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GEOLOGICAL SURVEY OF CANADA
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Canada1Water spring 2023 progress meeting summary report

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A. Kirkwood

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Canada

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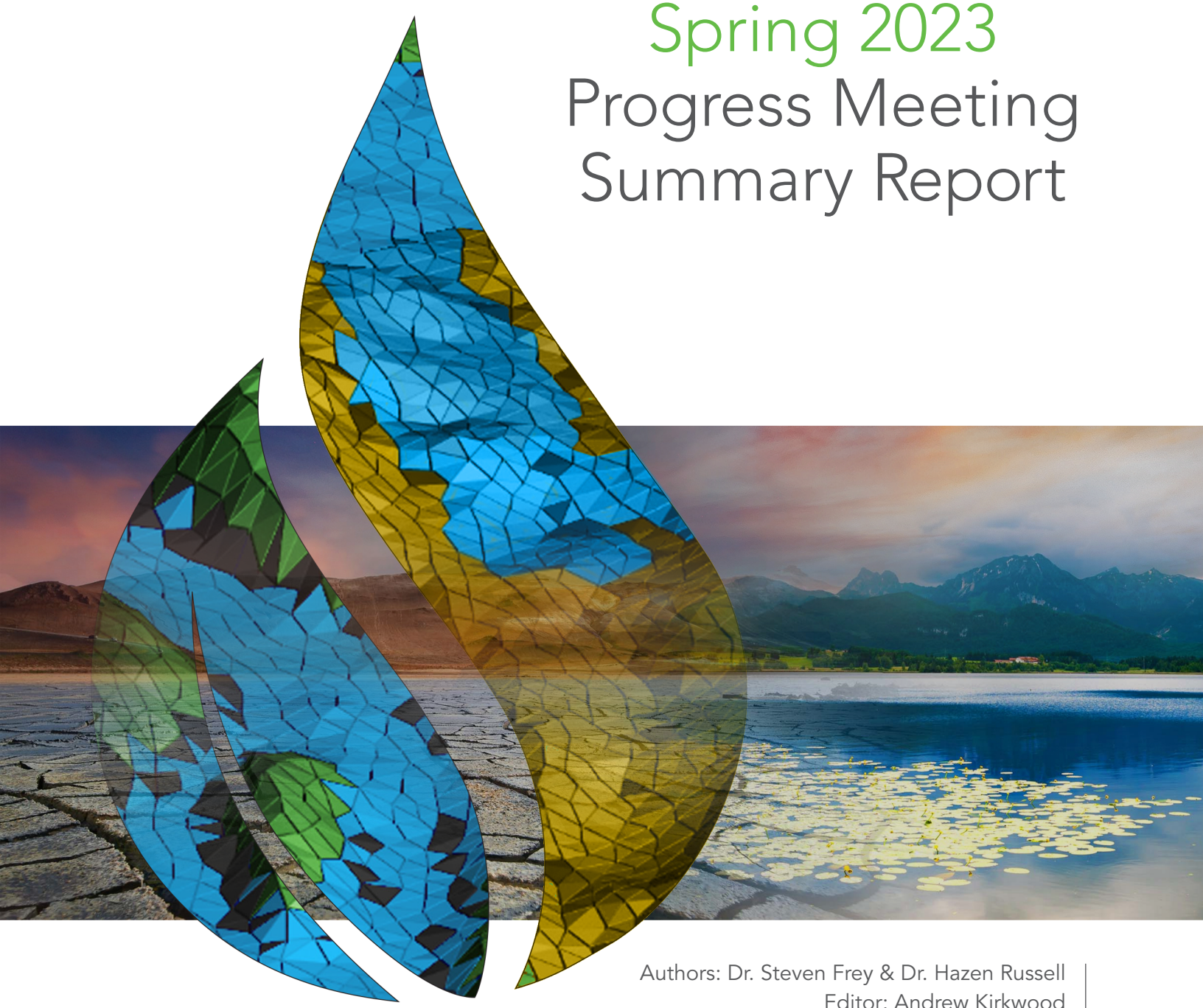
CANADA1WATER

Spring 2023 Progress Meeting Summary Report



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Editor: Andrew Kirkwood

aquanty · University of Toronto · University of Waterloo · Canada

Canada1Water

Project co-leads

- Geological Survey of Canada – Natural Resources Canada
- Aquanty Inc.

