Applicability of machine learning in agile decision making in open pit dewatering: A case of study in Antamina mine (Peru)

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Motivation: why to dewater?

- Because the presence of water (mines below “water table”) can:
  - Complicate access within the pit and operational times
  - Compromise the physical stability
    - Changes the resistive and driving forces of slopes
    - Pore pressure reduces effective stress and shear strength
    - Can lead to landslides and loss of sections of the pit, including associated risks to personnel
  - Cause detrimental effects on the mobility and hauling
    - Increases weight of the ore
    - Tyre wear
    - Reduces passability
  - Cause malfunctions with explosives (increases blasting)
  - …and others
- At the end, water increases costs dramatically
- A proper solution is to anticipate water problems, before and while, pit development, with foresight and planning of a proper dewatering

A case of study: Antamina mine

Video of the Antamina pit, provided by Antamina

WVTF IMWA 2024

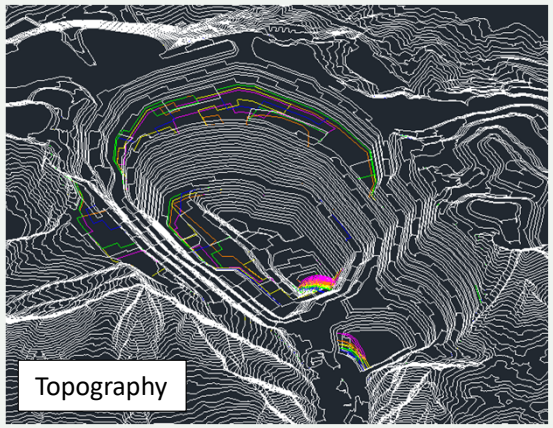
WEST VIRGINIA MINE DRAINAGE TASK FORCE

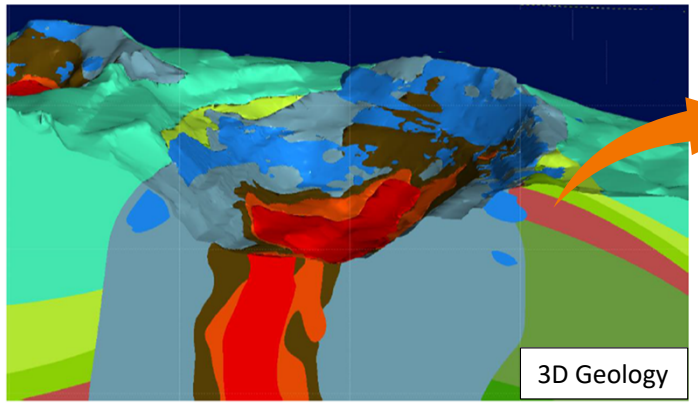
ANTAMINA

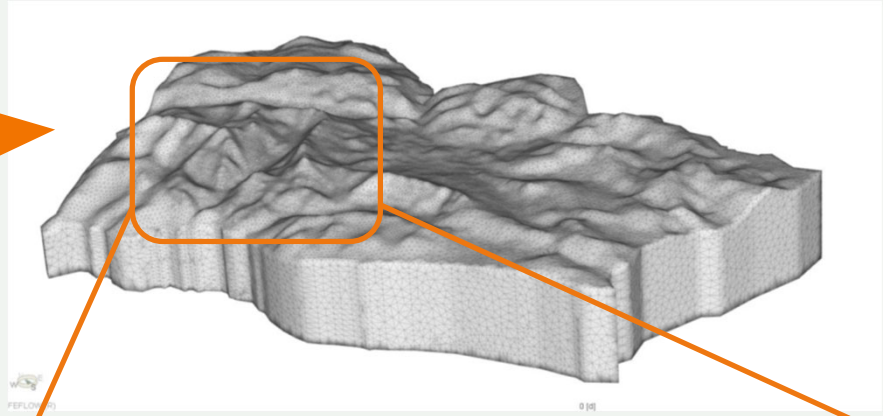
AMPHOS 21 an RSK company

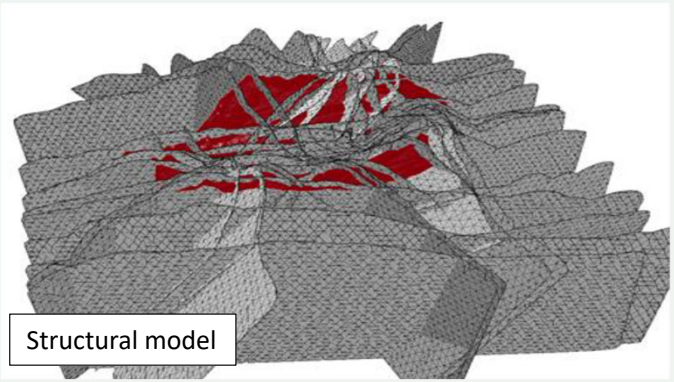
30 years and beyond 1994-2024

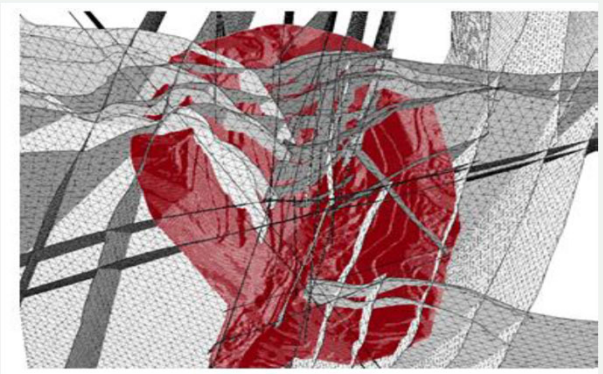
On the hydrogeological foresight and planning

