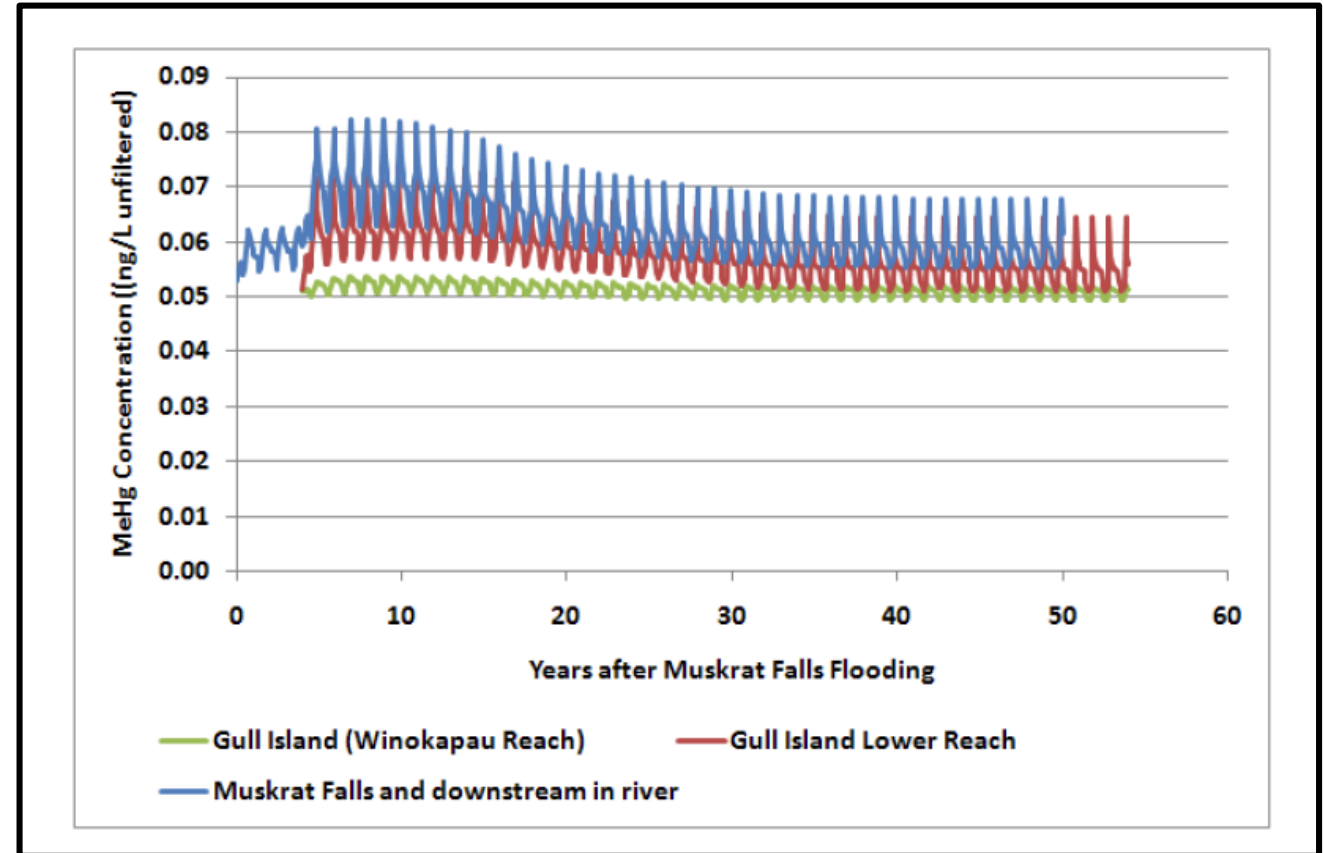
Don Beals  
Beals and Associates

December 2010



# Harris et al. 2010

- Forecast: Water column increase = **1.6x** downstream from Muskrat Falls
  - If baseline value is changed to  $0.02 \text{ ng L}^{-1}$ , increase = **2.5x**
- Key fish species increase = **2.3–6.0x**
- Effects of incorporating site-specific chemical data, influence of carbon, etc.?



Harris, R., D. Hutchinson and D. Beals (2010). "Application of a Mechanistic Mercury Model to the Proposed Lower Churchill Reservoirs." Responses to Information Requests from the Joint Review Panel. St. John's, NL: Nalcor Energy.

