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Modeling of methane capture from post-mining goaves to reduce methane emissions into the atmosphere

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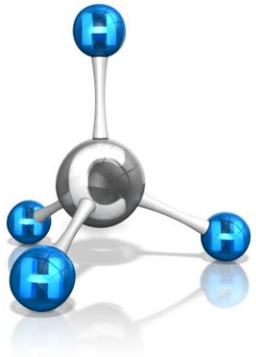
Introduction



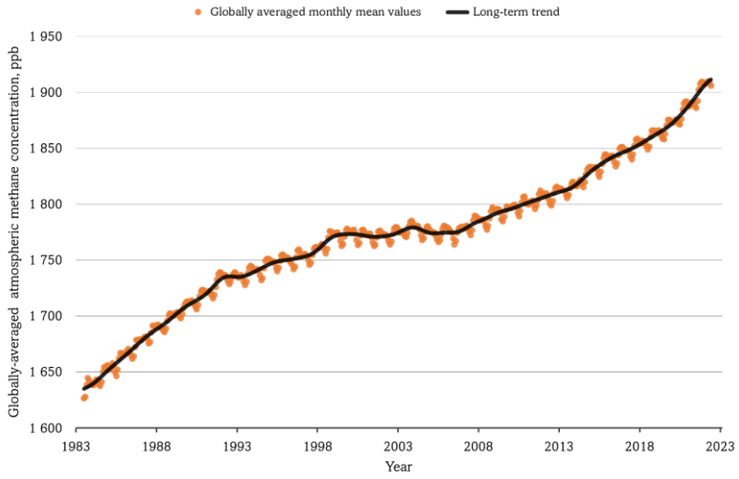
- Methane is a greenhouse gas with a high potential to contribute to climate change. During hard coal mining, methane is released from coal seams and released into the atmosphere. Due to its strong greenhouse gas properties, methane significantly impacts global warming.
- Moreover, methane is an explosive gas and poses a potential threat to mine workers.
- Therefore, controlling and reducing methane emissions in hard coal mines is a crucial challenge.
- Airflow simulations and modeling of methane emissions help understand and manage this issue, which can help increase worker safety and reduce the mine's environmental impact.

Introduction

- According to the declaration announced at the climate summit in Glasgow, EU countries are to reduce methane emissions by at least 30% by the end of the decade compared to their level in 2020.
- The EU is also preparing regulations regarding this - the second most important - greenhouse gas.
- According to the negotiated regulations, the energy sector, which, apart from agriculture, has the most crucial methane footprint, is to raise the standards of measurement, reporting, and verification of its emissions.
- Restrictive rules will also apply to coal mining. Under a position recently agreed by member states, mines would have to stop the practice of controlled gas firing at the end of next year. From 2027, active mines would be subject to a limit of 5 tons of methane per 1,000 tons of extracted coal, and the maximum emissions would be reduced to 3 tons in 2031.
- Although methane remains in the atmosphere for a shorter time than carbon dioxide, it has a greenhouse potential of over 80 times stronger in the first 20 years.

