Supplemental Materials

Monitoring the Human Health Consequences of Climate Change in the Great Lakes

Appendices and additional references to the report submitted to the International Joint Commission by the Health Professionals Advisory Board

December 2024

Supplemental Materials

Additional Uncited References

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Appendix A. Task 1, Literature Review Technical Memorandum

Memorandum

From: Samir Qadir (PHE)
Carrie Turner (LimnoTech)

To: Jennifer Boehme (IJC)
HPAB Project Advisory Team
Click here to enter text.

Date: June 8, 2023
Project: IJCCLIMATE
CC: John Bratton (LimnoTech)

SUBJECT: **Great Lakes Human Health Indicators and Climate Change – Task 1 Summary Technical Memorandum**

1 Introduction

The International Joint Commission (IJC), through their Health Professionals Advisory Board (HPAB), is trying to identify measurable human health indicators related to climate-driven environmental changes in the Great Lakes basin. These indicators are intended to be quantitative measures of human health impacts due to discrete climate-related events such as storms and long-term trends in water quality and quantity in the Great Lakes. As quantitative measures, they can be monitored over time and used to inform adaptive strategies in the Great Lakes basin or areas within the basin.

The project work plan identified three focus areas of potential human health impacts for review:

- Flooding;
- Precipitation extremes affecting pathogen and pollution runoff; and,
- Temperature and nutrient changes affecting algal and other ecological disruptions, water availability and safety (e.g., drinking water supply).

Additional areas to be considered that were identified in the work plan included:

- Changes in water level and temperature affecting ambient air temperatures and heat waves;
- Changes in blizzard and high winds due to water temperature and air humidity changes; and,
- Impacts on wild rice, fishing and other food sources.

These factors were captured in the review process when included in materials obtained for the primary focus areas.

The project is being executed in a series of tasks, including 1) a literature review, 2) a conceptual model linking climate change and health outcomes, with indicators that could support identification, mitigation, and /or response; 3) an invitational workshop; and 4) preparation of a draft and final report. This technical memorandum describes the outcomes of the literature review task.

2 Literature Review

The literature review included peer-reviewed publications, agency reports, white papers, newspaper articles, publications supporting potential project case studies, web-based toolkits and map-based information. The materials included in the review spanned medical (e.g., human health-focused) literature, such as from the Center for Disease Control (CDC), and environmental resources (e.g., climate-driven indicators), such as National Oceanic and Atmospheric Administration (NOAA). While the focus of this project is on the Great Lakes basin, the literature review also considered data and information outside the Great Lakes if it was deemed useful for developing the conceptual model.

2.1 Methods

The method for conducting the literature review consisted of the following steps:

1. Develop a set of review inclusion criteria to manage the number of resources returned in the literature search. The following criteria were used:
    a. Referenced/recommended/provided by the IJC and/or HPAB;
    b. Vintage, with publications after 2018 preferred, though earlier publications were included if they provided a unique or valuable perspective on a particular aspect of the project objectives or project work group interests;
    c. Great Lakes focused OR states or provinces that are in the Great Lakes basin OR provides information on effects in another part of the country (U.S. or Canada) that apply to the Great Lakes region;
    d. Focus on a) flooding affecting injuries, illnesses, behavioral, social/ mental and economic health; b) precipitation extremes affecting pathogen and pollution run-off; c) anticipated temperature and nutrient changes affecting algal and other ecological disruptions;
    e. Opportunistically retrieve materials that address other project areas of interest: changes in water level and temperature affecting ambient air temperatures and heat waves; changes in blizzard/high winds due to water temperature/air humidity changes; or expected impacts on wild rice/fishing and other food sources; effects on vulnerable (disaggregated from general population); and,
    f. Included a conceptual model relating climate-driven environmental impacts to one or more human health effects.

2. Develop a list of keyword search terms (Table 2). For the keywords in Table 2, OR functions were used to substitute terms within columns while AND functions were used to include terms between rows.[1]

Table 1. Keywords Used in Literature Review

Geographic Terms	Climate Terms[1]	Environmental Impact	Human Health-Related Effect	Population Segments[2]
Great Lakes	Climate change	Flooding	Pathogen	Vulnerable populations
U.S./United States	Climate indicator	Extreme precipitation	Injury	Indigenous
Canada	Climate health	Urban runoff	Waterborne illness	Elderly
Lake xxx[3]		Temperature	Mental health[5]	Immuno-compromised
City yyy[4]		HABs	Property damage	Children
		Harmful algal blooms	Drowning	First Nations
		Urban flooding	Gastrointestinal illness	Minority
			Heat stress	

Notes:

[1] Sometimes the search term did not include the preceding "climate" description.

[2] Used to address specific goals of the project.

[3] Each of the Great Lakes was used as a search term: Huron, Ontario, Michigan, Erie, Superior

[4] Major cities, especially with those that have experienced one or more effects of climate change impacts, were also searched, including: Detroit, Toronto, Hamilton, Milwaukee, Toledo, Cleveland.

[5] "Mental health" was refined into more specific terms, when warranted, including anxiety, depression, stress, trauma

3. Search on-line databases of peer-reviewed publications using the keywords as described in Table 2, including
    a. Google Scholar
    b. Web of Science
    c. PubMed
4. Search grey literature sites with a climate change emphasis or research, including
    a. IJC materials

[1] Not every column was required in an AND search, e.g. "Great Lakes climate change flooding", which only includes the first three columns of keyword categories was a suitable search.

b. Intergovernmental Panel on Climate Change (IPCC) site

c. U.S. National Climate Assessment site

d. U.S. Climate Resilience Toolkit

e. Government agency sites, including:

   i. NOAA
   ii. CDC
   iii. NIH (National Institutes of Health)
   iv. USEPA (United States Environmental Protection Agency)
   v. Health Canada
   vi. Environment Canada
   vii. NIEHS (National Institute of Environmental Health Sciences)
   viii. USDA (United States Department of Agriculture)

f. University-affiliated groups and non-governmental organizations, including:

   i. Center for Climate Change Research
   ii. GLISA (Great Lakes Integrated Sciences and Assessments)
   iii. Graham Institute at University of Michigan
   iv. Wayne State University Healthy Urban Waters
   v. Midwest Regional Climate Center
   vi. Center for Climatic Research at the University of Wisconsin
   vii. Environmental Law and Policy Center
   viii. NCICS (North Carolina Institute for Climate Studies)
   ix. TNC (The Nature Conservancy)
   x. STACC (Status of Tribes and Climate Change) Working Group
   xi. NWF (National Wildlife Federation)
   xii. CNT (Center for Neighborhood Technology), based in Chicago

g. Journalism-type sites for local reporting on potential case studies, including:

   i. New York Times
   ii. Toronto Star
   iii. Toledo Blade
   iv. Chicago Tribune
   v. Detroit Free Press and News
   vi. Bridge Magazine
   vii. Crain's Business

h. Springer Climate – an interdisciplinary book series devoted to climate research.

5. Review articles and summarize in an Excel-based project database (Attachment 1).
6. Review website tools and mapping sites for the conceptual model.

2.2 Results

A summary of the articles is included as Attachment 1. Seventy-eight (78) document reviews are included in the Excel-based project database. Table provides a summary of the results. Additional details are described in the database entries.

Information collected through the literature review was incorporated into the conceptual model. Table provides a summary of the literature review process and outcomes.

Table 2. Summary of Literature Review

Focus Area	Materials Reviewed	Frequently Listed Human Health Effects	Frequently Listed Indicators/Key Drivers
Flooding-related	45	Drowning, respiratory disease, waterborne disease, vector-borne disease, stress and anxiety, skin rashes, asthma, hypothermia	- Lake water level fluctuation - Precipitation pattern changes - Lower income level - Mold in flooded homes
Extreme Precipitation	42	Gastrointestinal (GI) illness, waterborne diseases (virus, bacteria, protozoa pathogens), asthma	- Precipitation pattern changes (frequency, intensity, depth) - Increased CSO/SSO overflows - High E. coli levels - More frequent anomalous weather events - Lower income level
Temperature/HABs	26	Exposure and illness (liver, GI, skin) from HABs	- Excess nutrients - Increase in HAB toxins
Air Temperatures/Heat Waves	31	Cardiopulmonary illness, heat-related stress, mental health, asthma	- Temperature increases, - Poor air quality, - More frequent anomalous weather events, - Higher humidity, - Increasing wildfire frequency, - Higher ground-level ozone levels and particulate matter
Blizzards/Winds	8	Respiratory disease, hypothermia	- More frequent anomalous weather events

Focus Area	Materials Reviewed	Frequently Listed Human Health Effects	Frequently Listed Indicators/Key Drivers
Food Sources	23	Malnutrition, mental health	- Degraded water quality - Expanded range of pests and invasive species due to ecosystem changes, decreased biodiversity

Some materials did not lend themselves to inclusion in the project database because they were web-based toolkits, map-based data summaries or the documentation could not be downloaded. Table 3 provides a list of the web resources considered in the review. As indicated in the last column of the table, the sites considered were assessed for their relevance to this project's objectives. The full list of sites is provided in the interest of completeness.

Table 1. Web-based Resources Identified in Literature Review.

Organization or Program	Description	Website URL	Relevant to this project?
U.S. Global Change Research Program	U.S. Climate Resilience Toolkit (see especially, the Climate Mapping for Resilience and Adaptation section)	https://toolkit.climate.gov/	Yes
U.S. Global Change Research Program	Climate and Health Assessment	https://health2016.globalchange.gov/	Yes
United Nations	The Intergovernmental Panel on Climate Change	https://www.ipcc.ch/	Yes[1]
National Environmental Modeling and Analysis Center (housed as UNC Asheville)	Climate Explorer at the city level	https://crt-climate-explorer.nemac.org/	Yes
Graham Sustainability Institute (University of Michigan)	Great Lakes Climate and Demographic Atlas (Great Lakes Adaptation Assessment for Cities)	https://graham.umich.edu/glaac/great-lakes-atlas	Yes
U.S. Global Change Research Program	Fourth National Climate Assessment	https://nca2018.globalchange.gov/	Yes[1]
Great Lakes Integrated Sciences and Assessments (University of Michigan)	Great Lakes Regional Climate Change Maps	https://glisa.umich.edu/great-lakes-regional-climate-change-maps/	Yes

Organization or Program	Description	Website URL	Relevant to this project?
CDC	National Syndromic Surveillance Program	https://www.cdc.gov/nssp/resources.html	No[2]
NIH	All of Us Research Hub	https://researchallofus.org/data-tools/data-sources/	No[2]
National Academies Science, Engineering, Medicine	Climate Resources to understand and prepare for climate change	https://www.nationalacademies.org/topics/climate	Yes[1]
NOAA	Social indicator mapping	https://www.st.nmfs.noaa.gov/data-and-tools/social-indicators/	No[3]

Notes:
[1] Not a toolkit or map-based site, but due to the wealth of materials available, we worked from the site directly.
[2] Limited to no data or information on climate change-driven impacts
[3] Did not include Great Lakes

Of particular interest in the literature review were resources that included conceptual models linking climate-driven environmental conditions to human health impacts. A number of candidate conceptual models were identified, as summarized in Table 4. As part of Task 2, these conceptual models are being used to inform the development of a Great Lakes basin specific conceptual model.