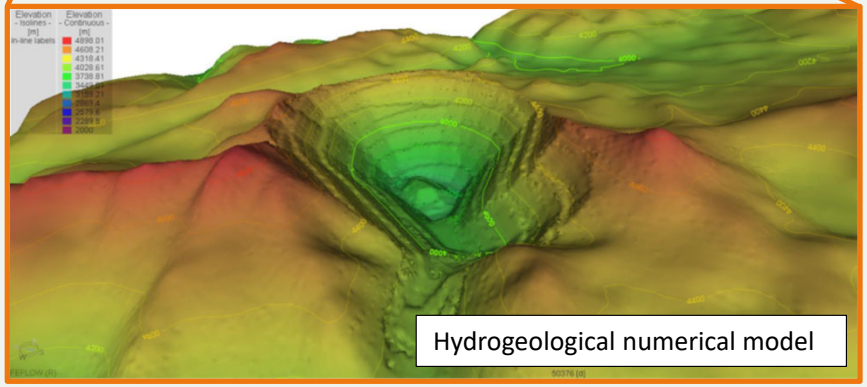






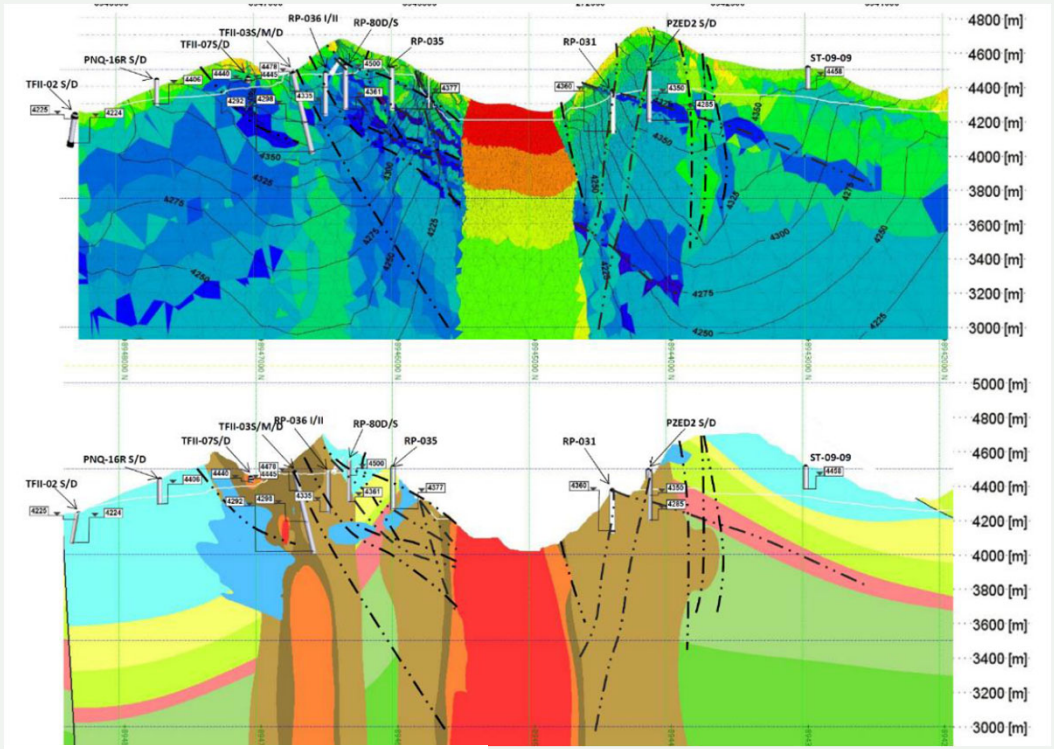


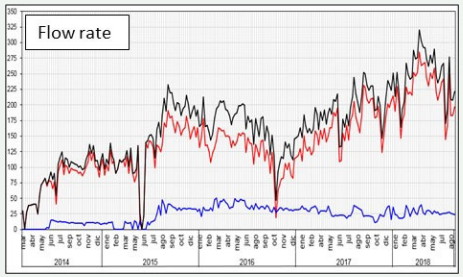


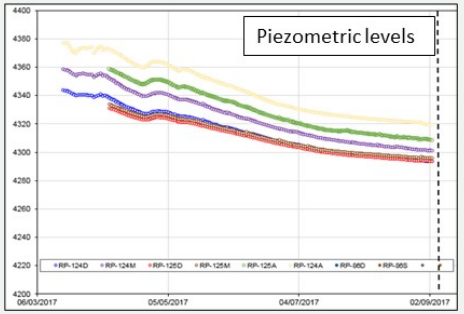