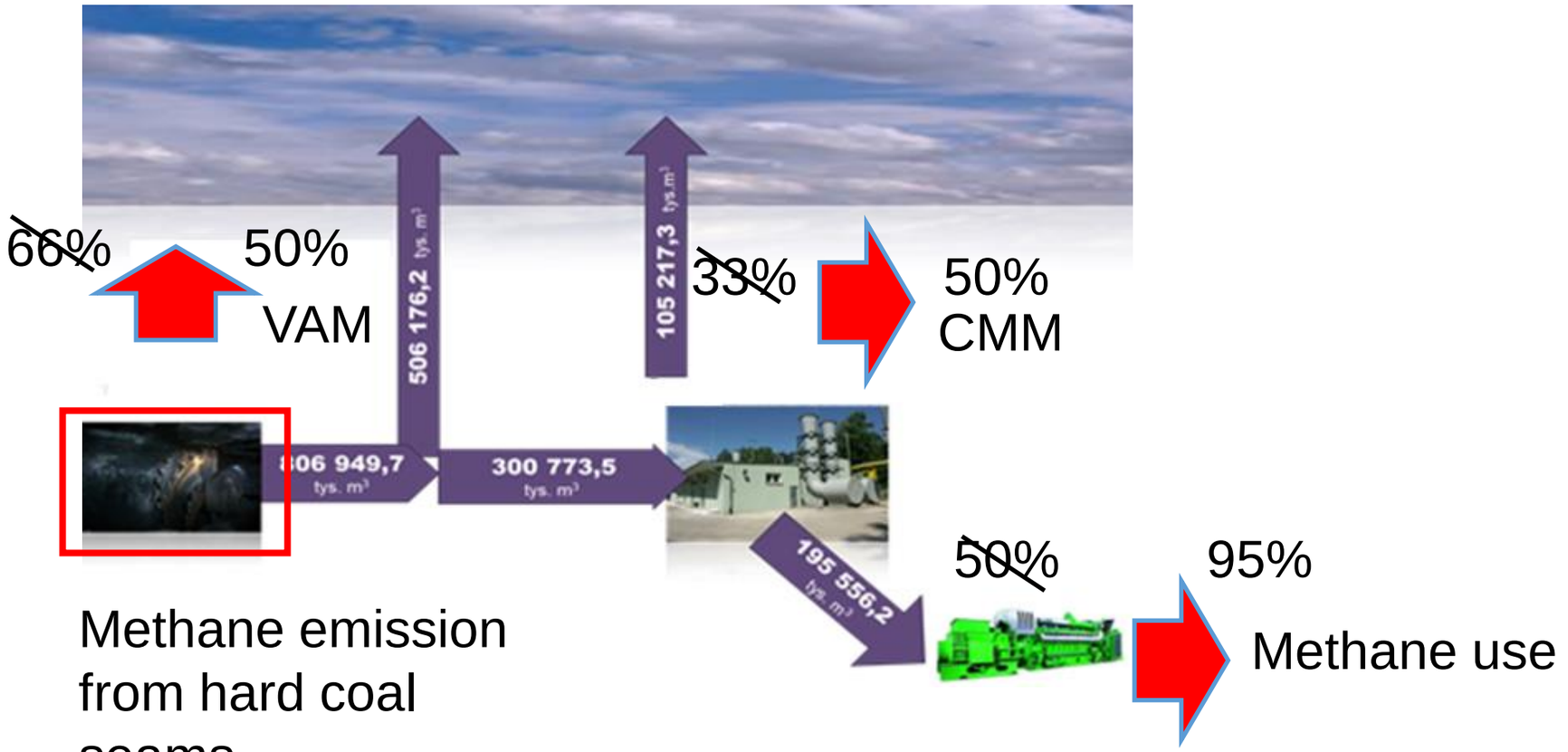
The issue of methane emissions in hard coal mines

- The mine's ventilation system keeps the methane concentration below the lower explosive limit. The average methane content in ventilation air can vary significantly depending on the methane content of the coal seams. In Polish hard coal mines, the methane content is usually 0.3% (it may be higher but never exceeds 0.75%).



- Despite low methane concentrations, ventilation air flow rates in mines are high enough to emit significant amounts of methane into the atmosphere. For this reason, ventilation air methane (VAM) is a key source of anthropogenic methane emissions.

