SHEET 07

THE **WATER** AROUND THE BEAUVOIR SITE

This initial sheet, designed for educational purposes, seeks to outline the methodology and the various aims of an impact study on the water around the Beauvoir site. It presents the conceptual hydrogeological model of the Massif de la Bosse currently in use and looks at the "prevent, reduce, offset" approach and examples of its application.

It will be supplemented by a second practical sheet which will look more specifically at samples taken from the Sioule for the Beauvoir site and use of water at the La Loue conservation plant site in the vicinity of the Cher.

These various details will also be presented to the general public at the special "water" meeting, which will be held on 30 May in Vichy.

WHAT DOES A WATER IMPACT STUDY INVOLVE?

Before commencing any project which might have an impact on the environment, it is important to have an overview of the state of the aquatic environments (watercourses, ponds, water tables) of the area in question. It is for this purpose that a water impact study is conducted.

Such an initiative determines the initial state (the state of the environments prior to any operations), and provides in-depth knowledge that will be used to determine the potential consequences of operating a mine and building a factory on the ecosystems – and on water in particular.

A WATER IMPACT STUDY: THE STEPS INVOLVED

BEFORE MINING OPERATIONS

MINING AND POST-MINING OPERATION

Knowledge of the physical environment

- **Knowledge of the water environment** surface water, underground water, quality and quantity (database, field measurements, etc.)
- Knowledge of the spatial distribution of geological formulations and their hydrodynamic characteristics (permeability)

Characteristics of mining activity

Impact assessment

- **Initial environmental state** (water, natural environments, uses, etc.)

Assessment of the impacts of mining through flow modelling:
- validation of models
- mine impact simulations / comparison with current state (quantity / quality)

- Possible implementation of prevention, mitigation or offsetting measures

Environmental monitoring

Environmental surveillance (instrumentation and tracking): checking of variation relative to the initial state

Site monitoring committee / IRMA monitoring committee

Possible adjustment of mitigation and offsetting measures

METHODOLOGY

To assess the impact on water, it is also important to understand which parameters influence flows: this is spatial distribution (in three dimensions) of geological formations and their uses. The geological formations were mapped and the installation of piezometers[1]both supplemented knowledge of the geology (the depth of various geological formations encountered during drilling operations) and enabled pumping tests to be carried out to determine the permeability of land and of the various rock formations.

Assessing the impact of mining operations then involves modelling underground flows.

First, a digital* hydrogeological model is created. This model incorporates data describing the environment through which underground water moves and simulates the physical laws describing the relationships between the underground and surface flows.

To ensure that the model is actually representative of Échassières' hydrogeological situation, the level of the water table simulated by the model is compared with the levels measured out in the field.

The mining operations (excavations) are then are incorporated into the digital hydrogeological model. The model then simulates the underground flows* resulting from this modified situation relative to the initial state.

The comparison between the water table levels simulated by the model and the actual water table levels is used to assess changes in the water table resulting from mining operations.

If these variations implying potential consequences on water or the aquatic environments were to be observed, Imerys would then consider implementing prevention, reduction or even offsetting measures.

CURRENT KNOWLEDGE OF THE WATER ENVIRONMENT

Literature review

In addition to data from geological exploration campaigns, a literature review was completed in December 2022. A summary produced by a specialist design firm was used to gather existing information, identify any potential missing data and put forward a more comprehensive investigation programme.