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- Canadian Safety and Security Program – Defence Research Development Canada
- Natural Resources Canada
  - Geological Survey of Canada Groundwater Geoscience Program and GEM-GeoNorth Program
- Agriculture and Agri-Food Canada
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- Aquanty Inc.
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  - University of Toronto
  - University of Waterloo

Collaborators

- Natural Resources Canada
  - Canadian Centre Mapping and Earth Observation
  - Canadian Forestry Service
  - Survey General Branch
- Environment Canada Climate Change

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Read the previous Canada1Water progress report:

Kirkwood, A. (ed.), 2023. *Canada1Water 2022 progress report*; Geological Survey of Canada, Open File 8961, 14 p.
https://doi.org/10.4095/331515

The background illustration on the next page shows an irregular finite element mesh used by HydroGeoSphere modelling software for modelling groundwater–surface water flow.

Canada1Water is a three-year research and development project to build the first-ever physics-based model of the complete water cycle for continental Canada, Baffin Island and transboundary watersheds with the U.S.

The final modelling framework will give community decisionmakers, infrastructure planners, researchers, the public and other interested users a long-term view of how Canada's water resources will change throughout the 21st century.

This report provides an update on the status of the project as of June 2023.

Dr. Hazen Russell, Geological Survey of Canada
co-lead

Dr. Steven Frey, Aquanty
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The image on the next page shows a low-flow stream setting sustained by groundwater discharge. The gravel bank indicates the depth achieved by spring freshet flows with melting snow. Image from James Wheeler, 2012, www.pexels.com

Contents

Introduction and progress summary

Canada1Water (C1W) co-lead **Hazen Russell** of the Geological Survey of Canada welcomed participants to the fourth C1W progress meeting, gave an overview of the project's structure and team, and reiterated its overarching goal: to model the water cycle for continental Canada and Baffin Island including the atmosphere, land surface and subsurface. Co-lead **Steven Frey** of Aquanty summarized the latest progress. Top takeaways:

- C1W is advancing as planned overall.
- Spin-up of C1W's integrated, continental-scale hydrologic model is underway using Aquanty's HydroGeoSphere (HGS) platform. Initial outputs are expected by the end of 2023.
- The project is advancing the production of two versions of the C1W model — one coarse and the other at high resolution — to support the widest range of applications.

Figure 1 shows the overall project stages and status.

Figure 1. Canada1Water project stages. The green background arrow indicates progress to date.

Climate and land surface modelling

Andre Erler of Aquanty highlighted two key areas of modelling activity in winter 2023: setting up the data infrastructure to generate climate projections, and bias-correcting permafrost estimates. Both involved intensive data engineering. The climate projections are essential for the integrated model to represent climate change impacts in the HGS modelling package. Erler said the C1W projections already show "significant improvements" over existing CMIP6 global climate projections.

The permafrost bias correction work helps address the longstanding problem of poor observational data in North America (most observations come from Russia). It also addresses the fact that permafrost estimates from models tend to be too cold, overestimating the extent of permafrost and soil freezing.

Erler said lake modelling was also an important focus over the winter, with the team presenting insights into lake effects at several conferences.