Structure of methane emissions from underground mines

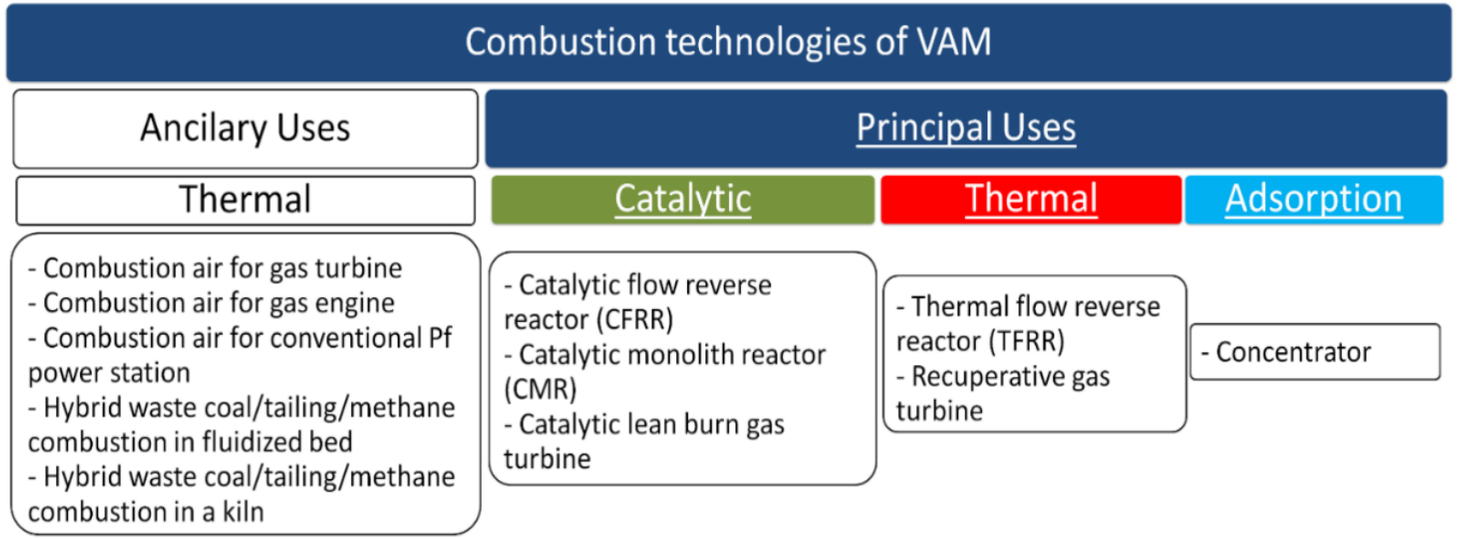


Methane emission from hard coal seams

The issue of methane emissions in hard coal mines

- The technologies, implemented on an industrial scale so far, are based on reducing VAM emissions mainly through thermal combustion. Others based on catalytic processes are being intensively developed.
- Technologies that enable the enrichment of the methane-air mixture to such methane concentrations that allow the use of capture mixture in existing devices are becoming more popular. This kind of solution requires higher contents of the flammable component in the fuel mixture for proper operation.