# Post-JRP Exposure Studies

Lower Churchill River Fish Consumption  
and Angling Survey

ENVIRONMENTAL BASELINE REPORT  
LCP 609068

FINAL REPORT

January 19, 2009

Prepared by Minaskuat Inc.  
for  
Newfoundland and Labrador Hydro

January 2011

NALCOR ENERGY - LOWER CHURCHILL  
HYDROELECTRIC GENERATION PROJECT

HUMAN HEALTH RISK  
ASSOCIATED WITH MERCURY  
EXPOSURE (PROJECT NO.LC-EV-006)

Submitted to:  
Nalcor Energy - Lower Churchill Project  
P.O. Box 12800, 500 Columbus Drive  
St. John's, NL  
Canada, A1B 0C9

REPORT

Report Number: 09-1113-0093

Distribution:

Nalcor Energy - 3 Hard Copies+ 2 Electronic  
Copies  
Sikumiut Environmental Management Limited - 1  
Copy  
Golder Associates Ltd - 2 Copies



December 2015

NALCOR ENERGY LOWER CHURCHILL  
PROJECT

Report on the Baseline Dietary  
Survey and Human  
Biomonitoring Program



NALCOR ENERGY LOWER CHURCHILL HYDROELECTRIC  
GENERATION PROJECT

Final Baseline Human Health Risk  
Assessment: Lower Churchill  
Hydroelectric Generation Project

Submitted by Dillon Consulting Limited



October 2016 -12-6331-7000



# Oceans Ltd. 2010

- Dispersion model for Lake Melville
- MeHg/THg input as tracers
  - No chemical reactions
- Not based on site-specific data so forecasted values are for demonstration purposes only (?)
- Demonstrates effect of mixing on concentrations of hypothetical inert inputs
- Depth-specific values not reported
  - Surface layer most important for uptake into food web

## Modeling the Dispersion of Mercury and Phosphorous in Lake Melville

Technical Memorandum in support of the Nalcor response to IR# JRP.166

Prepared for

Nalcor

Prepared by

Oceans Limited  
85 LeMarchant Road  
St. John's, Newfoundland, Canada  
A1C 2H1

December 2010

# Post-JRP Exposure Studies

- Indigenous population not explicitly considered
  - However, Sheshashiu is proxy for Innu
- Exposure and risk refer to measures of central tendency for the population vs. pTDI
  - Remember that MeHg is likely non-threshold
- Geometric means used to calculate vulnerability and risk
  - Not sensitive to subpopulations with high consumptions
- Low enrolment and suspect treatment of high values

“ The survey results indicate that there is currently little consumption of fish from the lower Churchill River by residents of central Labrador.”

– Golder Associates 2011

The mean [...] was 4.8 [...]. However, only 4 of 19 households responded [...]. When the **outlier** is excluded, the average [...] becomes 1.7”

– Golder Associates 2011

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# Harvard studies: goals

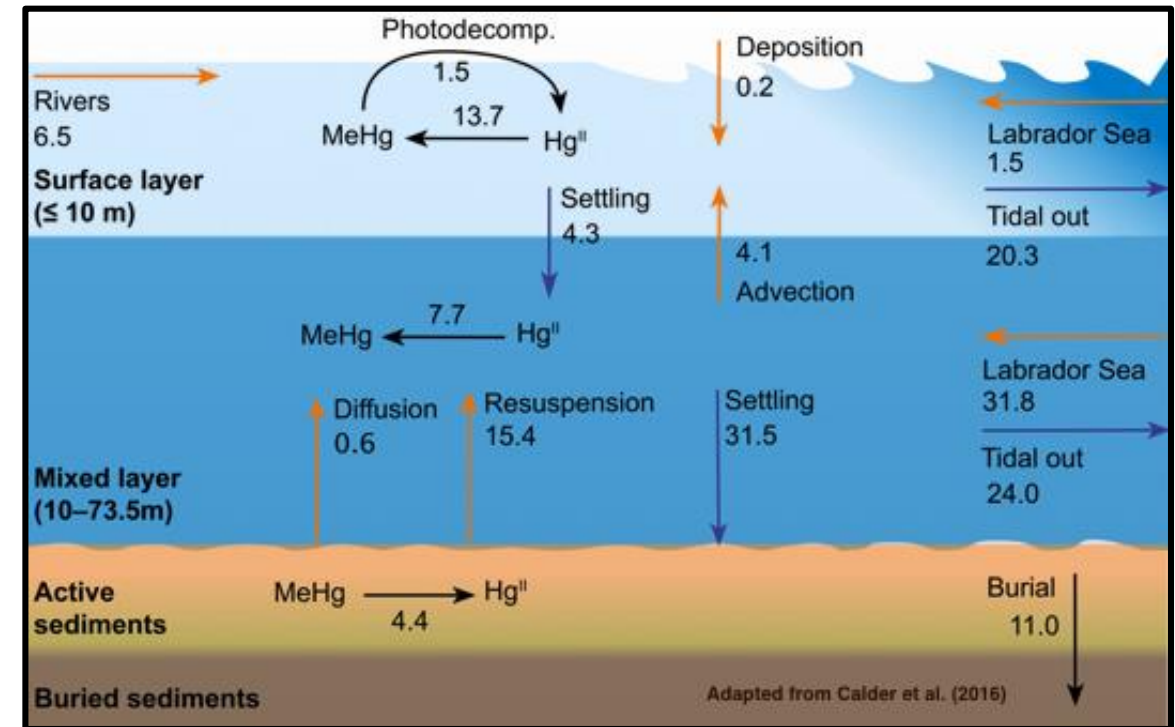
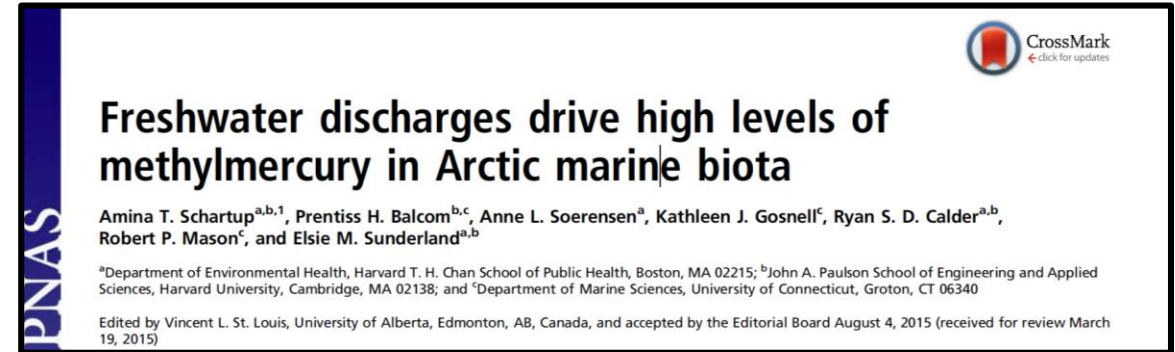
- Identify mechanisms controlling uptake of MeHg in northern aquatic environments
  - Climate change and industrial development
  - What are implications for MeHg exposures?
- Predictive framework
- Quantify vulnerability of indigenous populations