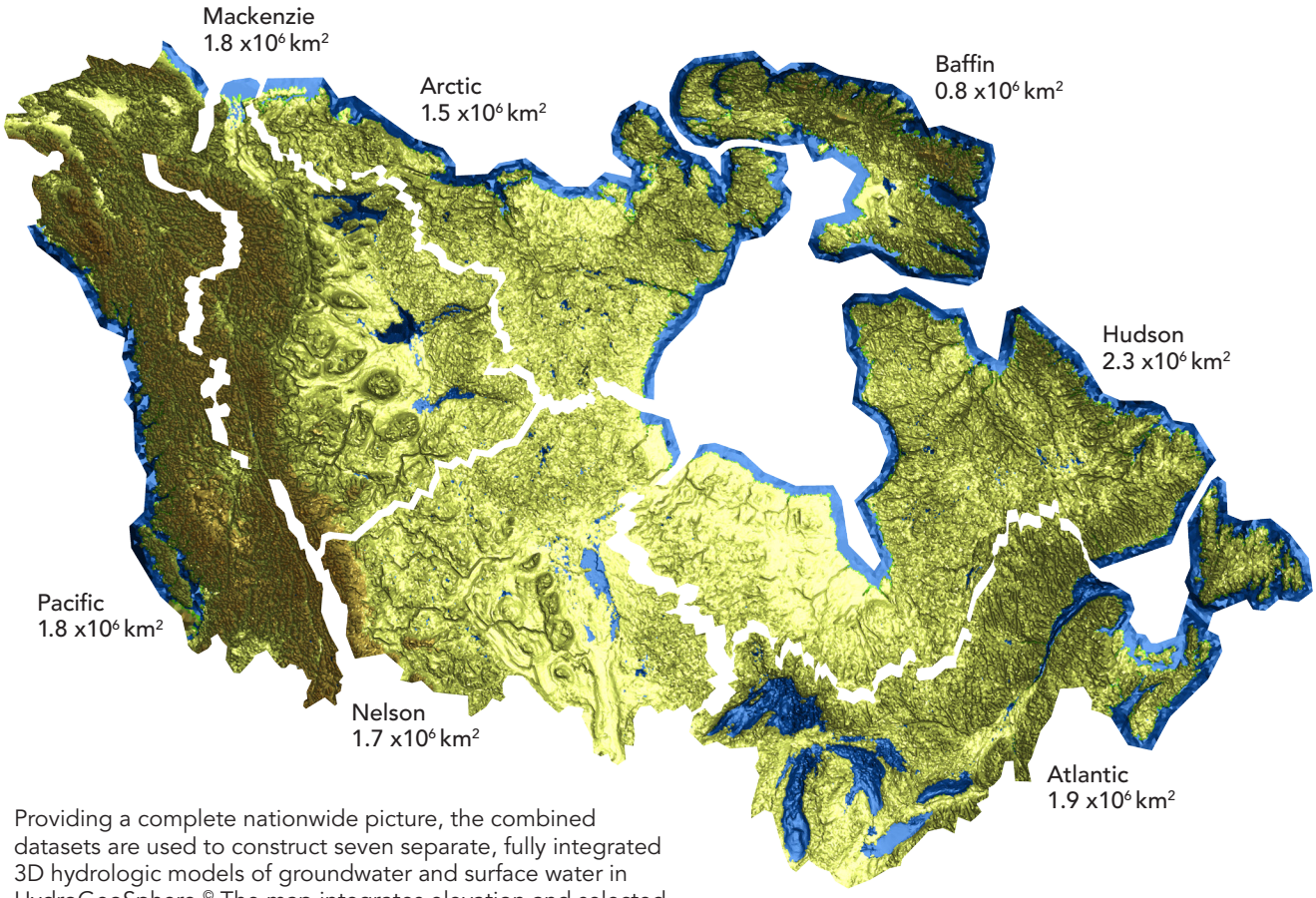
The post-doctoral specialist recruited to work on Community Land Model 5.0 for land-surface modelling was granted a visa after some delays and will begin work in July/August. Going forward, the team will work closely with the Canadian Forest Service on projected changes in the climate moisture index to support wildfire analysis. Several climate, lake and land-surface modelling papers are underway.

Canada1Water datasets

Aquanty's **Eric Kessel** reported that Canada1Water data assembly is complete, including the accompanying metadata and data specification documents. These datasets cover hydrological features, surface elevations and geological materials — enabling full parameterization of the integrated model in HGS.

Many different existing datasets were combined and enhanced to realize a single, continental-scale, transboundary framework for HGS (Figure 2). The team normalized drainage across domains; assigned Strahler Orders 4 and 5 to stream selection for coarse- and fine-resolution models; and combined maps of mineral soils, organic soils and peatlands for different depths and surficial and bedrock geology, which were then paramaterized into hydrostratigraphic layers.

The necessary time-series stream gauging and groundwater monitoring data have been processed from various sources including provincial agencies, Environment and Climate Change Canada, and the United States Geological Survey.



Providing a complete nationwide picture, the combined datasets are used to construct seven separate, fully integrated 3D hydrologic models of groundwater and surface water in HydroGeoSphere.© The map integrates elevation and selected drainage to provide a sense of physiographic and drainage control on the surface water domain. The coarse-resolution models have fewer than 250,000 total nodes and a cell edge length of 1 to 5 kilometres. These have been spun up and are currently being calibrated.