Table 4. Potential Conceptual Models

Source	Reference	Website URL
Health Canada	Takaro, T., et al. (2022). Water Quality, Quantity, and Security. In P. Berry & R. Schnitter (Eds.), Health of Canadians in a Changing Climate: Advancing our Knowledge for Action. Ottawa, ON: Government of Canada.	https://changingclimate.ca/health-in-a-changing-climate/
CDC		https://www.cdc.gov/climateandhealth/effects/default.htm
CDC	Midwest Fact Sheet	https://www.cdc.gov/climateandhealth/effects/docs/Midwest_Regional-Climate-Fact-Sheet-P.pdf
WHO		https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health
GlobalChange.gov		https://health2016.globalchange.gov/
USEPA		https://www.epa.gov/climate-indicators/understanding-connections-between-climate-change-and-human-health
Prata, et al.	Prata, J.C., 2022. A One Health perspective on water contaminants. *Water Emerging Contaminants & Nanoplastics*, *1*(3), p.15.	https://www.oaepublish.com/wecn/article/view/5165

Source	Reference	Website URL
Environmental Health Perspectives	Reuben, A., Manczak, E.M., Cabrera, L.Y., Alegria, M., Bucher, M.L., Freeman, E.C., Miller, G.W., Solomon, G.M., Perry, M.J. 2022. The Interplay of Environmental Exposures and Mental Health: Setting an Agenda. Commentary. Environmental Health Perspectives. Vol. 130, No. 2. Feb. 2022. https://doi.org/10.1289/EHP9889.	https://ehp.niehs.nih.gov/doi/10.1289/EHP9889
IPCC 2022 Technical Summary	Porter, H.O., et al. 2022. Technical Summary. Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 37–118, doi:10.1017/9781009325844.002	https://www.ipcc.ch/report/ar6/wg2/

2.3 Outcomes

The literature review's main objective was to understand current indicators of human health, preferably in the Great Lakes. Capturing potential human health impacts and corresponding climate change-driven conditions was an important aspect of the literature review as it forms the foundation for identifying and selecting indicators. Relating these factors through a conceptual model is another important tool for informing the selection of indicators. The literature review also included a compilation of conceptual models and diagrams that could be used to inform the conceptual models and/or development of indicators (see Table 4).

The following climate change-driven conditions were listed in multiple sources:

1. Changes in precipitation extremes
2. Increased air temperatures (and higher humidity)
3. Changes in the natural and built environments

Recent Great Lakes-based sources (GLISA, 2021) have documented trends in temperature and rainfall that suggest climate change may already be impacting the basin. Trends in air temperature, water temperature, and precipitation show an increasing trend since 1950 in most of the Great Lakes (Figure 1), as shown by the gray trendline in each chart. Lake Superior, the coldest and deepest Great Lake, shows the clearest increasing trend in these factors.

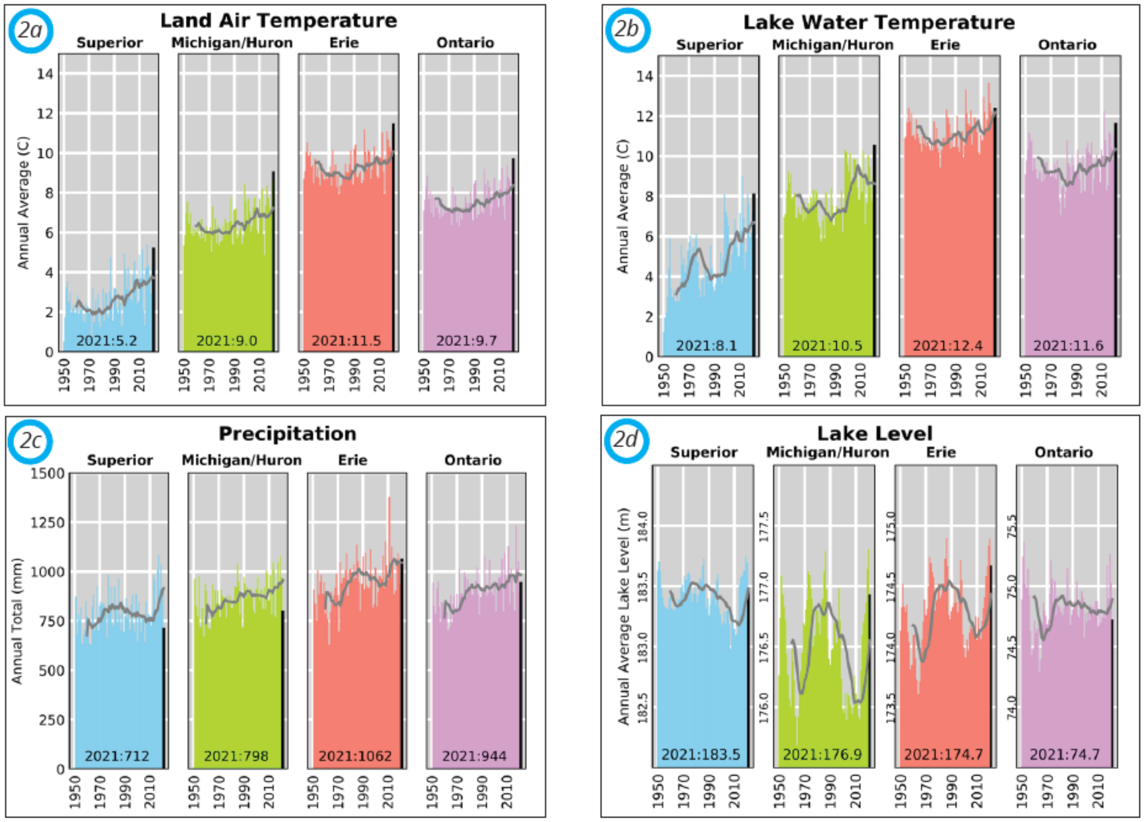

Figure 1. Historical Trends in Precipitation, Temperature and Water Levels in the Great Lakes (source: GLISA, 2021)

The consultant team is retaining these measures for consideration as potential indicators and potentially for use in the conceptual model.

The climate change conditions listed above can lead to numerous health-related impacts, with the most listed including:

1. Flooding
2. Drought
3. Extreme heat
4. Extreme weather events
5. Water quality
6. Air quality
7. Wildfires
8. Declining food security/ water scarcity
9. Vector-borne disease
10. Water-borne disease

While most resources tended to focus on the adverse effects of climate change, the most recent Intergovernmental Panel on Climate Change (IPCC) report (IPCC 2022) notes that some effects of climate change could be positive. For example, while soybean and corn yields are expected to decrease in North America due to climate impacts (primarily related to changes in precipitation patterns with too much rain in the spring and long periods of no rain in the summer), wheat yields are projected to increase.

The general approach to characterizing human health impacts from climate change-driven environmental factors follows typical risk assessment practice, as described here using flood-related impacts as an example:

1. Identify the hazard or climate change effect, such as flooding
2. Identify one or more exposure pathways; for flooding, exposure could be direct physical risk or indirectly through contact with areas or surfaces contaminated by the flood waters
3. Identify the associated impact, specifically human health effects; for flooding, this could include drowning, asthma or other respiratory diseases, mental health effects, such as depression, stress and anxiety.
4. Vulnerability assessment is also an important part of identifying the associated impact and characterizing the risk. Numerous resources (STACCWG, 2021; IPCC, 2022) cited the larger impacts that climate change conditions have on the elderly, indigenous and First Nations, people, low-income populations, people of color, pregnant women, and children.

As described in the STACCWG report, Indigenous peoples are particularly susceptible to climate change because of their cultural and spiritual connection to the natural world. The availability of "first foods," which include traditional foods, medicines, and technologies, is threatened by climate change, and is an important part of the health and wellbeing of indigenous peoples. The ability to maintain tradition and connection to the environment is important to tribes’ sense of identity, autonomy, and wellbeing. Mental health issues are associated with the displacement of communities affected by extreme weather events, or who are unable to support themselves in culturally significant and traditional ways, such as through subsistence fishing, hunting and gathering, etc. Indigenous peoples are more susceptible to other anticipated effects of climate change, such as temperature and precipitation extremes, increased exposure to vector-borne pathogens, and decreased air quality, because they have higher rates of illnesses like asthma, cardiovascular disease, and diabetes, which increase vulnerability, all of which is exacerbated by disparities in healthcare.

The draft Fifth National Climate Assessment (expected publication 2023) assessment notes the health of Midwestern populations is at risk from increased extreme heat, precipitation, drought, and flooding, along with reductions in air quality and increased incidence of vector- and waterborne illnesses (Baker et al, 2023). Physical injury and illness may also influence mental health and can reduce quality of life and community function as traditional forms of connection and culture are lost or diminished.

Developing a comprehensive set of human health impacts from climate change-driven conditions is complicated by the observation (Kreibach and Sairam, 2022) that humans interact with the natural and built environments in unpredictable ways. This also complicates the development of a conceptual model or selection of indicators, as both are unlikely to account for all exposure pathways and health outcomes (direct and indirect). Based on the scope of this project and direction from the HPAB work group, the focus of this review was on human health impacts aligned with the climate change-driven environmental challenges (focus areas) listed in Table 2.

The indicators developed previously by the IJC are still relevant and can be tied to human health impacts. Indicators based on exposure pathways could be an effective way to link climate change-driven environmental conditions and corresponding human health impacts. Alternatively, directly measuring human health conditions could also serve as indicators. Both approaches were suggested in the 2016 U.S. Global Change Research Program (USGCRP) Summary Report (Crimmins et al, 2016).

Based on a New York Times article on the drought-driven low water levels in the Mississippi River in 2022 (Smith, 2022), another approach to developing indicators could be to work up the value chain to find a suitable link between the environment and human health outcomes. The value chain for the drought-driven condition starts with the impact on crop yields, then advances to transporting the crops to market via cost-effective water transportation methods, then exerts its effect via higher prices at the grocery store, which affects everyone, but with a disproportionately greater impact on low-income and other vulnerable populations.