- VAM technologies

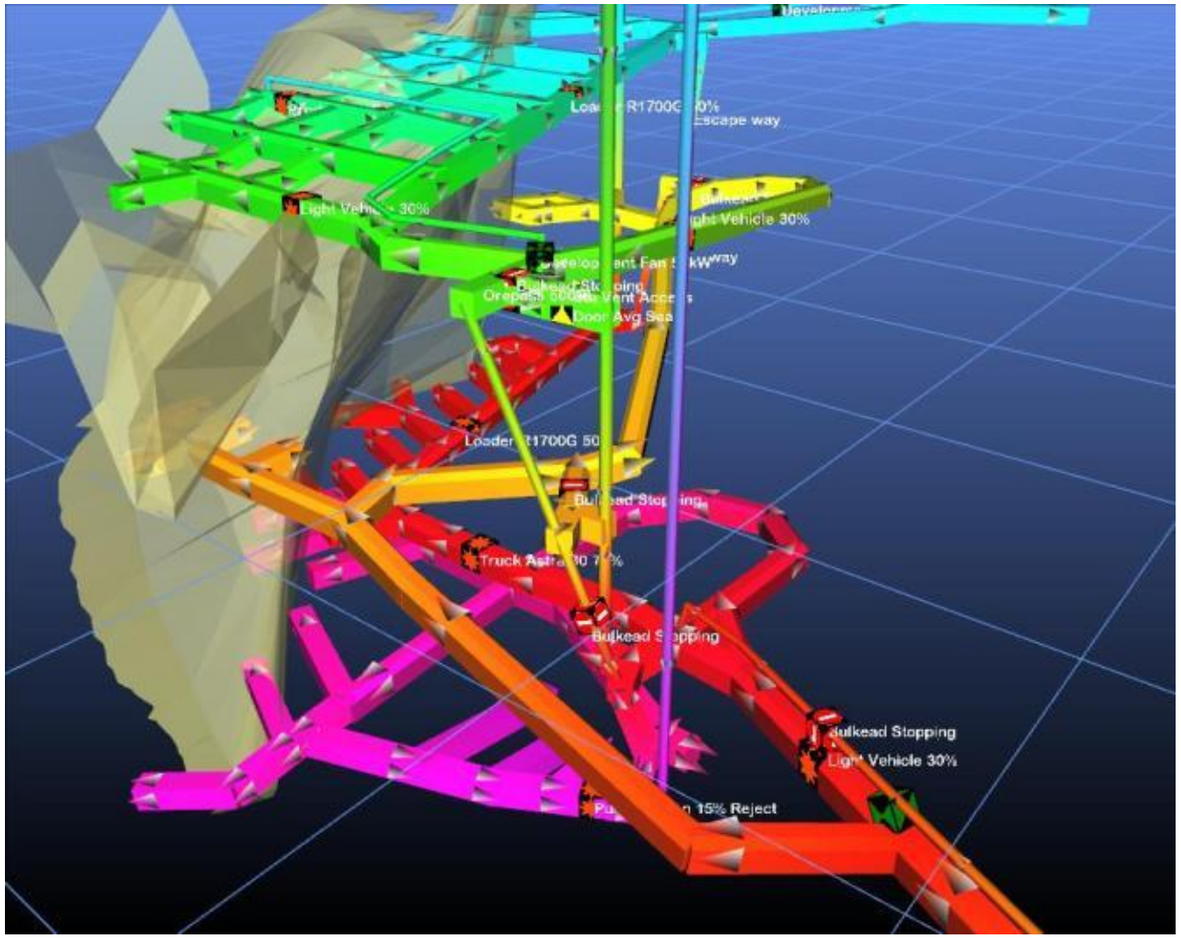


Mine characteristics

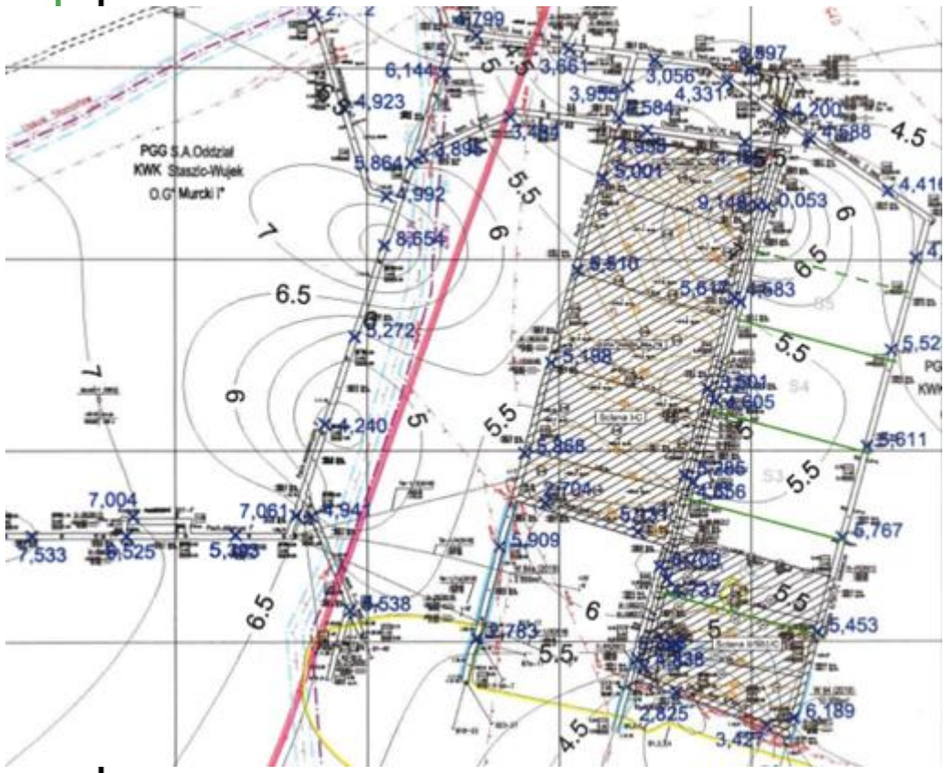
- Mining activities are carried out within the mining area of 26.9 km2. The hard coal deposit is located on the southern wing of the Main Basin of the GZW.
- The mine has 56.5 million tons of operational coal resources, with almost 42% located in the most productive seam, i.e., 510 (methane hazard category IV).