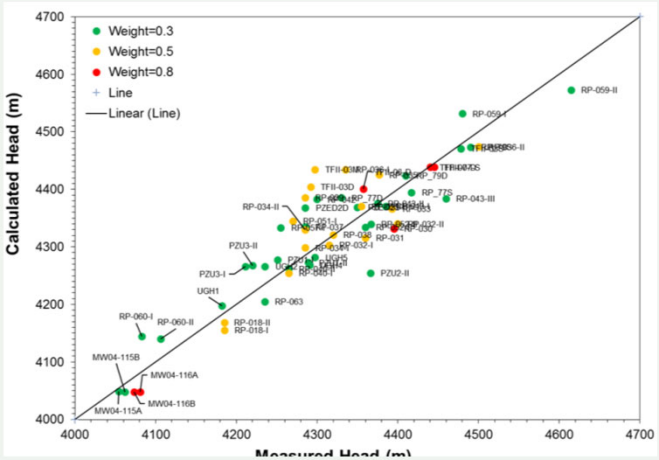
Images courtesy of Antamina

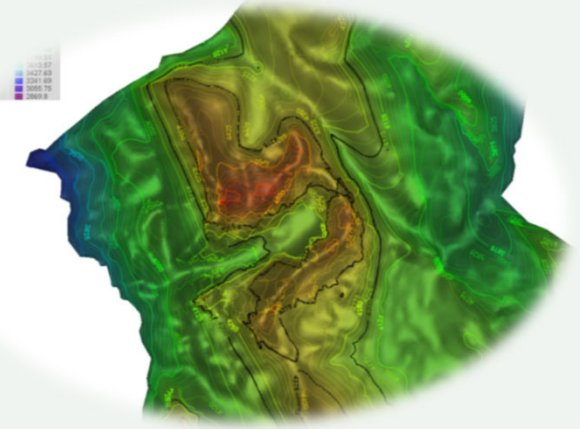
The process of simulation: it is really a complex and hard task