Another possibility for human health is to consider indicators that are oriented towards resilient practices rather than adverse conditions. This approach would acknowledge that we are in the midst of climate change already so shift the focus to adaptability and mitigation, as was done in the IPCC 2022 report.

3 Conclusion

The literature review was successfully executed by providing a suitable range of data and information to develop the conceptual model linking climate-driven environmental conditions to human health impacts and potential indicators. The model development and subsequent tasks for this project will be documented in task-specific technical memoranda and reports.

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Intergovernmental Panel on Climate Change (IPCC) [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. (2022). Technical Summary. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 37–118, doi:10.1017/9781009325844.002

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Appendix B. Task 2 Conceptual Model Technical Memorandum

Memorandum

From:	Samir Qadir (PHE) Carrie Turner (LimnoTech) John Bratton (LimnoTech)	**Date:** **Project:**	June 8, 2023 IJCCLIMATE
To:	Jennifer Boehme (IJC) HPAB Project Workgroup	**CC:**	

SUBJECT: Great Lakes Human Health Indicators and Climate Change – Task 2 Conceptual Model

1 Introduction

The International Joint Commission (IJC), through its Health Professionals Advisory Board (HPAB), is identifying measurable human health indicators related to climate-driven environmental changes in the Great Lakes basin. The vision for these indicators is to be quantitative indicators of human health impacts due to climate-related events and trends on water quality and quantity in the Great Lakes. As quantitative measures, they can be monitored over time and inform adaptive strategies in the Great Lakes basin or areas within the basin.

The project work plan identified three focus areas of potential human health impacts for review:

- Flooding
- Precipitation extremes affecting pathogen and pollution runoff
- Temperature and nutrient changes affecting algal and other ecological disruptions, as well as water availability and safety (e.g., drinking water supply)

These focus areas were the primary conditions considered for this project. Additional areas to be considered that were identified in the work plan included:

- Changes in water level and temperature affecting ambient air temperatures and heat waves
- Changes in blizzard and high winds due to water temperature and air humidity changes
- Impacts on wild rice, fishing, and other food sources.

These factors, while also important, were often included in materials obtained for the primary factors.

The project is being executed in a series of tasks, including 1) a literature review, 2) a conceptual model linking climate change and health outcomes, with indicators that could support identification, mitigation, and /or response; 3) an invitational workshop; 4) preparation of a draft and final report. This technical memorandum describes the conceptual modeling task (#2; describe in Table 1).

Table 1. Task 2 Description from Scope of Work

Task 2: Conceptual model linking climate change and health outcomes.	Prepared a model (with active workgroup participation) to link climate-driven environmental change to specific water-related human health outcomes in the Great Lakes basin and metrics of those outcomes, as follows: 1) Map predicted relationships between weather changes on aquatic environmental conditions and human health consequences to identify a set of indicators to reflect water-related human health risks from climate change 2) Consider how social, economic, cultural, and political factors influence the predicted relationships 3) Use the conceptual model and the literature review to identify indicators and data sources, and how they could be used to study, predict, and potentially mitigate climate-health interactions 4) Illustrate 3-4 climate-health interactions to describe the nature and degree of population health outcomes and how indicator data might guide possible adaptive/resilience interventions

2 Task 2.1 Human Health Risks from Climate Change

The Task 1 literature review included consideration of peer-reviewed publications, agency reports, white papers, newspaper articles, publications supporting potential project case studies, web-based toolkits, and map-based information. The materials included in the review spanned medical and environmental resources. As information was gleaned through the literature review, it was incorporated into conceptual model development. A subsequent review considered conceptual models and associated diagrams developed by a variety of agencies, as compiled in Table 2. Diagrams from these sources are reproduced in Attachment 1.

The primary water-related health risks in these models are associated with extreme precipitation events and coastal storms that produce flooding and water quality impacts such as increased pathogens and toxic algal blooms in drinking water and at swimming beaches. Intermediate physical factors such as infrastructure, geography, or ecology are also mentioned. Mental health impacts due to traumatic or chronic stress are also considered in some model diagrams and tables.

Table 2. Summary of Conceptual Models Reviewed

Organization	Source Document or Website (Hyperlinked)	Description of Conceptual Model*
Health Canada	Takaro, T., et al. (2022). Water Quality, Quantity, and Security	Examples of the direct and indirect ways that climate change can alter water quality/quantity and affect health
US Centers for Disease Control and Prevention	Climate Effects on Health	Shows relationships among source water, drinking water, storm water, and wastewater under changing climate, plus seven potential human health impacts
World Health Organization	Climate Change and Health	Links more extreme weather to water quality impacts (pathogens, algal blooms)
US Global Change Research Program	The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment	Links extreme rainfall and flooding to water-borne diseases and mental health impacts
US Environmental Protection Agency	Understanding the Connections Between Climate Change and Human Health	Connects precipitation extremes and extreme weather events to reduced water quality and increases in infectious agents
US National Institutes of Health	The Interplay of Environmental Exposures and Mental Health: Setting an Agenda	Describes individual and community mental health impacts of disasters and more chronic climate change impacts

*Conceptual model diagrams are included in Attachment 1.

3 Task 2.2. Influence of Social, Economic, Cultural, and Political Factors

Non-climatological and non-biophysical environmental factors can have a major impact on physical and mental health outcomes associated with climate change stressors. These factors can determine the resilience of an individual, family, or community in the face of extreme events or more gradual shifts that strain resources over time. Some components of this interplay between human dimensions and environmental stressors are captured in the concept of environmental justice, although historically this concept has tended to include more aspects of localized toxicological exposure than broader exposure to climatological stressors. That said, there is often significant overlap (e.g., disadvantaged neighborhoods may be adjacent to industrial areas with high emissions **and** subject to higher flooding risks).

USEPA's Environmental Justice Screening and Mapping Tool (Version 2.11), EJScreen, makes multiple U.S. data layers available that can show pollution, socioeconomic indicators, and health disparities, among other factors: https://ejscreen.epa.gov/mapper/ (example display below, Figure 1). Canada's EJ Atlas shows specific sites where environmental justice issues have been identified around the Great Lakes and elsewhere, as shown by clickable icons (Figure 2; Temper et al., 2015).

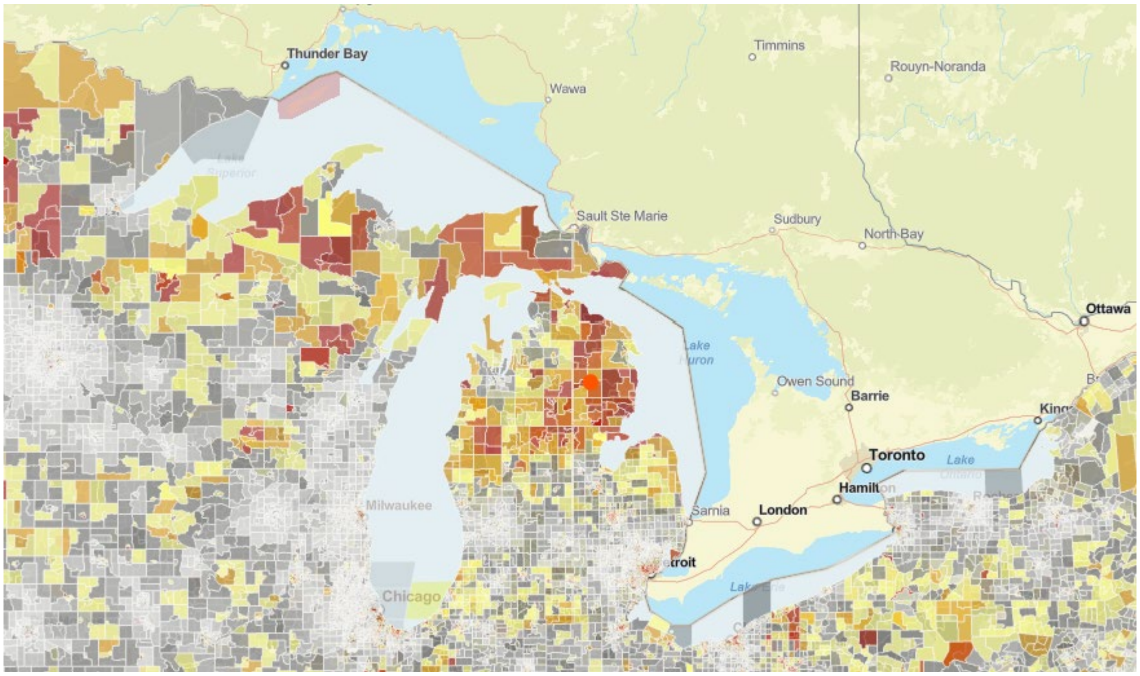


Figure 2. Example display from USEPA's [EJScreen Tool] showing unemployment hotspots in rural and urban areas of the Great Lakes states.

Figure 3. Example display from Canada's EJAtlas, a tool developed by Temper et al. (2015) that documents and catalogues social conflict around environmental issues with interactive icons.

4 Task 2.3 Indicators and Data Sources to Support Study, Prediction, and Mitigation of Climate-Health Interactions

Data on both climate-related stressor status and trends, as well as health-related impacts and mitigation are available in the U.S. and Canada, although direct causal linkages may not be possible to establish in all cases. For example, increased occurrence of algal blooms may be expected as a result of climate change (e.g., Chapra et al., 2017) but other factors could be to blame such as shifts in agricultural practices (e.g., Jarvie et al., 2017) and associated nutrient loads from watersheds to lakes. Likewise, increased reports of gastrointestinal illnesses related to swimming might be reported in certain areas, but a direct climate change linkage may be difficult to tease out. Some examples of data sources and associated indicators are shown in Table 3. Canadian beach surveillance programs and risk in a climate change context were recently reviewed by Young et al., 2022.