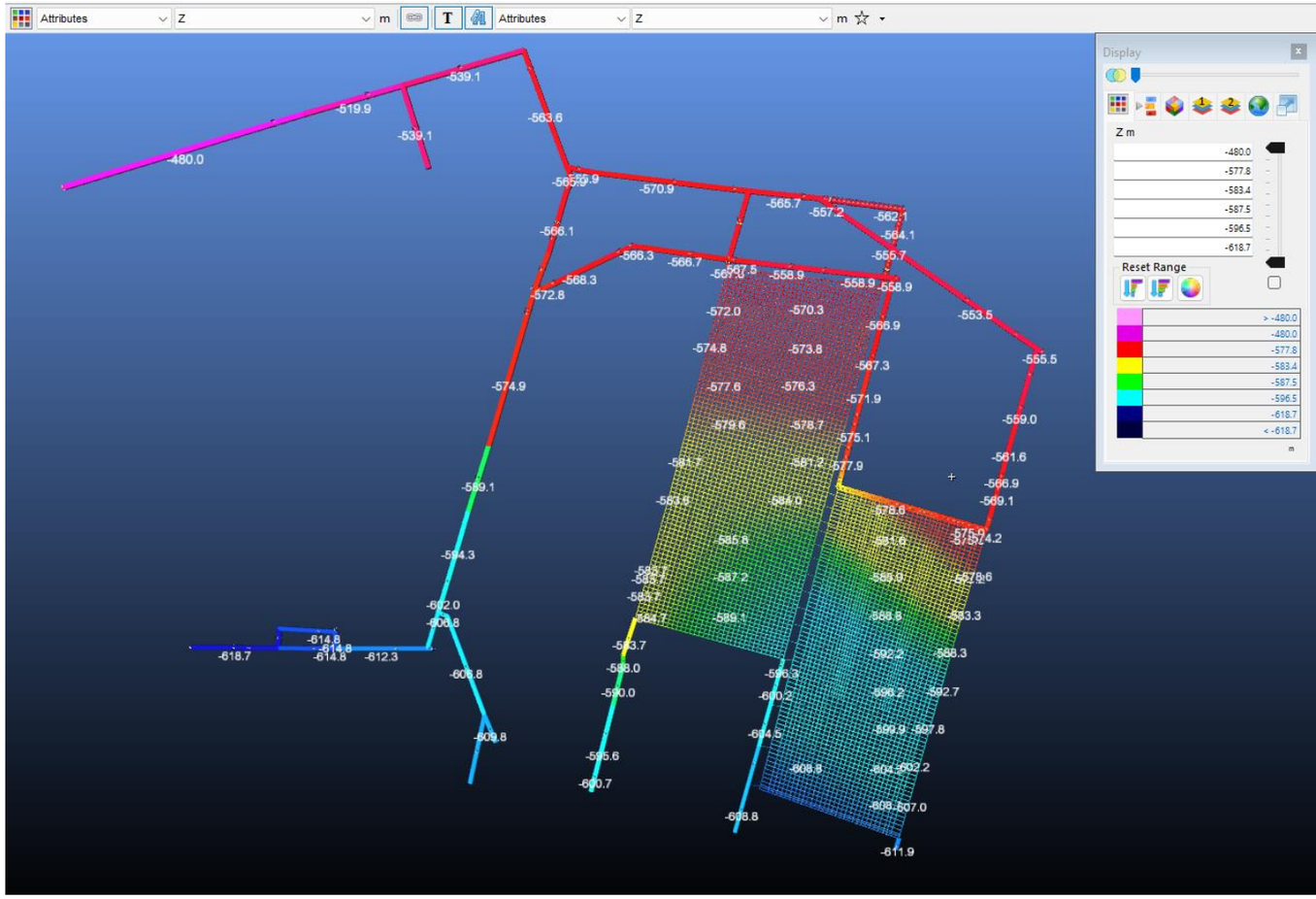
Simulation methodology - software

- 3D Ventsim interactive ventilation design
- Full use of graphics, color, animation and even sound to help you design and understand ventilation systems.
- Continuous modeling changes in ventilation systems as models are built and modified.
- Take full advantage of the 3D world environment to build, modify, extend, and design real systems;
- Incorporating other 3D graphics to build a real world with which the ventilation model interacts.



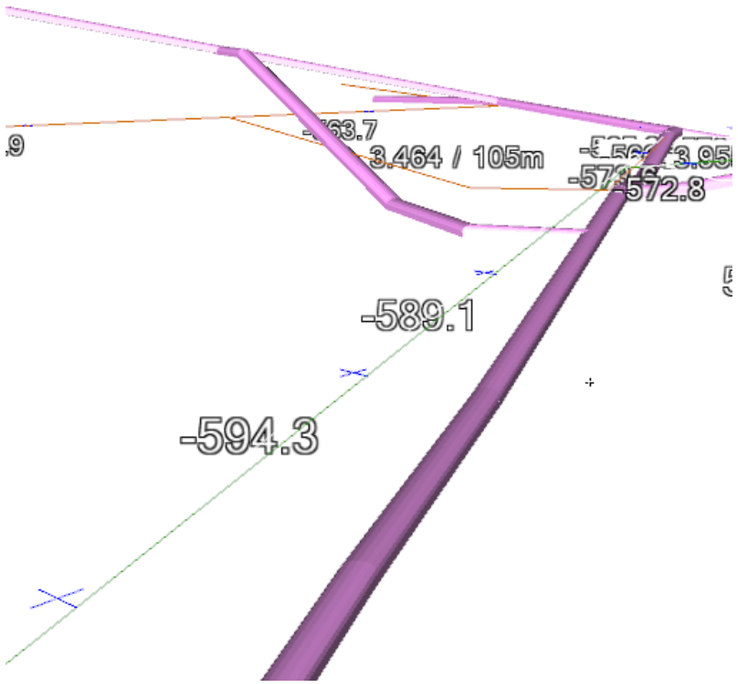
Modeling the structure of the ventilation network