Images courtesy of Antamina

The 'pain': too many changes

- Changes occur continuously affecting forecasting and new predictions become to be reevaluated:
  - Geological (and structural), and thus hydrogeological behaviour
  - Climate conditions
    - Changes the recharge
    - Pore pressures
    - Run-off
  - In the ore grade led to changes in mining plan, so excavation changes
  - Strategical planning predictions and scenarios can be needed
  - Malfunctions while operations (pumping, energy boosters,…)
  - ….. others
- At the end, there is a need to re-evaluate predictions, usually it is needed a quick foresight (often weeks not months)

We set ourselves a goal: how to achieve fast and agile forecasting?

From ML towards a hybrid methodology – why?

2021

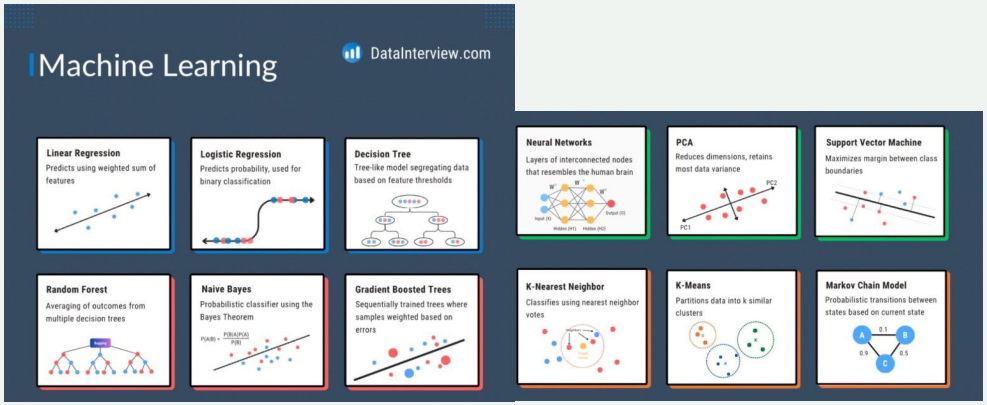
Database Generation
Statistical study
Algorithm Selection
Algorithm Training and Verification
Algorithm Validation (blind predictions)
Applicability and opportunities

SpeedWise® ML © by QRI

2022

CNN ML tool (convolution Neural Network arch.) development and validation

TensorFlow

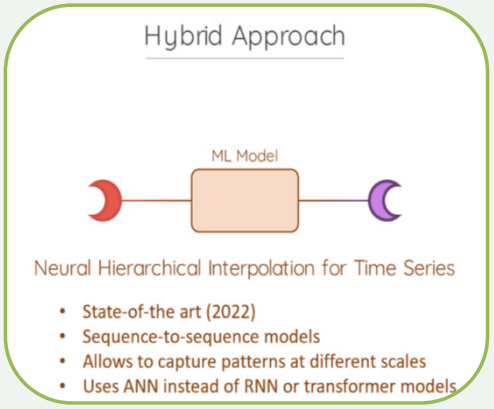


2023

Hybrid Approach
Analytical solution on wells interference
Recurrent Neural Networks (RNN)