Figure 2. The Canada1Water model spanning seven watershed domains.

HydroGeoSphere model development and calibration

Aquanty's **Omar Khader** said HGS model construction is progressing as planned. The coarse version has between 250,000 and 800,000 3D elements; the high-resolution version ranges from roughly one to four million 3D elements.

Since the December progress meeting, the finite element mesh has continued to be refined and tested, including:

- Adding a 1D domain to represent stream networks
- Adjusting 3D mesh elevations
- Updating surface water/groundwater observation points
- Adding soil freeze/thaw cycles
- Adding a temporally and spatially variable leaf area index

These updates are already improving the accuracy of the coarse model, with 72% of Arctic region observation points posting acceptable-to-optimal NSE[1] values and 64% showing percent bias[2] (PBias) of under 20% (Figure 3). Manual calibration of the watershed domain models is underway, with automatic calibration to follow for all seven domains. The coarse model outputs will be used to guide the calibration process for the high-resolution model.

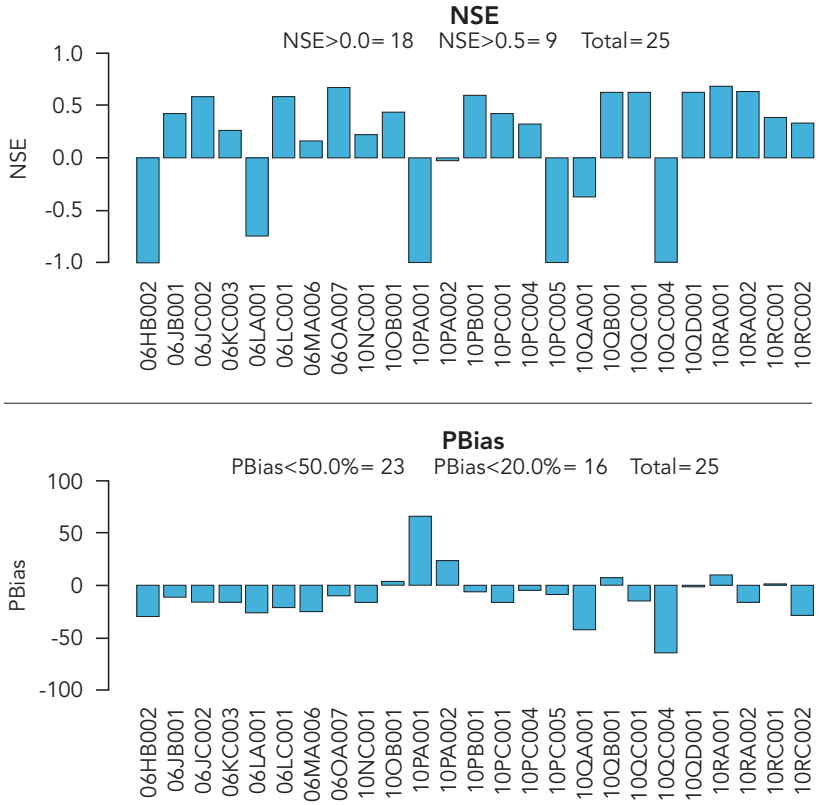


Figure 3. NSE and percent bias calculated using Arctic model results and observed data at Water Survey of Canada hydrometric stations.

[1] NSE: Nash-Sutcliffe Efficiency value. The NSE is commonly used to measure the predictive efficiency of hydrologic models. Positive NSE values indicate stronger agreement with observations, while negative values indicate weaker agreement with observations.

[2] Percent bias is the percentage difference between average simulated flows and observed flows at a specified station over a specific period of time — in the case of C1W, one year. An optimum value is 0%.

Canada1Water data portal

The project team has developed a data portal to share all the final datasets in standard WMS/WFS formats. Some datasets are already in use by other researchers. Going forward, all will be available for widespread public use through the C1W and Geological Survey of Canada open data platforms.