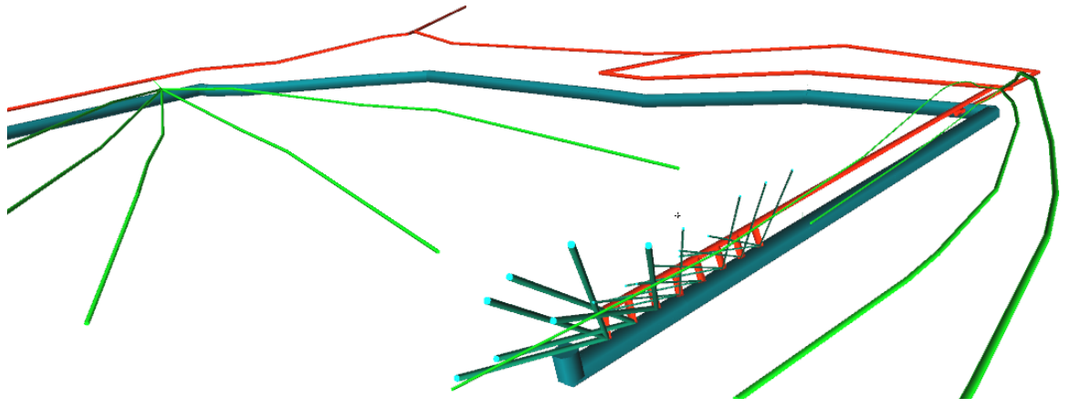


Modeling the structure of the ventilation network

- Creating a model of underground workings in VentSim DESIGN based on a vector drawing

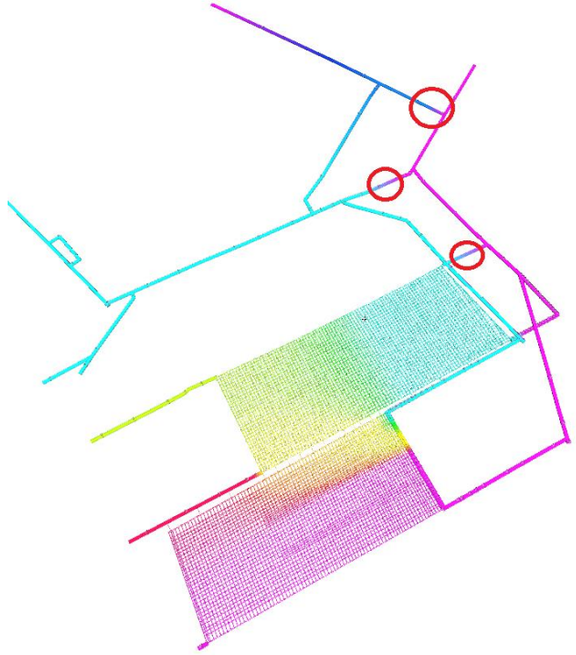


- Infrastructure of underground workings in the area in question (color: light green - directional holes, light blue - classic methane drainage holes, red - methane drainage pipelines, dark blue - duct fan and duct pipeline)