Dashboard / web_app

2024



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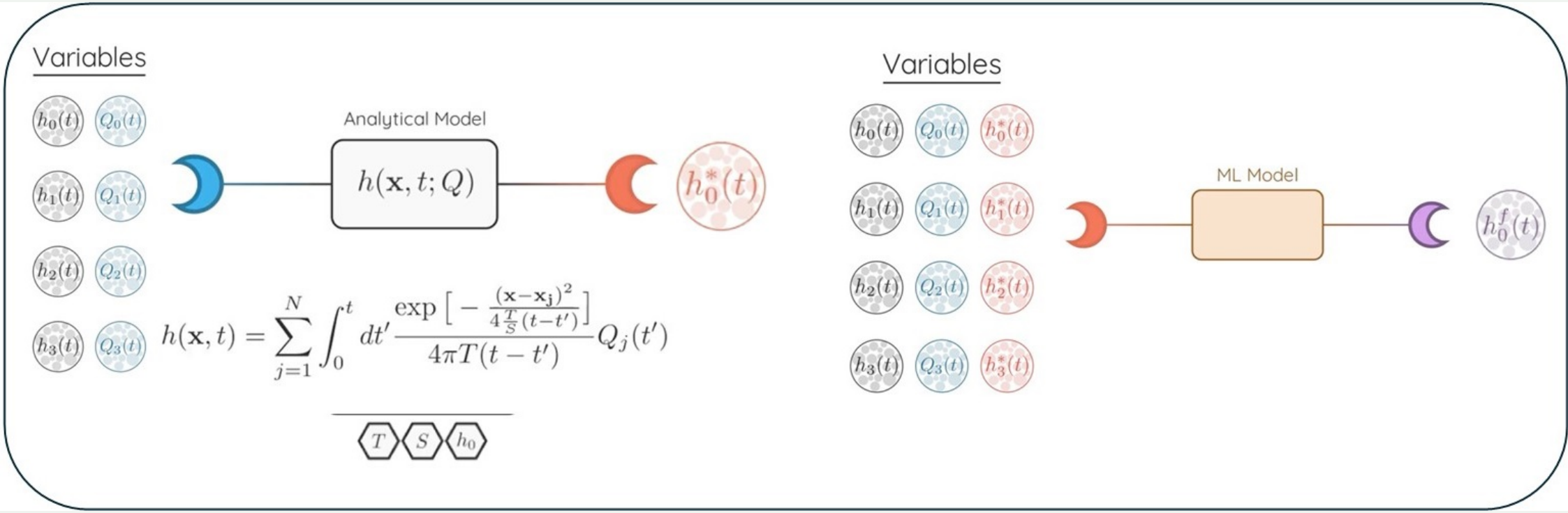
Could a machine learning approach help to be more agile?

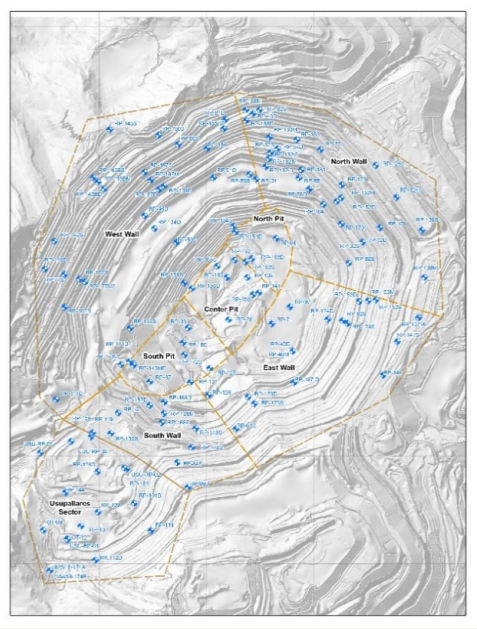
Or even could we combine ML approaches with numerical or analytical models to build a workflow that improves the prediction of groundwater dynamics?

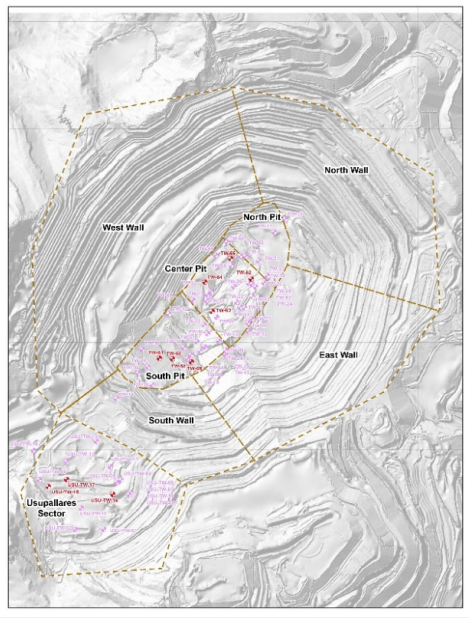
	Advantages	Disadvantages
Numerical and Analytical models	• Interpretability • Consistency on unseen or new scenarios • Well know and used for a long time	• Difficult or increasingly complex to include all the relevant processes • Constrained to the underlying conceptualization
Supervised Machine Learning	• Can extract complex patterns from data • Inference is quicker	• Needs huge information (big data) and with the best quality as possible • May not generalize well to unseen data