Investigation programme implemented since 2021

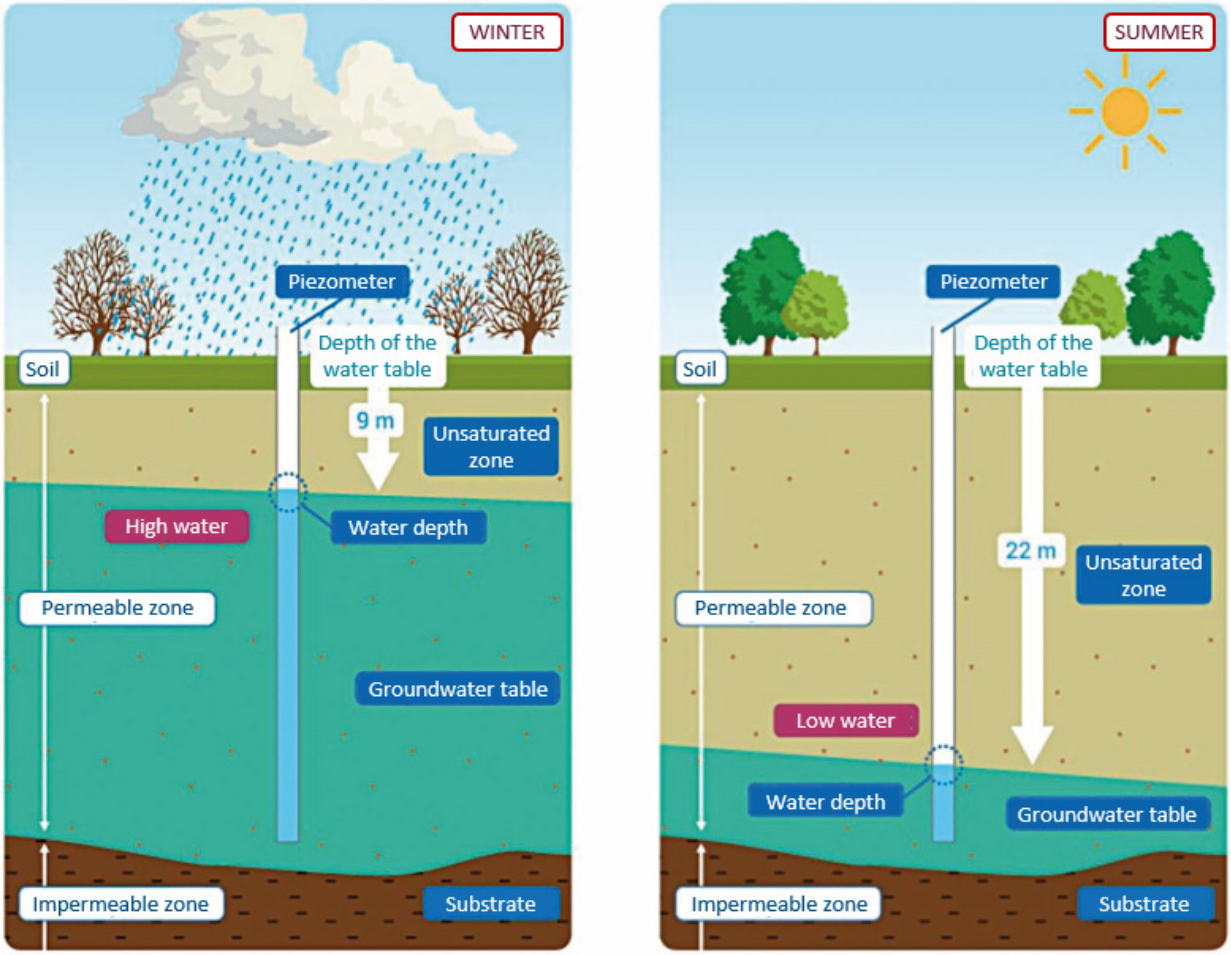
Nearly a hundred points (private wells, sources, watercourses, etc.) have been mapped at various distances from the project in different environments. Of these, 70 representative points have been selected for tracking water levels and around thirty for conducting water quality analyses in order to obtain robust and representative data.

[1] You will find a detailed definition of what a piezometer is on page 3
[2] Explanations of words with asterisks feature in the glossary on page 8

WHAT IS A PIEZOMETER?

New piezometers (15), devices for measuring water levels and water quality, were installed in 2022 and 2023 in addition to the ones already in place (8) for the kaolin open pit.
These arrangements will be complete by mid-2024 with the installation of deep-sunk piezometers.
Piezometers are filtering tubes of a reliably determined diameter intersecting with underground water level(s) and giving the depth of the groundwater table.
They can also be used to take samples for analysing water quality and conducting various tests.
When doing so is possible, these piezometers are kept in place during mining and are used to monitor the effects of the activity being carried out on an ongoing basis.