Derek Steinmoeller of Aquanty gave a preview of the user interface (UI) being developed for C1W. Users will log in to see a continental-scale map of Canada, with the option to toggle between OpenStreetMaps, hybrid and satellite base maps and between downloadable datasets (e.g., watershed boundaries, lake bathymetry, etc.). Users will be able to download data that is trimmed to complete watersheds or dive into the model that is based on regular tiles from the map grid.

Next steps for web portal development include quality assurance and hosting a demonstration version, with a public cloud launch to follow.

Communications, engagement and decision support

Hazen Russell reviewed the three-pronged C1W outreach approach: public-facing and science community communications; user engagement; and decision support, which includes disseminating the C1W datasets and generating specialized datasets.

Over the winter, the team refined its content strategy with help from a marketing consultancy and a social media partner, and published a progress report up to December 2022. A prototype animation of Baffin Island precipitation was produced with the Ontario Oil, Gas and Salt Resources Library and released in video and augmented reality (AR) formats (Figure 4).

Team members held 12 engagement meetings with partners and stakeholders and presented at nine conferences and workshops. Engagement with Indigenous peoples continued with presentations to the Fort Hill Qu'Appelle Tribal Council and the Treaty 3 Grand Council, and through collaboration with the Vice Provost of Indigenous Initiatives and the Dean of Natural Resources Management at Lakehead University, and Algoma University Chancellor Shirley Horn. An Indigenous story of water honouring Indigenous storytelling traditions was co-created for use in C1W communications materials.

Russell listed several early users of C1W datasets, including Cornell University, Health Canada, the Department of Fisheries and Oceans, and the private-sector company, GeoLogic. He also noted that finer-grained nested models have been developed for users based on the C1W model and data.

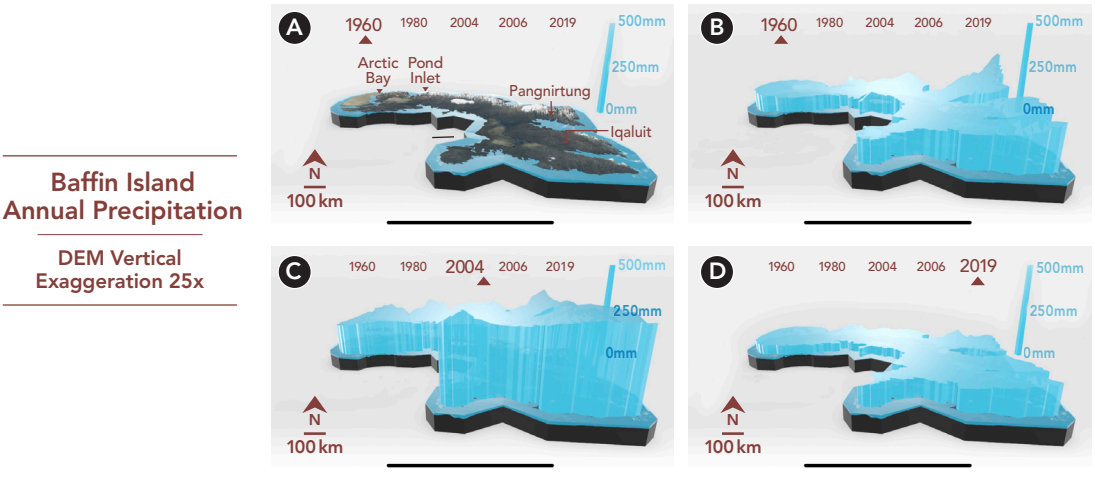


Figure 4. Screenshot of the Baffin Island precipitation animation, a prototype for new ways of visualizing model data. The augmented reality (AR) realization shows topography and landcover (A) and precipitation for select years (B–D). The version shown here covers five sets of data from 1960 to 2019, with significant variation in precipitation levels over time. No multidecadal trends are inferred from the selected years.

What's next

Steven Frey closed the meeting saying that, over the next six months, the team aims to generate surface water, groundwater and soil moisture projections in HGS, with focus on identifying regions that may be particularly stressed in the mid- and end-of-century time periods.

The team will continue working on the web portal (Figure 5) to ensure easy access for users, will publish the papers currently being prepared, and strive to determine Canada's first real valuations of groundwater resources.

Figure 5. An early preview of the C1W integrated web-based data interface, which will allow users to visualize and download data and model results.

For more information, visit **www.canada1water.ca** or contact:
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