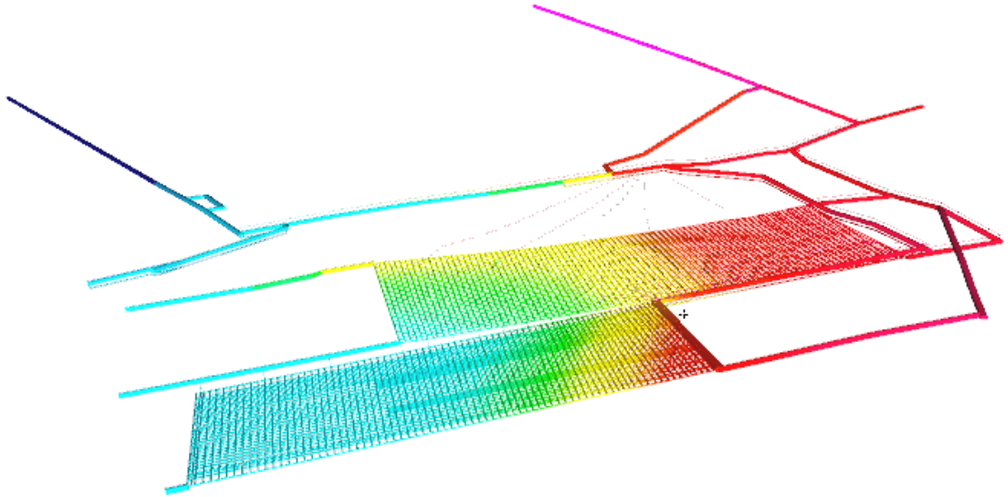


Modeling the structure of the ventilation network

- Change in total pressure along the airflow path (red circles indicate a large pressure drop and show places with built-in ventilation devices - dams separating fresh and used air streams)

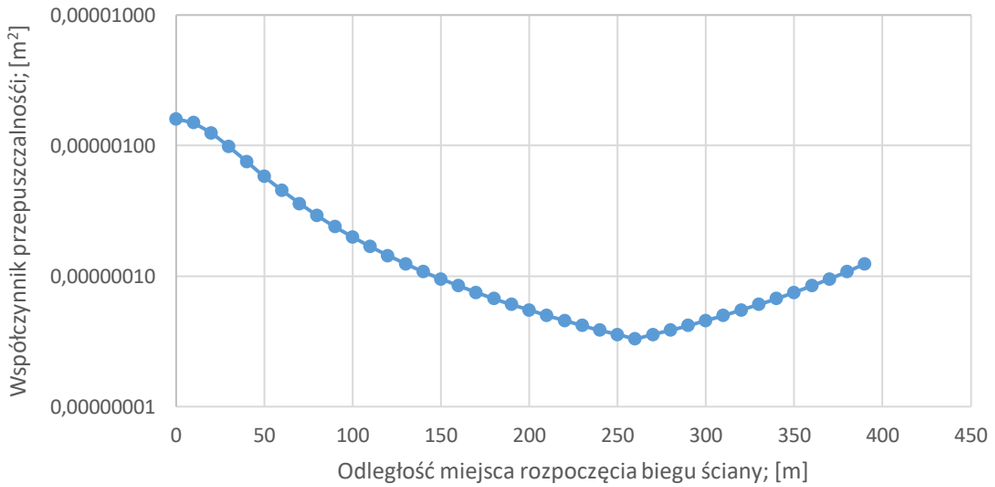


- Ventilation network with installations consisting of 11,652 sidings with a color scale showing the depth of deposition expressed in meters

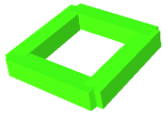


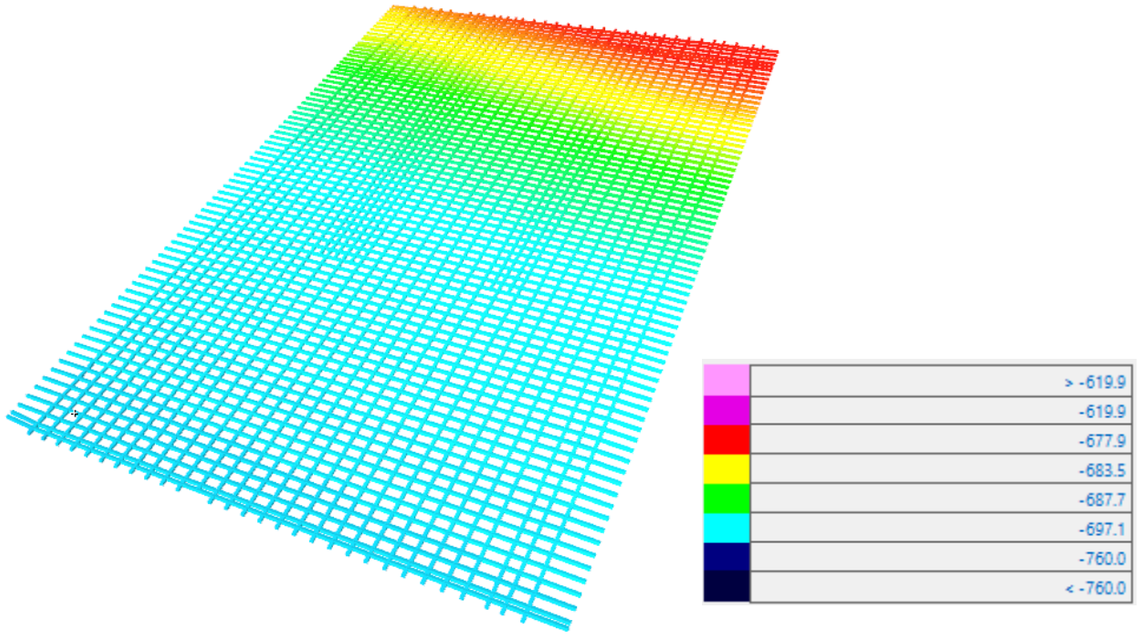
Modeling the structure of the ventilation network