Indicators associated with the study, prediction, and mitigation of climate-health interactions would include the following:

- Recreational swimming health
  - Acute gastrointestinal disease reports
  - Beach pathogen counts (e.g., *E. coli*)
  - Beach closure data
  - Nearshore harmful algal bloom occurrence and toxicity
  - Combined sewer overflow frequencies and volumes discharged
- Source water and drinking water quality
  - Monitoring buoy and intake sonde data
  - Drinking water plant monitoring data
  - Drinking water notices (boil water, do not drink)
  - Drinking water plant upgrades
  - Reports of algal blooms near water intakes
- Flooding impacts
  - River flows, lake levels, and news reports
  - Residential, commercial, and infrastructure insurance claim data
  - Disaster declarations and evacuation notices
  - Major investments in flood control, especially in urban areas

Table 3. Example Data Sources and Indicators

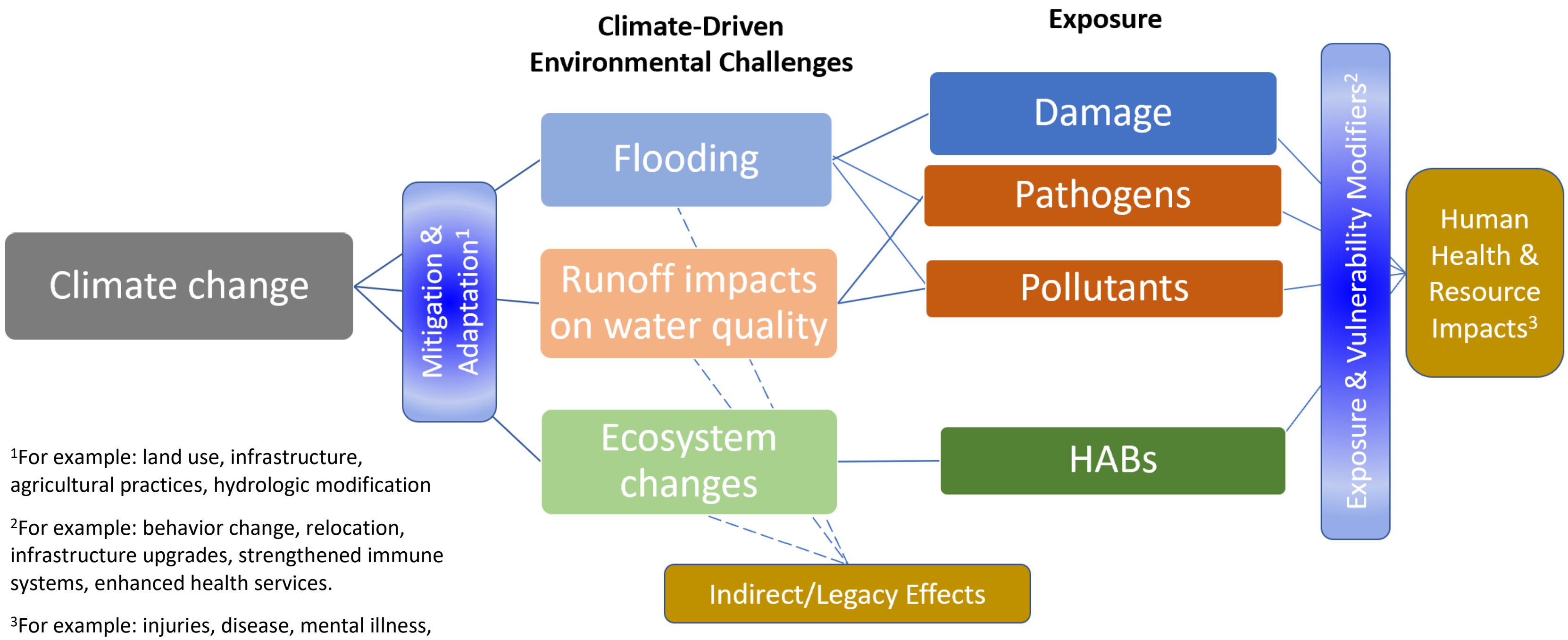
Organization	Source Document or Website (Hyperlinked)	Description of Data and Indicators
Environment and Climate Change Canada	ClimateData.ca	Data portal to support decision makers across a broad spectrum of sectors and locations by providing the most up to date climate data in easy-to-use formats and visualizations
Environment and Climate Change Canada	Overview of freshwater quality monitoring and surveillance	Numerous links to information and data from monitoring and surveillance programs in the Great Lakes and other freshwater systems in Canada
US Centers for Disease Control and Prevention	One Health Harmful Algal Bloom System (OHHABS)	Collects information to help CDC and partners better understand human and animal illnesses linked to harmful algal blooms and help prevent illnesses caused by them
Great Lakes Integrated Sciences + Assessments (GLISA)	Great Lakes Climatologies	Summaries of climatology for select sites (stations), multi-county areas (climate divisions), and each Great Lake, developed in partnership with the Office of the State Climatologist
National Oceanic and Atmospheric Administration	Severe Weather Data Inventory	An integrated database of US severe weather records that provides access to data from a variety of sources
National Oceanic and Atmospheric Administration	Lake Erie Harmful Algal Bloom Resources	Forecasts and historical data on algal bloom occurrence and toxicity in Lake Erie
Swim Drink Fish Canada	The Swim Guide	Provides real-time information on beach safety based on monitoring results
Michigan Dept. of Environment, Great Lakes, and Energy	BeachGuard	Data on current and historical beach closures and *E. coli* counts for the State of Michigan

5 Task 2.4 Illustrations of Climate-Health Interactions and Associated Indicator Data to Guide Interventions

The diagrams on the following pages show conceptual models of climate-health interactions in the Great Lakes region. Associated data to guide interventions include data described above. Additional relevant data would include population density, ages and elevations of housing stocks, demographic and public health data, and specific information on stormwater management and associated infrastructure issues and mitigation timelines and budgets in Great Lakes municipalities. Climate change forecasts with the lowest possible uncertainty (Xue et al., 2022) would also be helpful in predicting future conditions and providing engineering solutions, where appropriate, to mitigate impacts.

Mitigation and adaptation measures in the following diagrams can occur before or after the climate change or the associated environmental challenge. Likewise, exposure and vulnerability modifiers can be applied before or after exposure in some cases, depending on the nature of the exposure, such that exposure can be prevented or reduced, or post-exposure impacts can be minimized or treated. The timing and nature of the mitigation, adaptation, and modification measures applied can have substantial impacts on their effectiveness and costs. Interventions that are too conservative, however, can also result in negative economic impacts that are not proportional to the threat. For example, a beach closure can have severe impacts on nearby businesses, which should be considered when designing and implementing a sampling and analysis program for beach water quality.

Great Lakes climate change and human health conceptual model

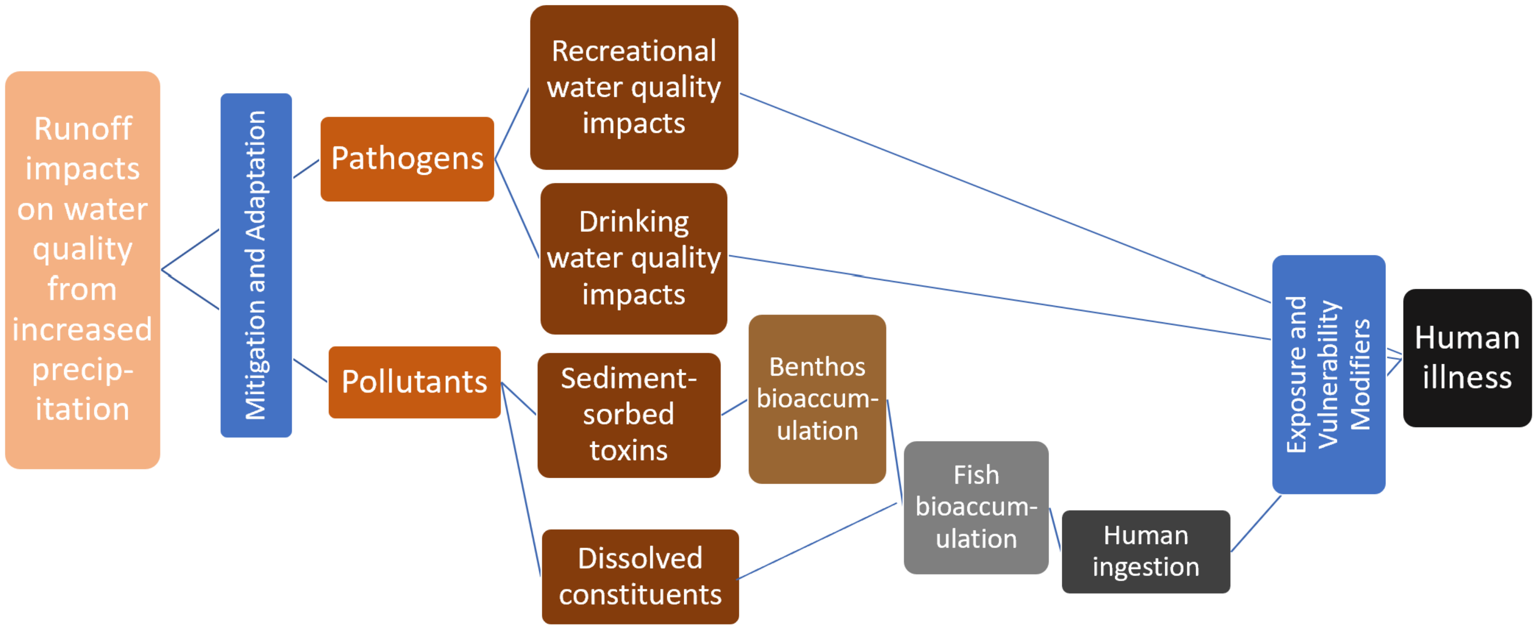


[1]For example: land use, infrastructure, agricultural practices, hydrologic modification

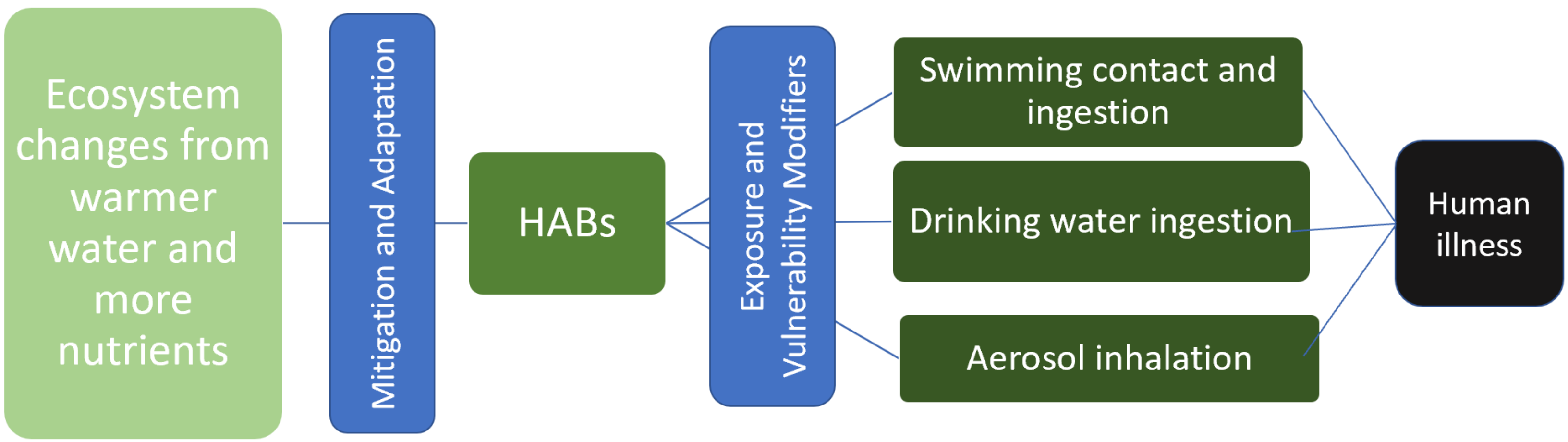
[2]For example: behavior change, relocation, infrastructure upgrades, strengthened immune systems, enhanced health services.

