Mechanisms Driving Pit Lake Evolution

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Background and Motivation

Fig. 1: Bird's-eye view of FPL from [1].

The Faro Pit Lake (FPL) is a water reservoir created by filling an open pit with mine-impacted water. It is located at an abandoned zinc and lead mine complex in Faro, Yukon. The FPL is surrounded by waste rock that contains elements which, when are oxidized and come into contact with water, create Acid Rock Drainage (ARD). ARD can deteriorate water quality by making it highly acidic, harming local ecosystems and communities [2].

Important features of the FPL include the high embankments surrounding the lake, with an average step height of roughly 100 meters. High embankments affect the way wind interacts with the lake's surface [3]. When the wind flows over the embankment, turbulent flow detaches from the surface and reattaches after a distance of 5-8 times the step height. Similarly, on the other side of the lake, the flow detaches from the surface at a distance of about 1-2 times the step height.

Another important factor when considering the evolution of a body of water is the solar heating it receives. Due to the high embankments surrounding this lake, we wanted to see how much direct solar heating the lake receives, compared to what heating may be coming in indirectly.

Fig. 2: Overhead map of FPL from Yukon Digital Surface Models and aerial images.

Putting everything together, we begin by developing a 1D heating model for the surrounding waste rock. This model serves as a tool to further understand the evolution of the FPL and the impact of different natural inputs. The work presented here lays the groundwork for a more complex model of the FPL itself.

Aknowledgements

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Sun Position

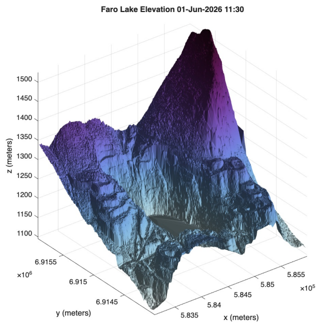


Fig. 4: Sun position above FPL at 11:30am on June 1st.

Method:

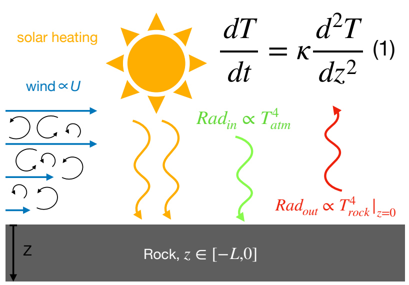
- DSM of the FPL was used to create an elevation plot of the site of interest.
  - FPL is the flat surface in the centre of the plot.
- The Sun's position above the FPL is calculated as a function of time (day of year **and** time of day) and site latitude (62.35265 degrees).

Result:

- Sun position during a day in June reveals the **FPL does not receive much direct sunlight** due to shading from surrounding rocks.
- **Indirect heating** from surrounding rocks **likely important** for heating in FPL and should be considered in future lake models.

One-Dimensional Heating Models

1D Heating Model



$$\frac{dT}{dt} = \kappa \frac{d^2T}{dz^2} \quad (1)$$

Fig. 5: 1D rock heating model with flux contributions.

30-Day Simulation: June Parameters

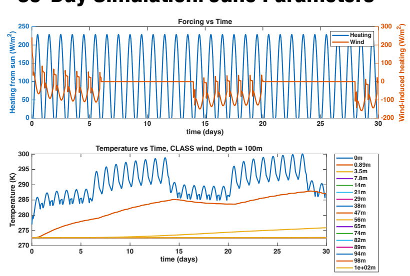


Fig. 6: Top - Incoming Solar forcing and wind. Bottom - Temperature at various rock depths.

Boundary Conditions for (1)

- No flux in the deep ($z = -L$).
- At the surface ($z = 0$) the flux is a sum of the solar heating, the radiation in from the atmosphere, the radiation out from the rock, and flux due to wind/turbulence effects.

Adding Realistic Weather Conditions

- Consistent with observations from ECCC data [4], wind effects are 7 days on, followed by 7 days off.
- Atmospheric temperature is reduced by 5 degrees at nighttime.
- We use the Canadian Land Surface Scheme [5] parametrization for heat exchange at the surface due to wind effects.
  - Exchange depends on surface drag, windspeed, and temperature differences.

Results

- **Temperature increases with time**, despite dropping during windy weeks.
- Active Layer depth is roughly **6.18 meters**. Near the end of the month, some depths close to, but still below, the surface become warmer than the surface.
- **Forcing impacts not only the surface, but lower depths** as well. The magnitude of these deeper effects appear to **diminish in time**.

The main differences for the lake model at this point are the use of water-specific parameters and the inclusion of a thermocline at 9 meters below the surface.

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Conclusions and Future Work

Conclusions:

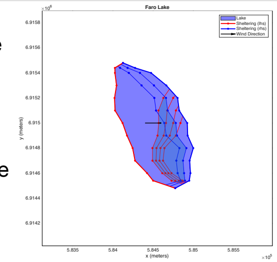

Fig. 7: Example of unsheltered area with wind direction (black arrow).

- A significant portion of the lake is sheltered by the wind, even in the best-case scenario. This will have an impact on the wind-induced mixing in the FPL.
- The Sun's position in northern regions is highly variable. Even at the beginning of summer the lake does not receive much direct heating and we can expect this heating decreases throughout the summer and early fall.
- Determining realistic weather conditions for the region will aid in developing future models of the FPL.

Future Work:

- Continue developing the lake model and investigating what physics may be missing:
  - Use a Beer-Lambert-type model to incorporate the fact that solar heating penetrates deeper into the lake then just the surface.
  - Account for turbulence build-up in our diffusion parameter (no longer constant).
  - Incorporate changes to wind due to sheltering effects on the lake.
- Create a two-box model for the lake and rock to study feedbacks.
- Demonstrate sheltering effects in a lab setting.

References

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[3] A. Huber, G. N. Ivey, G. Wake, and C. E. Oldham, "Near-Surface Wind-Induced Mixing in a Mine Lake," *Journal of Hydraulic Engineering*, vol. 134, no. 10, Oct. 2008, doi: https://doi.org/10.1061/(ASCE)0733-9429(2008)134:10(1464).

[4] Environment and Climate Change Canada (ECCC), "Daily Data Report for June - October, 2015 - 2025 at Faro AUT Station," *Government of Canada* [Online]. Available: https://climate.weather.gc.ca/ (Accessed May 11, 2026).

[5] D. Verseghy, "CLASS - A Canadian land surface scheme for GCMs. I. Soil model," *Int. Journal of Climatology,* vol. 11, no. 2, pp. 111-133, 1991.