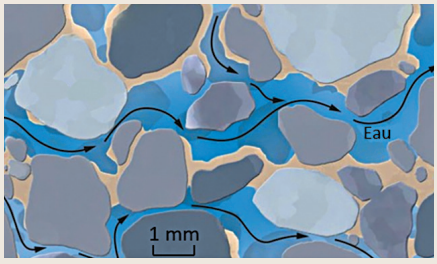
PIEZOMETER OPERATION – (BASIC DIAGRAM)



source: https://www.eaufrance.fr/le-niveau-des-nappes-souterraines

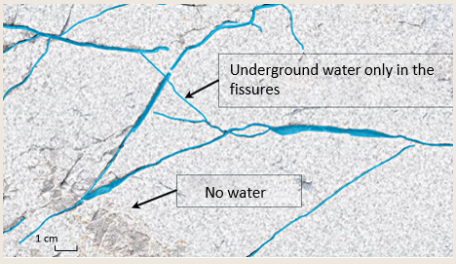
VARIOUS TYPES OF UNDERGROUND WATER FLOW

In a porous environment* (granitic sand, for example)



(source: N. Gerdes)

In fissured rock* (non-altered granite, for example)



Surface flows in the sector

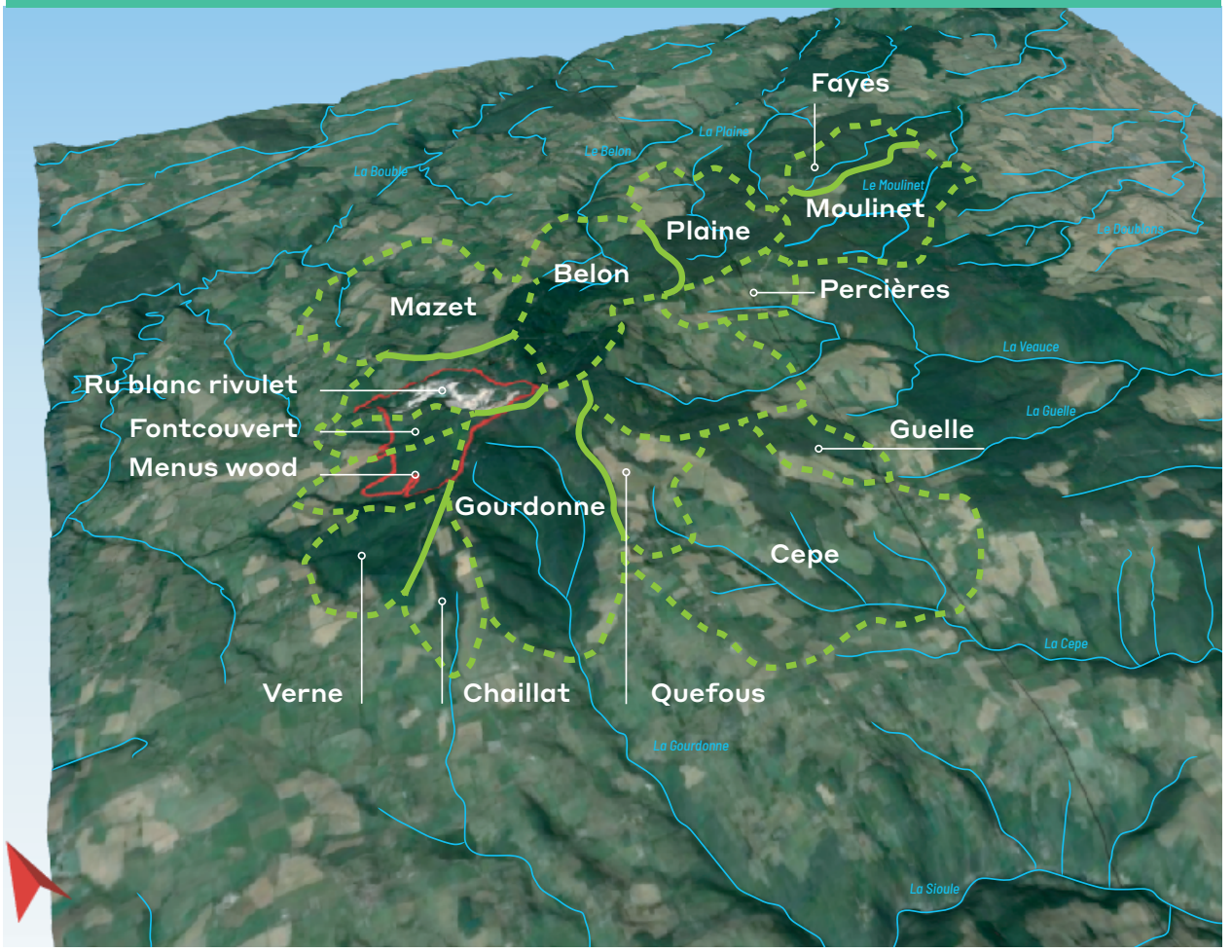
The mining site and current open pit are located between the Menus wood and the Colettes public forestland, on a topographical headland referred to as the Pyramid.