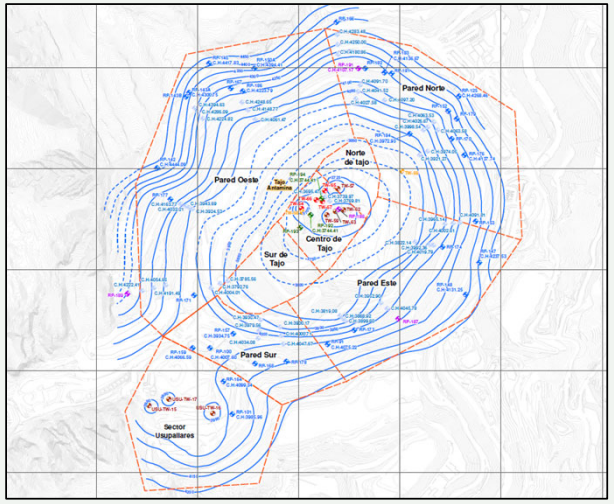
Methodology: hybrid approach

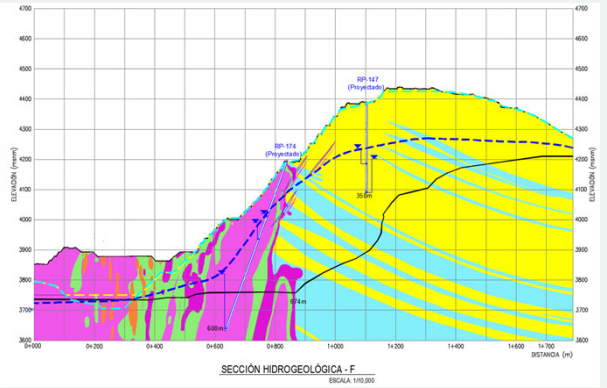


Our case of study: on the hydrogeological conceptual model support

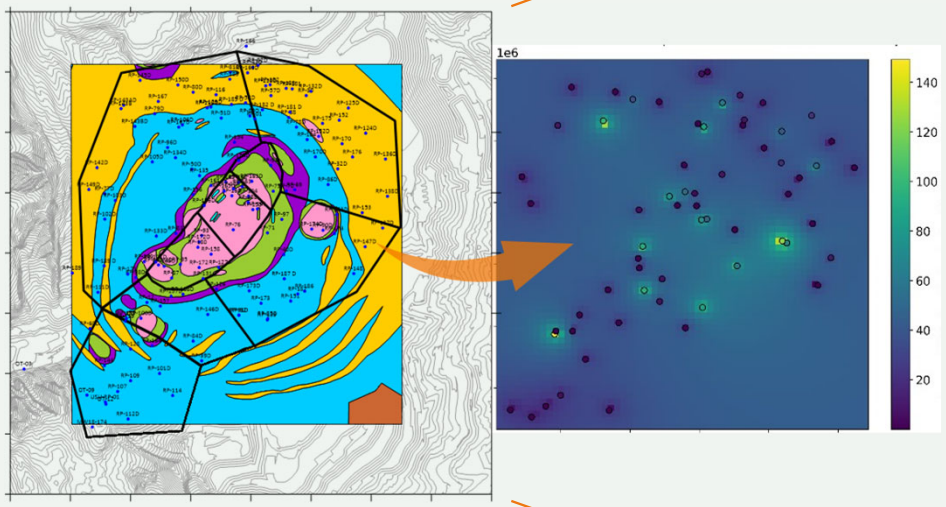


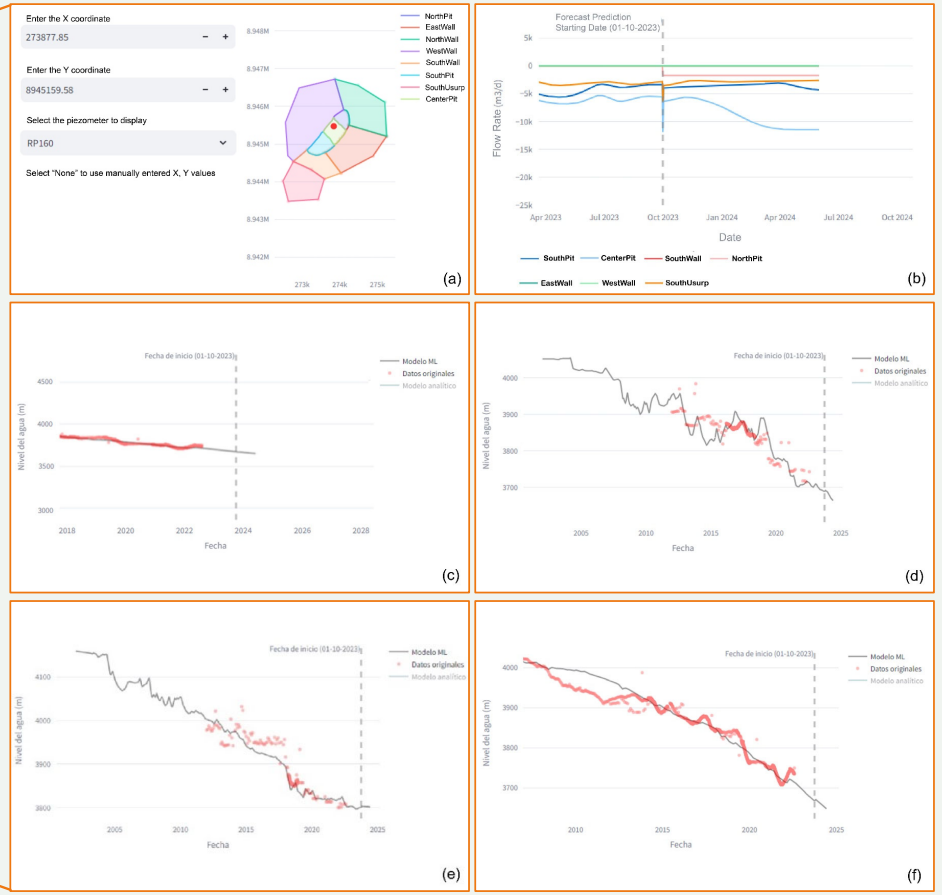






Our case of study: on the data treatment as model input

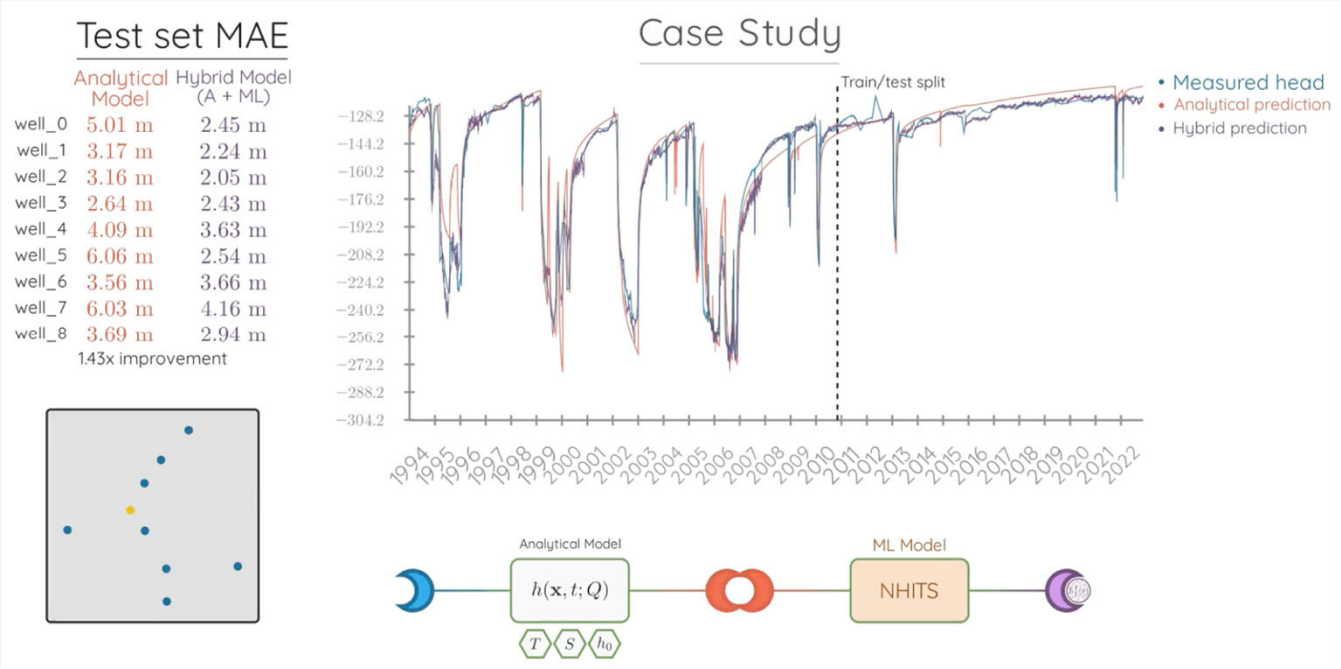




A quick demo view on the use (sorry for the Spanish)

what are the next steps?

- Neural Hierarchical Interpolation for Time Series (NHITS)



- Coupling numerical simulations to be refined by ML model

Some conclusions at this stage

- The results obtained have shown that machine learning approaches:
  - Present satisfactory predictive capacity
  - They can be quick and effective tools in making decisions about the impacts of production wells during development of open pit mine dewatering