[3]For example: injuries, disease, mental illness, loss of recreation, food contamination.

Runoff impacts on water quality and human health



HABs and human health conceptual model



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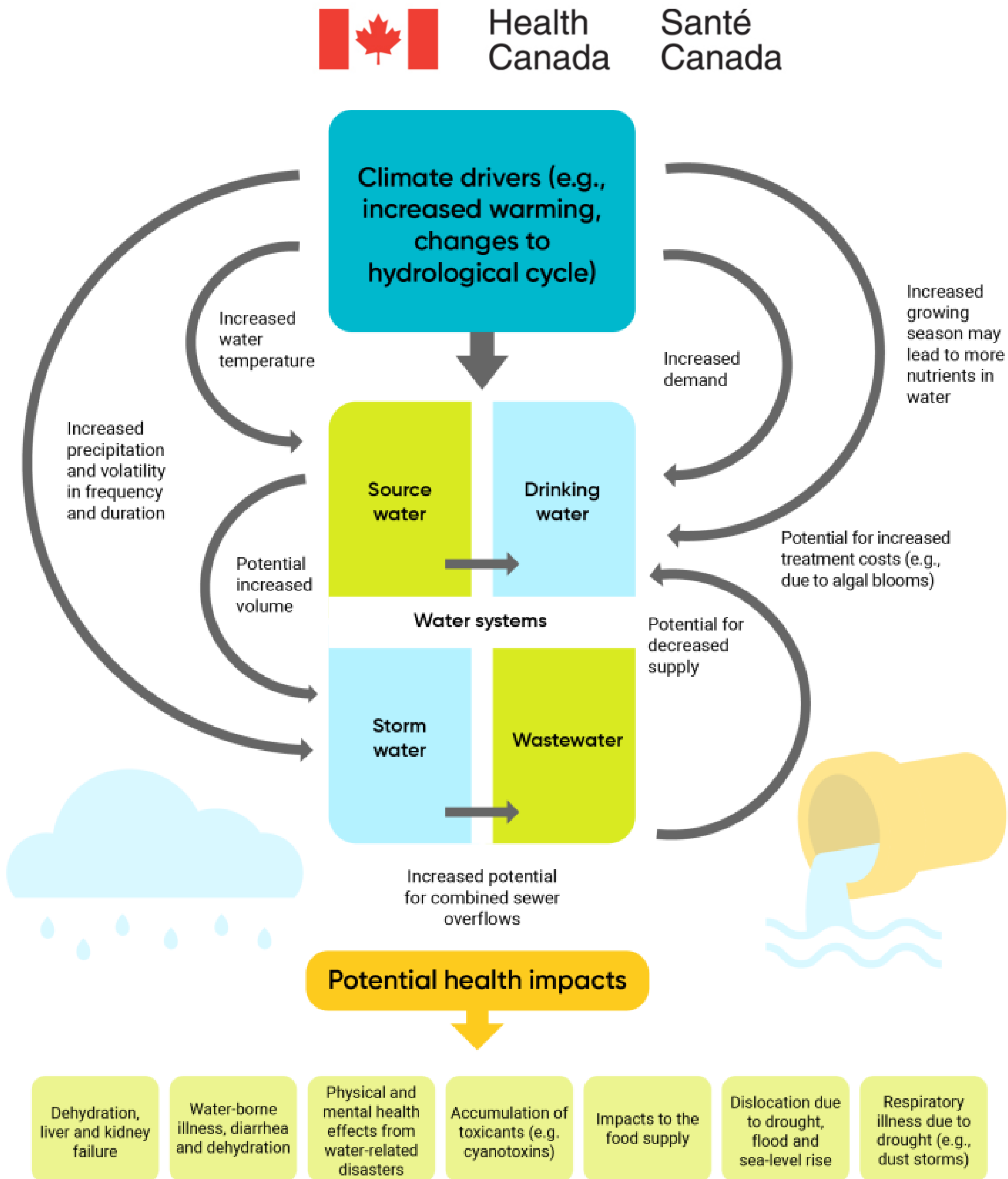
Xue, P., Ye, X., Pal, J.S., Chu, P.Y., Kayastha, M.B. and Huang, C., 2022. Climate projections over the Great Lakes Region: using two-way coupling of a regional climate model with a 3-D lake model. Geoscientific Model Development, 15(11), p.4425.

Young, I., Sanchez, J.J. and Tustin, J., 2022. Recreational water illness in Canada: a changing risk landscape in the context of climate change. Canadian Journal of Public Health, 113(6), pp.940-943.

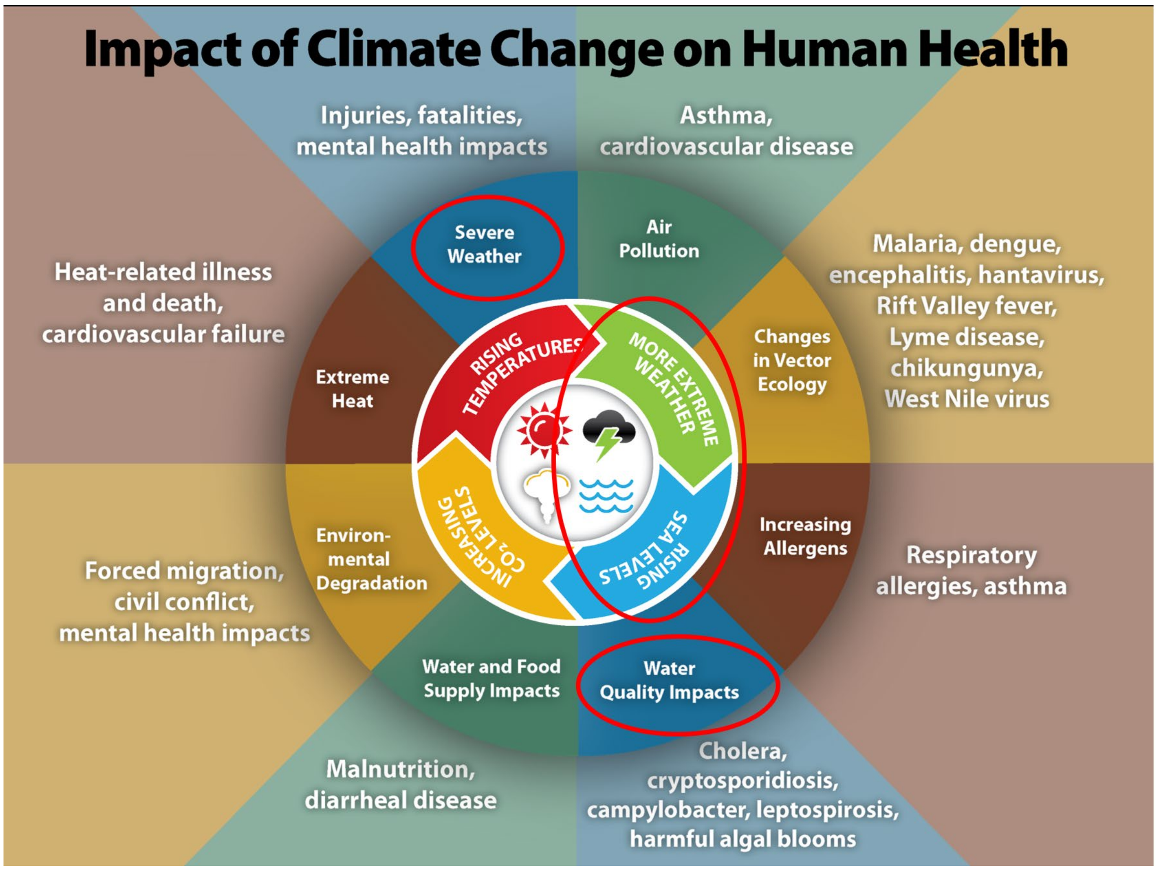
Attachment 1 – Conceptual Model Diagrams Reviewed



Takaro, T., et al. (2022). Water Quality, Quantity, and Security. In P. Berry & R. Schnitter (Eds.), Health of Canadians in a Changing Climate: Advancing our Knowledge for Action. Ottawa, ON: Government of Canada. https://changingclimate.ca/health-in-a-changing-climate/

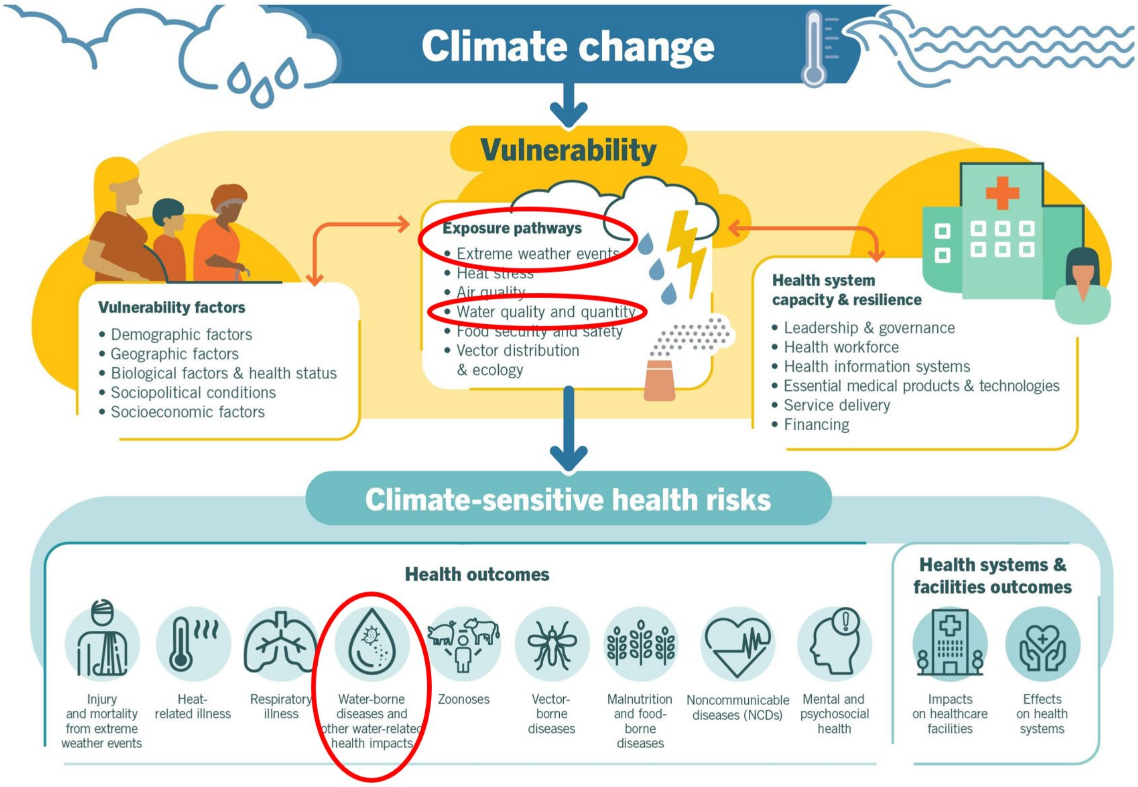
The most project-relevant elements are circled in red