The source of the small streams running across this sector is at this high point – they flow out from it in all directions.

The northern part of this headland is part of the catchment area of the Échassières stream, a tributary of the Bouble.

To the north of the Beauvoir, the source of the Blanc rivulet is in the Croix Lambin hamlet. It winds its way down into the Échassières stream. Its flowrate is usually a few L/s, but it can run dry at low water*. The southern part of the site is drained by a low thalweg* stream hemmed in by steep hills, in which intermittent or less-than-plentiful streams commence (the main ones being the Cèpe and the Gourdonne), before joining the Sioule in the Chouvigny gorges.

MAP OF THE CATCHMENT AREAS[3]



Key:

- Catchment area boundary
- Imerys property boundary

Underground flow across the sector

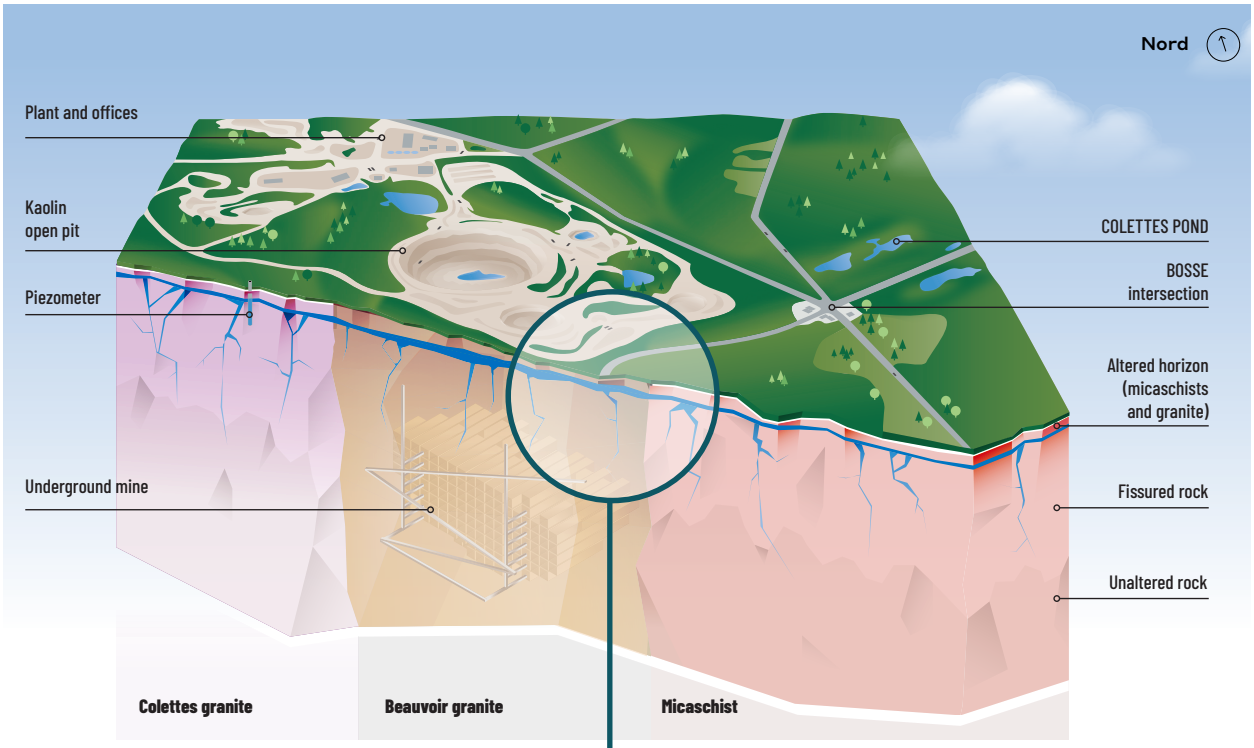
As a general rule, the information collected and available (land works, literature) shows that underground water circulates across two main types of geological formation:

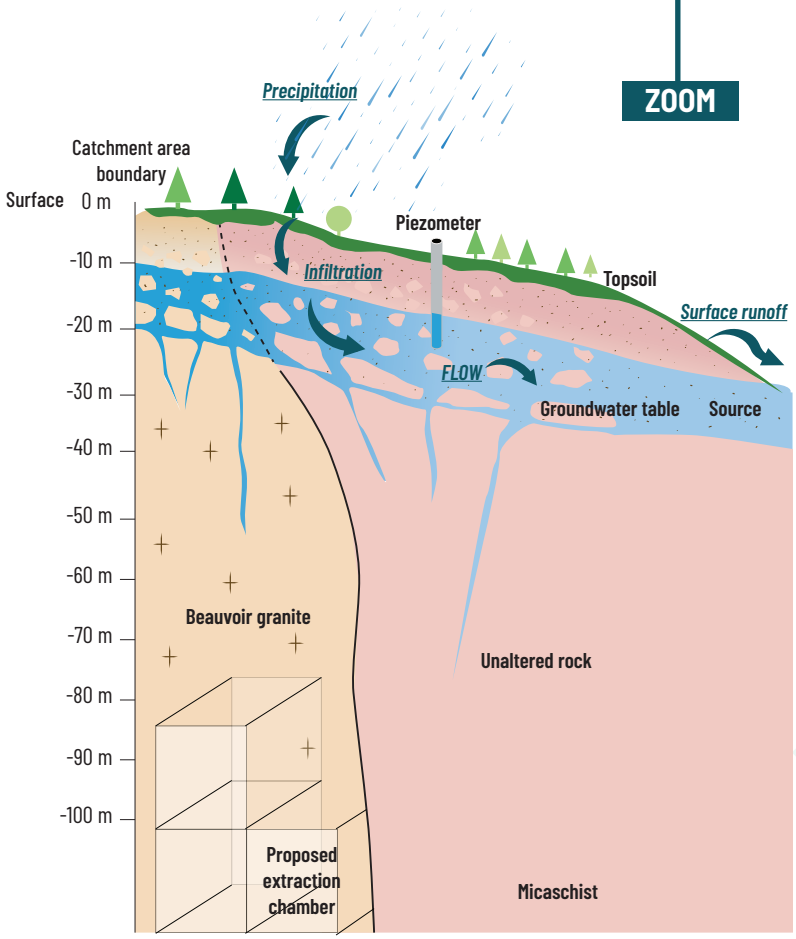
- The surface layer, which is around 10 to 30 m thick (an altered strip of micaschists* and granite) where the groundwater table is located;
- Granite, the permeability of which can be attributed to fissures.

[3] More details available at: https://www.eaufrance.fr/les-eaux-souterraines

CONCEPTUAL HYDROGEOLOGICAL MODEL OF THE MASSIF DE LA BOSSE

Operation as basement nappe (schematic illustration)





Further down, namely at depths of around 100 m and lower where mining operations occur, the Beauvoir granite is hardly cracked at all. This means that it can be considered practically impermeable – underground water will have great difficulty circulating through it.