  - Can be applied as support in the planning for the water operations in the pit.

- There is a need of having a big amount of data, and 'as good as possible'...
  … Taking care with this! ML can increase the speed of interpretation but may lead to poorer outcome
- Some dewatering methodologies (e.g. drains in the wet walls of the pit) can hardly be reproduced
- Same than with numerical models, it is fully recommended that the ML-based hybrid model be developed with the site knowledge and singularities, it is crucial to reflect geology features within the assignment of hydraulic properties, a set of piezometric data and pumping information, that is sufficiently extensive well validated by water specialists with historical knowledge on the pit

A final thought

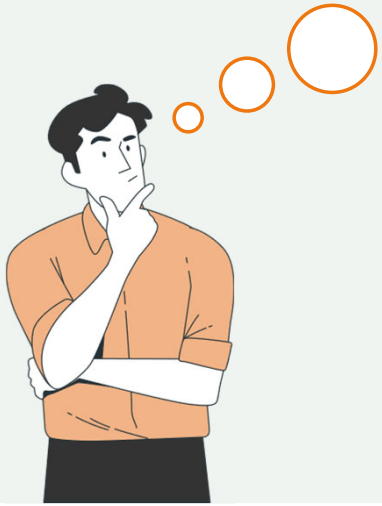
Let us use both **intelligences**

on the one hand, the **human** one, in which we integrate all the knowledge of the specialists involved: mining engineers and geologists, geotechnical engineers and groundwater specialists to recognise and accommodate water-related factors

on the other hand, the **artificial** one, which will allow us to extract and integrate complex patterns in the management of large volumes of information, with an astonishing speed for predictions.

Thanks a lot for your attention!

The authors would like to thank Antamina for the years of work in the development of hydrogeological and dewatering activities, for the search for innovative solutions that allow more agile and accurate decisions to be made, and for the presentation of these results.



questions / comments

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references