US Centers for Disease Control and Prevention



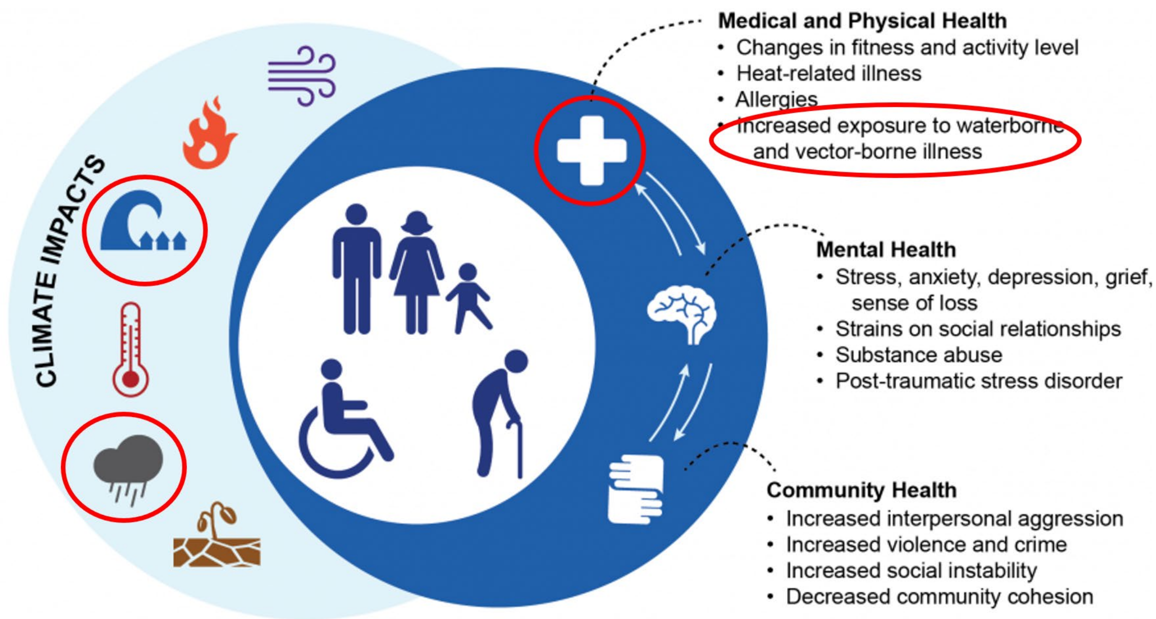
https://www.cdc.gov/climateandhealth/effects/default.htm

World Health Organization



https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health

US Global Change Research Program (diagram plus table on next page)

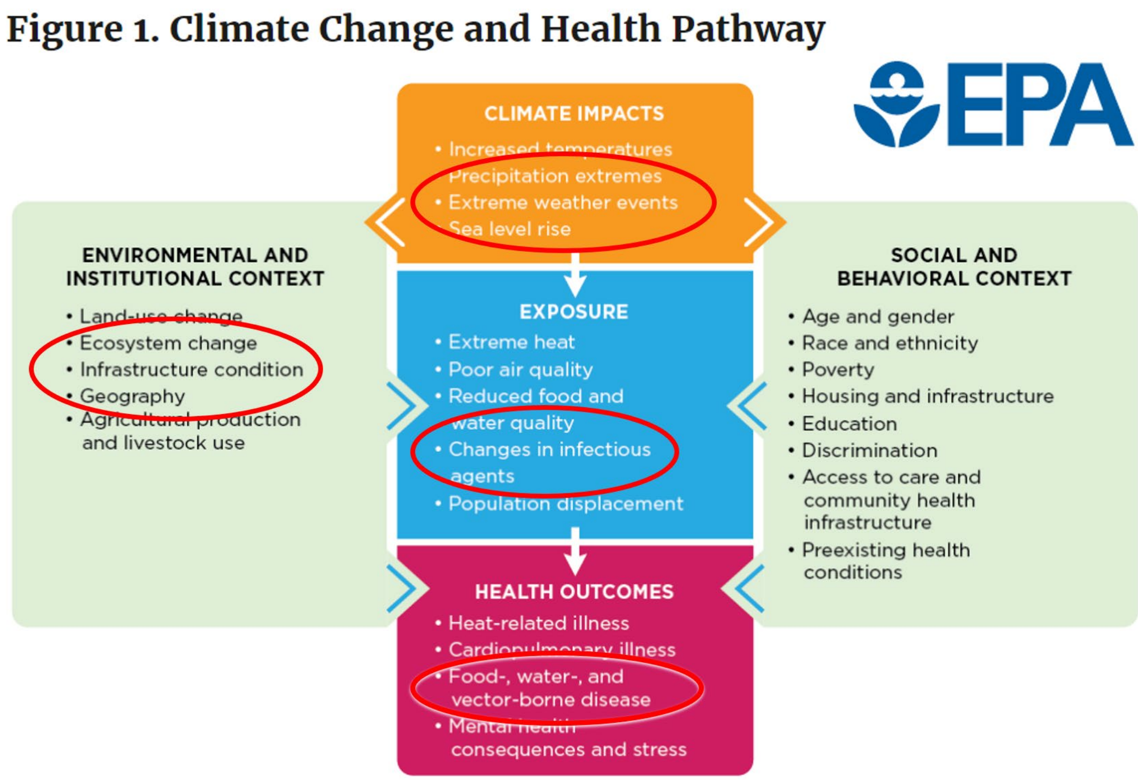


https://health2016.globalchange.gov/

US Global Change Research Program (cont.)

	Climate Driver	Exposure	Health Outcome	Impact
Extreme Heat	More frequent, severe, prolonged heat events	Elevated temperatures	Heat-related death and illness	Rising temperatures will lead to an increase in heat-related deaths and illnesses.
Outdoor Air Quality	Increasing temperatures and changing precipitation patterns	Worsened air quality (ozone, particulate matter, and higher pollen counts)	Premature death, acute and chronic cardiovascular and respiratory illnesses	Rising temperatures and wildfires and decreasing precipitation will lead to increases in ozone and particulate matter, elevating the risks of cardiovascular and respiratory illnesses and death.
Flooding	Rising sea level and more frequent or intense extreme precipitation, hurricanes, and storm surge events	Contaminated water, debris, and disruptions to essential infrastructure	Drowning, injuries, mental health consequences, gastrointestinal and other illness	Increased coastal and inland flooding exposes populations to a range of negative health impacts before, during, and after events.
Vector-Borne Infection (Lyme Disease)	Changes in temperature extremes and seasonal weather patterns	Earlier and geographically expanded tick activity	Lyme disease	Ticks will show earlier seasonal activity and a generally northward range expansion, increasing risk of human exposure to Lyme disease-causing bacteria.
Water-Related Infection (*Vibrio vulnificus*)	Rising sea surface temperature, changes in precipi-tation and runoff affecting coastal salinity	Recreational water or shellfish contaminated with *Vibrio vulnificus*	*Vibrio vulnificus* induced diarrhea & intestinal illness, wound and blood-stream infections, death	Increases in water temperatures will alter timing and location of *Vibrio vulnificus* growth, increas-ing exposure and risk of water-borne illness.
Food-Related Infection (*Salmonella*)	Increases in temperature, humidity, and season length	Increased growth of pathogens, seasonal shifts in incidence of *Salmonella* exposure	*Salmonella* infection, gastrointestinal outbreaks	Rising temperatures increase *Salmonella* prevalence in food; longer seasons and warming winters increase risk of exposure and infection.
Mental Health and Well-Being	Climate change impacts, especially extreme weather	Level of exposure to traumatic events, like disasters	Distress, grief, behavioral health disorders, social impacts, resilience	Changes in exposure to climate- or weather-related disasters cause or exacerbate stress and mental health consequences, with greater risk for certain populations.

USGCRP. [The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment.]() U.S. Global Change Research Program, Washington, DC, 2016.



https://www.epa.gov/climate-indicators/understanding-connections-between-climate-change-and-human-health

US National Institutes of Health

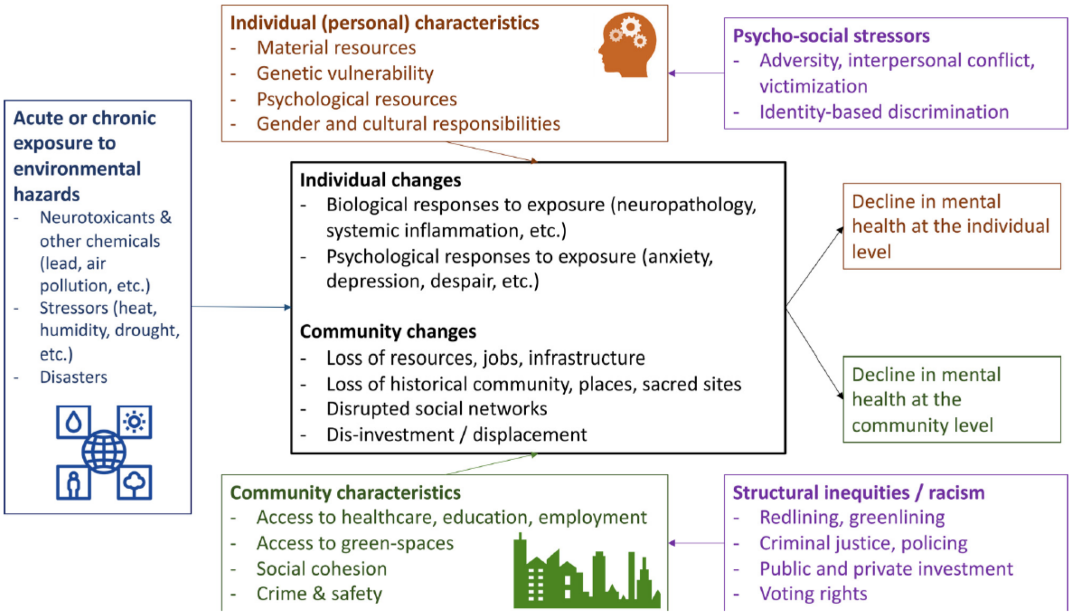


Figure 1. Conceptual model of the association of environmental hazards with mental health outcomes at the individual and community level.

https://ehp.niehs.nih.gov/doi/10.1289/EHP9889

Appendix C. Experts Workshop (Task 3) Detailed Summary

Workshop Summary

The workshop, held virtually on two half days over September 18th and 19th, aimed to identify trackable human health indicators and to provide feedback on the Conceptual Model designed to describe relationship between climate drivers and potential human health outcomes. In addition to workgroup members, IJC staff, and the support contractor team, 16 experts participated in the workshop (see Table C-1).