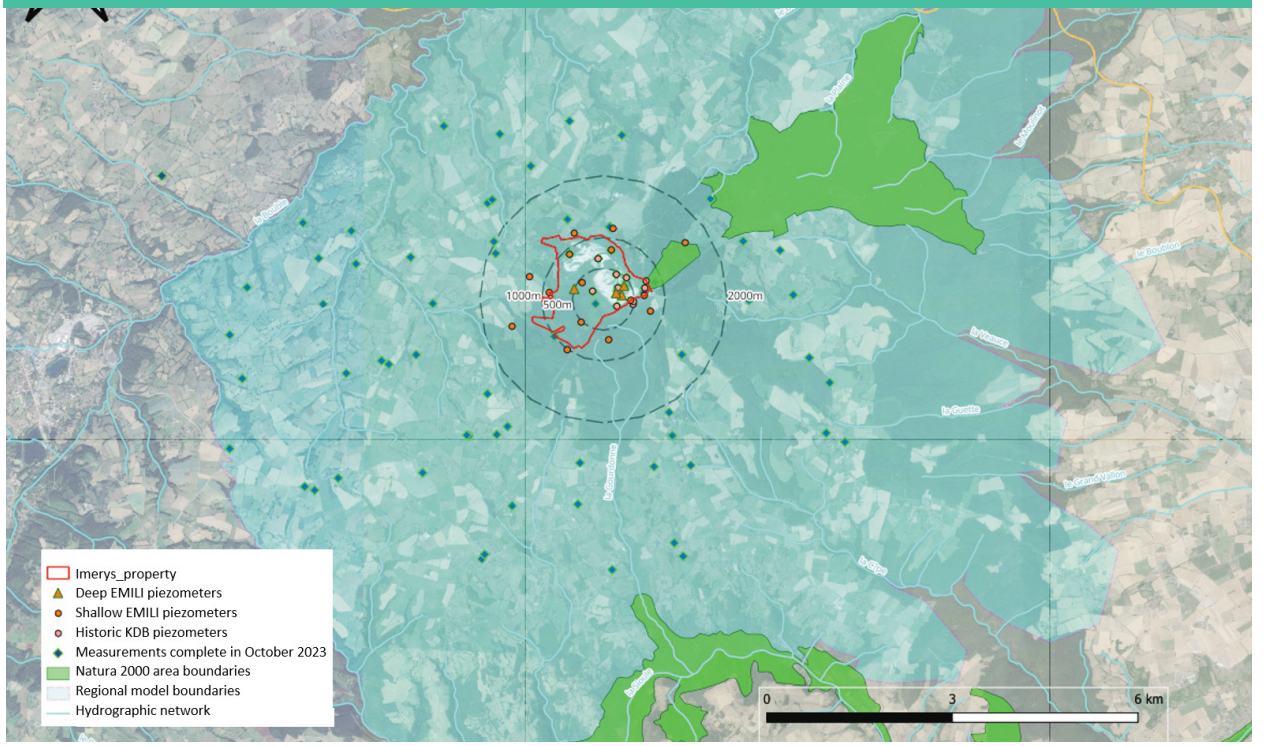
At this stage of exploration, only cracks and fissures in the subsoil could increase its permeability.

The surface layers, on the other hand, which are made up of micaschists and granitic sand, seem more altered. That means that they contain "empty" chambers within which water could circulate.

So naturally, the groundwater table is in this layer. It is fed by precipitation, the flow of which is influenced by topography, and the sources and watercourses make up its outflow.

The initial results of the piezometric level analyses show that the underground water rapidly flows towards the closest thalweg, taking the path of least resistance. The directions of these underground flows are therefore highly comparable to the flows of the rivers and streams on the surface.

SURFACE AND GROUNDWATER MONITORING NETWORK



Particular geological structures, such as cracks and seams from other rocks, as well as occasionally former mining galleries (mainly located in the micaschist), can function as preferential drains. Some of this precipitation could therefore filter through to deeper layers and feed a network of fractures within the mine. Installing piezometers deep down and undertaking analyses will make it possible to quantify the volume of water that could filter through into these fractures and seams potentially in contact with the surface layer.

WHAT ARE THE NEXT STEPS?

MINING SCENARIO IN THE PROCESS OF BEING FINALISED

To better understand and analyse any consequences on groundwater and surface water, two types of water flow modelling are in the process of being developed.

- **A regional model,** in the process of being finalised, for simulating the current physical environment. Its purpose is to assess effects both on the pilot gallery and on the commercial mine. This model characterises surface and groundwater over a 5 km radius around the site (from the Bouble north of it, to the Sioule south of it).
- **A proximity model**, for more finely factoring in the Beauvoir site's geology and the underground infrastructure, scheduled for the end of 2024. Its purpose will be to more precisely assess the mine's overall effects. This model will be supplemented by additional in-situ measures.

However, some detailed elements are not yet available for simulating the effects of the future mine with one of the other of these models:

Indeed, the following elements are in the process of being acquired or defined:

- Physical properties of deep granite: this data will be available when analyses of the deep piezometers, in the process of being carried out, are complete;
- Structural geology at the edge of the site, and more specifically under the Colettes forest;
- Design of the access openings and mining sites (size, implementation sequence);
- Ownership (permeability and leaching) of the backfill that will be used to fill in the mined sites;
- Phasing of mining and backfilling operations

PROVISION OF THIS INFORMATION

- The studies undertaken focused on a literature review for the massif de Beauvoir (groundwater and surface water). A scoping study was undertaken for the supply of water to the concentration plant, and data from the first three field investigation campaigns was analysed.
- The public meeting about water will be an opportunity to present the first available results.
- Further studies will be undertaken to supplement this first round, and their results will be shared with the public as part of the ongoing dialogue process.