# Schartup et al. 2015

- Baseline MeHg budget of Lake Melville
- Freshwater inputs important for uptake into estuarine food web
- Buoyancy and stratification effects concentrate freshwater inputs into surface layer
- Suggests that MeHg pulse on Churchill River may impact



# Calder et al. 2016

- Probabilistic forecast of post-flooding MeHg in Churchill River and Lake Melville
- Integrated into baseline MeHg exposure assessment
- Exposures modeled on an individual basis
  - Population-wide statistics
  - Upper exposure percentiles
- Based on years of site-specific data and peer-reviewed Hg budget
- Confidence bounds

**Environmental**  
Science & Technology

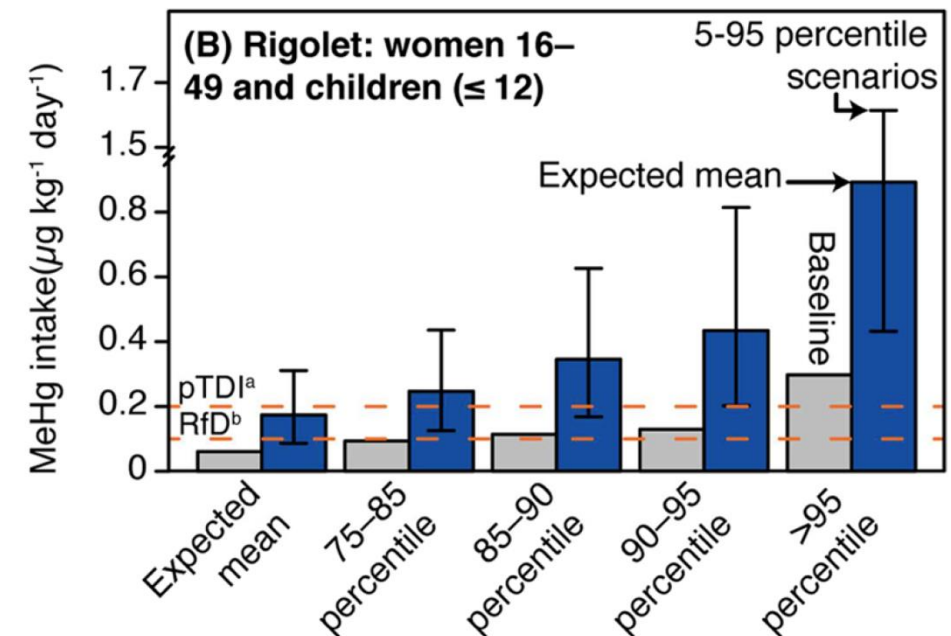
Article  
pubs.acs.org/est

**Future Impacts of Hydroelectric Power Development on Methylmercury Exposures of Canadian Indigenous Communities**

Ryan S. D. Calder,<sup>\*,†,‡</sup> Amina T. Schartup,<sup>†,‡</sup> Miling Li,<sup>†,‡</sup> Amelia P. Valberg,<sup>†</sup> Prentiss H. Balcom,<sup>‡</sup> and Elsie M. Sunderland<sup>†,‡</sup>

<sup>†</sup>Department of Environmental Health, Harvard T. H. Chan School of Public Health, Boston Massachusetts 02215, United States

<sup>‡</sup>Harvard John A. Paulson School of Engineering and Applied Sciences, Cambridge Massachusetts 02138, United States



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# Agenda for Webinar 2 (comments/requests?)

- Technical presentation of integrated environmental and human health modeling (Calder et al. 2016)
  - Mechanistic model for MeHg forecasting
  - MeHg exposure model
  - Exposure forecast
  - Sources of uncertainty and implications





# Other questions? Thank you!

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