The project team (consisting of IJC and contractor staff) conducted the workshop using small breakout sessions on each day, with a pre-assigned facilitator/rapporteur responsible for moderating the discussion and taking detailed notes. The technique ensured that all members of each breakout group had the opportunity to speak and present their points of view. Augmenting the breakout groups were plenary remarks and whole-group discussions to review and harmonize breakout group findings and recommendations. The workshop agenda is included in Attachment C-1.

High-level observations and recommendations from workshop general discussions and breakout sessions are included below:

- There is a need to consider audience, like health systems, public health officials, or general public when addressing indicators.
- Time scale is important when considering indicators:
  - There is a difference between long- and short-term impacts that needs to be considered.
  - Acute vs long term events have different effects and need to be considered appropriately.
- Cumulative and Compounding impacts need to be considered because different Modifiers can affect one another.
- There is a need to consider community and health system capacity as it can vary significantly.
- Considering risk to the healthcare system is also important.
- There is a need to include more communication and data-sharing between countries.

Table C-1. Workshop Participants

Name	Affiliation
Jonathan Patz	University of Wisconsin
Dr. Peter Berry	Health Canada
Jerome Marty	International Association for Great Lakes Research
Michael Tjepkema	Statistics Canada
Paddy Enright	Health Canada
Aaron Ferguson	Michigan Department of Health and Human Services
Matthew Quick	Statistics Canada
Alisa Young	National Oceanic and Atmospheric Administration
Dr. Sherilee Harper	University of Alberta
Dr. Mike McKay	University of Windsor
Ana Sirviente	Great Lakes Observing System
Omar Gates	University of Michigan
Dr. Seth Foldy	Denver Health and Hospital Authority (retired), Workgroup co-chair
Barry Jessiman	Health Canada (retired), Workgroup co-chair
Eileen Murphy	New York State Department of Environmental Conservation, Workgroup member
Elaine Faustman	University of Washington, Workgroup member
Raj Bejankiwar	IJC Staff

Name	Affiliation
Kathey-Lee Galvin	IJC Staff
Samir Qadir	Contractor Team (Potomac-Hudson Engineering, Inc.)
John Bratton	Contractor Team (LimnoTech)
Katelyn Kopp	Contractor Team (Potomac-Hudson Engineering, Inc.)

Workshop Presentation and Discussion Summary

Day 1 of the workshop began with welcome and introductory comments by the hosts, organizers, and facilitators. The workshop team, composed of contractors, IJC staff, and the IJC Co-chairs, outlined the objectives and approach and reviewed material sent to the group in advance. The focus of this day was on the Conceptual Model, which was designed to describe relationships between climate drivers and human health outcomes. Three case studies were presented to characterize use of the model and to describe health impacts of climate change in the Great Lakes.

Day 2 of the workshop began with a recap of Day 1 activities and a review of workshop objectives. The opening session was followed by another round of breakout group discussions. The Day 2 breakout discussion focuses on identifying gaps, strategies, and indicators for monitoring and research. Additional supporting material is available in report appendices.

Day 1

Introductory Sessions

IJC Commissioner Henry Lickers welcomed workshop participants and emphasized the need for IJC to considering public health and climate change in the context of water quality, as well as the need to focus on vulnerable community. The Co-chairs (see agenda in Appendix for names) then shared their thoughts on impacts of climate change drivers and health outcomes in the Great Lakes. They also provided an overview of the Great Lakes Water Quality Agreement (GLWQA), the role of the Health Professionals Advisory Board (HPAB), and how the present project fits within that role. Dr. Peter Berry (Health Canada) served as the keynote speaker for the day. He discussed multiple topics, including:

- Climate change risks to the health of Canadians,
  - Changes in precipitation and temperature due to climate change will result in impacts to water quality and quantity and disrupt both natural and human water systems and thereby increase risks to the health of Canadians.
  - Small communities may be more vulnerable to impacts from climate change,
  - Adapting to risks to health related to climate change impacts on water quality and security.
- Application of climate change and health indicators,
- Approaches and resources for developing climate change and health indicators,
  - Health authorities, researchers and partners are increasing efforts to measure, monitor and evaluate climate resilience of health systems.
- Framework for Measuring the Climate Resilience of Health Systems.
  - Upstream determinants of exposure and vulnerability,
  - Climate resilience of health systems functions,

- Outcomes of health system resilience.

Dr. Berry presented criteria for indicator selection:

- Specific, based on an association between climate and health
- Actionable, related to climate and health conditions that are amenable to adaptive actions
- Measurable, based on timely and unbiased data of acceptable quality
- Understandable, applicable and acceptable to stakeholders and potential users
- Representative of the issues and areas of concern
- Consistent and comparable over time and space
- Robust and unaffected by minor changes in method, scale or data
- Scalable, capable of being used at different scales
- Cost-effective, capable of being constructed and used at an acceptable cost benefit ratio
- Sustainable, able to provide data for the next 20-30 years

Following the Co-chairs' and keynote presentations, the contractor team provided a detailed summary of the Conceptual Model development as well as three case studies and how they applied to the Model. This included the results of the literature review, database summary, and stakeholder/rights holder interviews. Key points of the contractor team presentation on Day 1 included:

- A brief background of the literature review
  - The goal was to identify quantitative indicators of human health impacts due to climate related events and trends on water quality and quantity in the Great Lakes
  - The review included flooding and precipitation.
- The overarching themes of the review:
  - There is a substantial amount of information available on climate change and variability in the Great Lakes, but forecasting is challenging;
  - Extreme events have clear impacts on human health, but the climate change signal is difficult to extract, and indicators are not well developed;
  - General investments in community resilience in the Great Lakes basin will likely bear fruit in terms of improved human health;
  - Government agencies, academic institutions, and larger cities or regional groups are producing many helpful resources for use in climate resiliency planning, but implementation funding is a critical limitation.
- An overview of the Conceptual Model, working up to the most complex version.
- A presentation of three case studies applied to the Model.
  - Detroit Urban Flooding 2021,
  - Pathogen and Pollutant Runoff in Hamilton, OH,
  - and Harmful Algal Blooms Toxins in Toledo, OH

Day 1 Breakout Session

Following the introductions, workshop participants were divided into two breakouts rooms. Each group was asked to consider if the Conceptual Model accurately describes relationship between climate change and human health outcomes. They were also asked to evaluate whether the case studies adequately demonstrate the connection between climate change and human health. Groups were given an hour to discuss both questions.

Conceptual Model

It was brought to attention that there needs to be more consideration for effects to Indigenous communities and resources. Two examples of moose migration patterns or wild rice being affected by climate drivers or environmental change. The greater discussion of audience was brought up as well. The question was asked whether the selected drivers are appropriate to focus on.

Some examples of effect modifiers were brought up, including:

- Storm runoff swales,
- Combined Sewer Outflow (CSO) elimination, and
- Ozonation treatment of potable water.

A need for consideration of healthcare and community infrastructure was emphasized. There is a wide range of community ability to respond and use the material provided effectively. Both need to be considered because health risks are about individuals, the community, and the healthcare agencies.

Participants highlighted the need for climate drivers to be considered jointly, whether that be cumulative or as compounding. Group 1 highlighted that heat and temperature also need to be considered in drivers as those conditions can drive compounding health risks during water-related events. There was a discussion of weighting boxes and arrows to emphasize.

Case Studies

Neither group spent considerable time on the case studies but some similar themes to the Model discussion arose. The Detroit Flooding and Toledo Harmful Algal Blooms case studies were both noted to need more human risk relationships to chronic disease complications. A suggestion was made by a participant in Group 1 to weight arrows from climate drivers to visualize cumulative impacts. The Hamilton Pathogen and Pollutant case study was mentioned to be well-represented by the model.

Day 2

Introduction

Day 2 began with a review of workshop activities and outcomes on Day 1, followed by a refresher of the tools and techniques to be used. Key objectives for Day 2 included:

- Propose indicators and describe gaps in readiness of current surveillance and observing systems.
- Recommend strategies for collecting, storing, and provisioning indicator data and metadata for research, policy, and public use.
- Identify policy and science gaps that challenge establishing monitoring or responding to anticipated impacts.

- Propose a strategy and recommendations for establishing climate-environment-human health indicators surveillance and monitoring across the Great Lakes.

Key themes from Day 1 included:

- Need to consider target audience/users for indicators:
    - Health systems
    - Public health officials
    - General Public
- Effects of multiple, compounding events/stressors
- Community and health system capacity varies significantly:
    - Major factor in determining health outcomes.
- In addition to health risks to individuals, also consider risks to the healthcare system.

Current indicators and indicator reports were reviewed, such as the State of the Great Lakes Report. Dr. Seth Foldy emphasized that the project was not just recommending a set of indicators but a solid framework for collecting and storing data. Parties have been slow to adopt health/climate change indicators. From the review of current indicators report it was concluded that that both climate change and health threat indicators are currently available for the Great Lakes, but there are no linkage indicators. Health outcome indicators that link climate change and health, or intervention and mitigation status, have not yet been established. The Proposed Indicator Framework was also reviewed.

Day 2 Breakout Session

Like Day 1, after the introductory session, workshop participants were divided into two breakout groups and were asked to identify indicators, assess their applicability, and identify data gaps. Each group was given approximately 1 hour to identify indicators and strategies for collecting and storing indicator data. Groups were then given approximately 30 minutes to identify policy and science gaps as well as strategies for implementing indicator surveillance programs.

The topics explored by the groups on Day 2 were flooding, HAB toxins, heat waves, CSO elimination or reduction, increasing lake temperatures, and urban heat islands. Priorities and key themes identified for each group topic are listed below, along with high impact research topics. Screenshots of the Day 2 Mural workspaces can be found in the Appendices.