They will focus in particular on:

- the proximity hydrogeological model, the result of studies to be conducted using deep piezometers in the process of being drilled (end of 2024);
- where to locate the pumping site on the Sioule (end of 2024);
- study into factoring in global warming on the Sioule (end of 2024);
- studies into leaching on the cemented backfill once tests have been carried out and the post-mining plan defined.

THE PRO SEQUENCE

PREVENT: a prevention measure modifies a project in order to remove an identified negative impact, such as changing the project's footprint, its location or the techniques used.

REDUCE: a reduction measure seeks to reduce the duration, intensity and / or scope of a project's impacts as much as possible if they cannot be completely prevented.

OFFSET: an offsetting measure seeks to counter any direct or indirect notable negative effects of the project which cannot be prevented or sufficiently reduced.

Application examples:

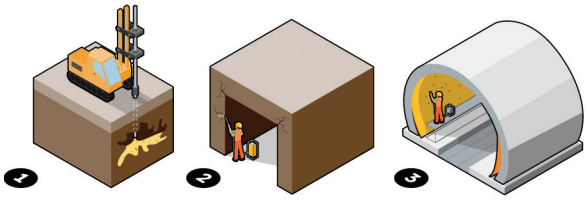
PREVENT:

Give preference to accessing the mine in non-fractured materials so as to prevent any potential infiltration.

REDUCE:

• Sealing discontinuities and fractures using the best available methods:

1. Targeted injections from the surface of the grout* (cement, resins).
2. Targeted and local injections under the grout* (cement, resins).
3. Sealing by laying a high-density polyethylene sealing geomembrane*, reinforced by sprayed concrete and / or shielding in rare cases where more permeable geology is encountered.



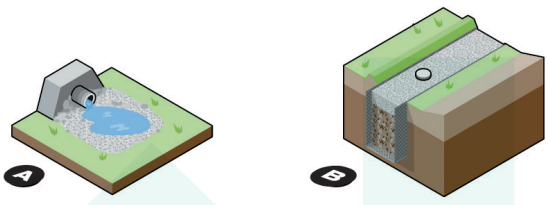
4. Adapting the mining sequence so as to limit the number of simultaneous open pits.
5. Adapting blasting operations to limit fracturing at site openings.

OFFSET:

• Implementation of methods commonly used in managing rainwater in particular:

A - Direct flowing watercourse flow support.

B - Trenching / infiltration guttering for groundwater.



GLOSSARY

Digital hydrogeological model (p.2):

In hydrogeology, digital modelling is used to represent, using a computer programme, groundwater flows, and in some cases the migration of pollutants in an aquifer system.

Digital models are used as a tool for understanding, managing and predicting resources and / or water quality. For more information, refer to: https://sigescen.brgm.fr/Modeles-hydrogeologiques-principes-et-methodes.html

Underground flows (p.2):

Movement of water as it filters down to the water table, and the flow from this water table to its emergences, in contrast with surface flow.

Porous environment (p.3):

Term used to refer to any material or rock the elementary particles of which have cracks between them – tiny empty chambers that are interconnected. Different to cracked or joined, where the interstices are not always interconnected.

Fissured environment (p.3):

Term used to refer to any material or rock featuring discontinuities (fissures and joints) through which water might circulate.

Low water (p.4):

Low water refers to the lowest level of a watercourse or lake, generally during a period of drought or low rainfall. It is the opposite of high water, which is the period during which water levels are at their highest, as a result of high rainfall, melting snow or other factors During low water, water flows can fall significantly, and watercourses can become very shallow. This period is often associated with more arid environmental conditions, and these can have repercussions on the local ecosystem, the availability of water for irrigation and other human activities for which water is required.

Thalweg (p.4):

Line of lowest elevation in a watercourse or valley.

Micaschist (p.4):

Rock composed of mica and quartz.

Basement nappe (p.5):

Water sheet incorporated at depths into an ancient geological formation (basement), in which water is contained and circulates in small discontinuous systems (fissures and fractures). To be distinguished from alluvial groundwater and sedimentary groundwater.

Grout (p.7):

Grout is a very fluid blend which can be made up of cement, water, resin and possibly additives. It can be used to strengthen foundations, seal fissured environments or bolster the geotechnical aspects of a structure. It is frequently used in the construction sector.

Geomembrane (p.7):

Artificial watertight membrane that can be made up of synthetic elements (elastomers, polyethylene) and / or natural ones (clay, bentonite). It can be used, for example, to render basins or storage units watertight.

IMERYS