Flooding

Group 2 discussed flooding in two domain contexts, water level and as a human risk exposure. Group 1 characterized it within the adaptation and mitigation domain. Modifiers were determined to be things like changes in source water quality, increase in monitoring frequency, drinking water treatment adjustments, wastewater capacity, inflows, and precipitation. Multiple data sources were brough up, most commonly the National Oceanic and Atmospheric Administration (NOAA), Environment and Climate Change Canada (ECCC) and the U.S. Geological Survey (USGS). Flood state and gage measurements as well as remote sensing was identified as the data standard. The frequency was suggested to be event-specific, with inclusion of post-event data collection.

Heat Waves

Key heat wave modifiers were determined to be physical and mental health effects and productivity and financial status. Data sources were generally identified as state, province, municipalities and NGOs.

HAB Toxins

Key HAB toxin modifiers were identified as viruses that attached to HAB cells, drinking water plant upgrades, beach user warnings, dashboards, bulletins, and nutrient loading reductions.

CSO Elimination or Reduction

Group 1 categorized CSO elimination as an Adaptation Effect Modifier and stated that it affects drinking water sources and beach water quality. The participants specified microbial and chemical contamination. They cited state and provincial oversight of wastewater systems as a data source. Annual monitoring was put forth as a frequency. Decreasing CSO without increasing storage or treatment capacity might worsen urban flooding and non-point source runoff was mentioned. It raises the question of how to reflect the opposite consequence.

Lake Temperature

Key lake temperature modifiers included nutrient loading, fish heat tolerance, impacts to fish distribution, commercial fishing disruption with impacts to local fishing communities and food security, increased evaporation and corresponding precipitation and river flow. Participants identified data sources as linkage of meteorological data, river temperature seasons info, historical and predicted temperatures on an hourly and daily basis, seasonal and long term temperature, and sensors deployed on buoys reporting to GLOS or other platforms (agency, academic labs, NGOs).

Collecting, Storing, Provisioning Indicator Data

IJC could take the role of a facilitator, but it is not possible for the organization to be an aggregator or reporter. It was mentioned that ECCC has an indicator team, and a similar structure could be helpful for this project. Keeping in mind the basin-wide scale, a central location of indicator storage was determined to be appropriate. Within that vein, a common data repository or harmonized data sets from different geography levels was suggested. Health Canada and the U.S. Centers for Disease Control and Prevention were put forth as agencies to take the lead.

Policy and Science Gaps

Participants identified that data sharing between and within countries was lacking. There is not as much communication as there could be. The discussion of time was also brought up, specifically the difference between short-term and long-term applicability. Group 1 discussed the issue of sustaining monitoring and maintaining the appropriate frequency. There was also emphasis that there was a gap in standardization in event reporting and data collection and analysis across the basin. It was also mentioned that there is a gap in consistency in approaches between provincial/territorial governments in Canada.

Implementing Indicator Surveillance & Monitoring Programs

Participants discussed multiple strategies for monitoring but suggested that reviewing existing indicator programs and reusing is an option. They suggested developing a small set as a prototype that includes related items from each domain. Two examples provided are temperature and water temperature or microbial exposure and microbial disease. Participants also suggested utilizing aggregated health reporting systems.

Overarching Workshop Themes

The following themes emerged as overarching concerns expressed by participants. They were mentioned multiple times during the workshop in various contexts.

- There is a need to consider audience, like health systems, public health officials, or general public when addressing indicators.
- Time scale is important when considering indicators:
    - There is a difference between long- and short-term impacts that needs to be considered.
    - Acute vs long term events have different effects and need to be considered appropriately.
- Cumulative and Compounding impacts need to be considered because different Modifiers can affect one another.
- There is a need to consider community and health system capacity as it can vary significantly.
- Considering risk to the healthcare system is also important.
- There is a need to include more communication and data-sharing between countries.
- Impacts on sub-populations of concern, including indigenous communities and vulnerable groups, should be differentiated from impacts to the general population where possible.

Attachment C-1. Workshop Agenda

International Joint Commission (IJC)
Great Lakes Climate Change and Public Health Workshop
Sep 18 (1pm – 4:30pm) and Sep 19 (9am – 12:30pm), 2023
DRAFT Workshop Agenda

Virtual meeting link:
https://us06web.zoom.us/j/83256059860?pwd=cDJ1Q3llQThxazdtbm85VlhCb0ZaUT09

IJC Contact: Raj Bejankiwar, Rajesh.Bejankiwar@ijc.org

Workgroup Co-Chairs: Dr. Seth Foldy, sethfoldy@icloud.com
Dr. Barry Jessiman, barry.jessiman@outlook.com

Support Contractors: Samir Qadir, Potomac-Hudson Engineering, Inc., samir.qadir@phe.com
John Bratton, LimnoTech, jbratton@limno.com
Carrie Turner, LimnoTech, cturner@limno.com

Objectives:
Day 1
1. Review and provide feedback on the Conceptual Model describing relationships between climate drivers and potential human health outcomes.
2. Review and provide feedback on case studies describing health impacts of climate change in the Great Lakes.

Day 2
1. Propose indicators and describe gaps in readiness of current surveillance and observing systems.
2. Recommend strategies for collecting, storing, and provisioning indicator data and metadata for research, policy, and public use.
3. Identify policy and science gaps that challenge establishing monitoring or responding to anticipated impacts.
4. Propose a strategy and recommendations for establishing climate-environment-human health indicators surveillance and monitoring across the Great Lakes.

Day 1, Sep 18, 1pm – 4:30pm

Time	Topic	Speaker
1:00 – 1:15 pm	Welcome and Introductions	Co-chairs and IJC Staff (RB)
1:15 – 1:30 pm	Project Background and Goals	Co-chairs
1:30 – 2:00 pm	Keynote Speaker	Dr. Peter Berry (Health Canada)
2:00 – 3:00 pm	Review of conceptual model and case studies followed by Q&A	Contractor staff
3:00 – 3:15 pm	Break	
3:15 – 4:00 pm	Review case studies - Breakout group activity - Each group to review the model and one or two of the presented case studies	Contractor staff facilitate, IJC staff to take notes
4:00 – 4:30 pm	Breakout groups report out; day 1 wrap up	HPAB leads w/ IJC staff

Day 2, Sep 19, 9am – 12:30pm

Time	Topic	Speaker
9:00 – 9:15 am	Recap of Day 1 and Day 2 Objectives	Contractor Staff
9:15 – 9:30	Review of 2014 IJC report and indicators	IJC Staff/HPAB members
9:30 – 9:45	Indicator framework overview	HPAB Co-chairs
9:45 – 10:45 am	Breakout groups: - Propose indicators - Strategies for collecting, storing, provisioning indicator data Each breakout group to take one topic (flooding; pollutant/nutrient run-off; temperature changes affecting algal blooms and other disruption) and explore possible indicators	Contractor (facilitation); IJC staff (notetaking)
10:45 – 11:00 am	Break	
11:00 – 11:30 pm	Breakout groups (continued): - Identify policy and science gaps - Strategies for implementing indicator surveillance programs	Contractor (facilitation); IJC staff (notetaking)
11:30 – 12:00 pm	Breakout groups report out	HPAB leads w/ IJC staff
12:00 – 12:20 pm	Large group discussion	Contractor facilitation
12:20 – 12:30 pm	Workshop wrap-up - Next steps - Schedule - Workshop survey	Co-chairs

Appendix D. Additional Topics Considered

While developing the conceptual model and discussing potential indicators, several additional topics were considered by the Workgroup and the contractor team but were not ultimately included in the conceptual model or the proposed indicator list for a variety of reasons. Brief summaries of some of the topics are included here for the sake of completeness.

Forest Fires

During the summer of 2023, the Great Lakes region and other areas experienced air quality impacts of extensive forest fires that occurred outside the Basin in Quebec and elsewhere that have been linked to climate change (Barnes et al., 2023; Marlier et al., 2023). Previous large fires in the Basin have included the Parry Sound 33 wildfire in 2018 in the Georgian Bay watershed (Markle et al., 2020). Although the local and regional human and ecological health effects of forest fires that may be increasing in frequency and intensity due to climate change were recognized, the topic was considered to be insufficiently studied to develop associated indicators at this time and potentially outside the scope of the current study.

Groundwater Quality

Groundwater is an important source of drinking water for millions of Great Lakes basin residents and the potential of climate change to alter groundwater in the Basin has been recognized. Costa et al. (2021) concluded that studies of climate change impacts on groundwater quality are scarce in the region but that outcomes may be mixed, with expected greater recharge and other factors decreasing concentrations of some contaminants (e.g., agricultural nitrate, geologically sourced arsenic, chloride from road salt). The GLWQA Annex 8 Subcommittee report (Granneman and Van Stempvoort, eds., 2016) similarly concluded that there is high uncertainty about climate change impacts on groundwater quality in the basin. The 2022 State of the Great Lakes report (ECCC and EPA, 2022) includes a groundwater quality indicator based on nitrate and chloride data, but a trend in this indicator has not been determined due to limited consistent monitoring. Areas with karst or fractured rock aquifers that have close linkages between land use practices and well water quality (Erb et al., 2015) may be especially vulnerable to climate change impacts on groundwater recharge and contaminant mobility. Regional changes in water table elevations that are monitored in Canada and the U.S. may be important indicators of the driver state of climate change influences on groundwater quality and enhanced discharge of groundwater to surface water or increased impacts on infrastructure (e.g., basements, septic systems, storm sewers). At this time, however, specific datasets or direct metrics that would link climate change to human health via the groundwater pathway are not available.

Heat Waves

Urbanization is known to increase temperatures in cities due to the heat island effect, but this is partially mitigated in shoreline cities (e.g., Chicago or Toronto) due to cooling from the adjacent water body (Allen et al., 2015; Chakraborty et al., 2023). Climate change has been shown to be increasing Great Lakes water temperatures at the surface and at depth (Anderson et al, 2021; Xue et al., 2022). Increases in prolonged periods of anomalously warm surface waters in the Great Lakes, known as lake heatwaves, have also been demonstrated (Woolway et al., 2021), but their impacts are understood to primarily affect lake ecosystems, with only secondary effects on human health (e.g., intensifying harmful algal blooms or increasing pathogen viability). Projected summer warming of average lake surface temperatures of 2 to 5 °C (Chakraborty et al., 2023) could reduce the summer cooling effect of lakes on shoreline cities, but the land-to-water temperature gradient would persist if cities were also warmer. While the likely increase in human health impacts of urban heat waves in the Great Lakes is recognized, any reduced impact of the mitigating effect of adjacent lakes is not expected to be large at this time so this topic was not considered further. Note that warming influences on lake ice extent and associated lake effect snow (Notaro et al., 2015; Ellis et al., 2020) are separate topics that are considered in more detail in the report.

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