- Graph of the permeability coefficient of wall goafs

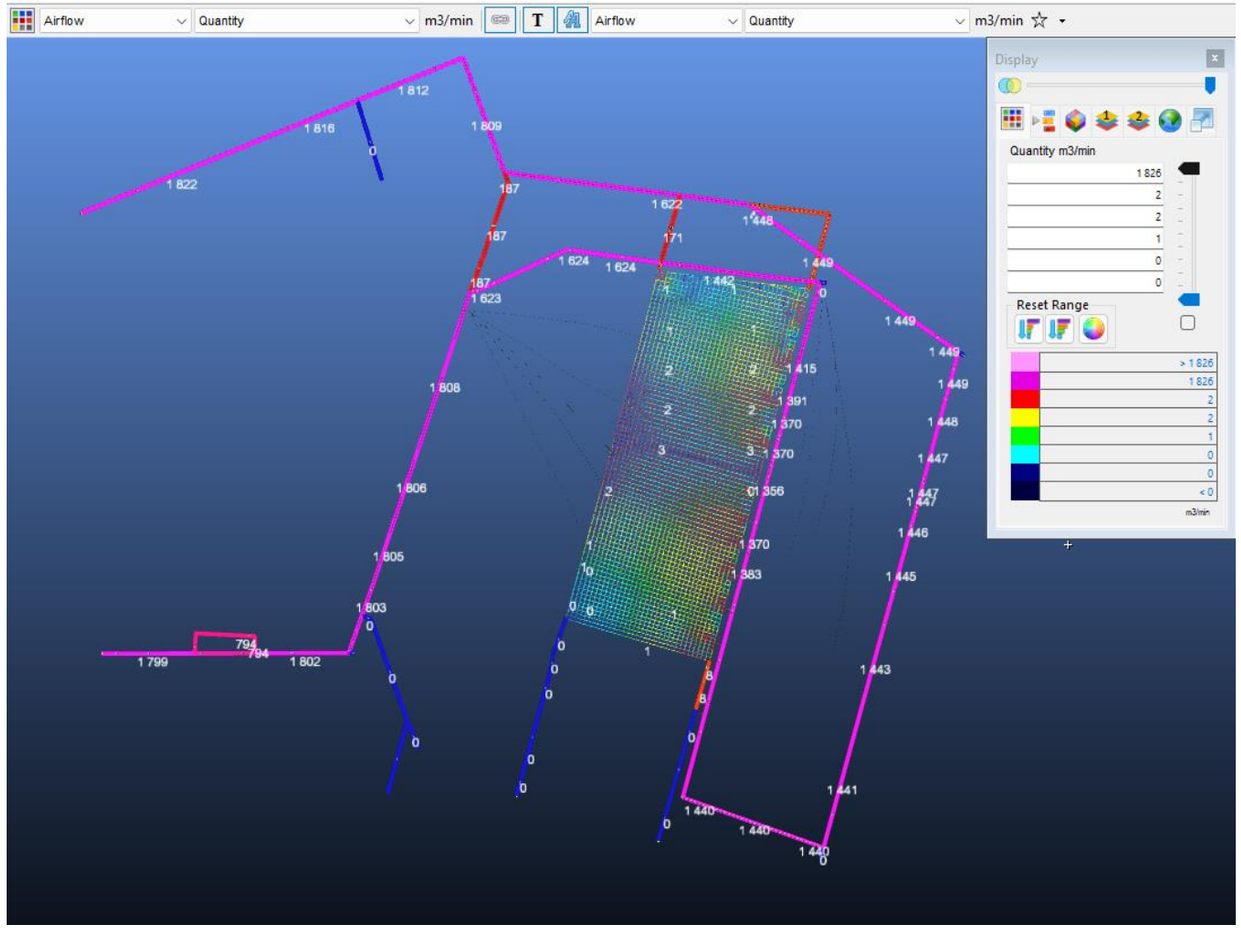


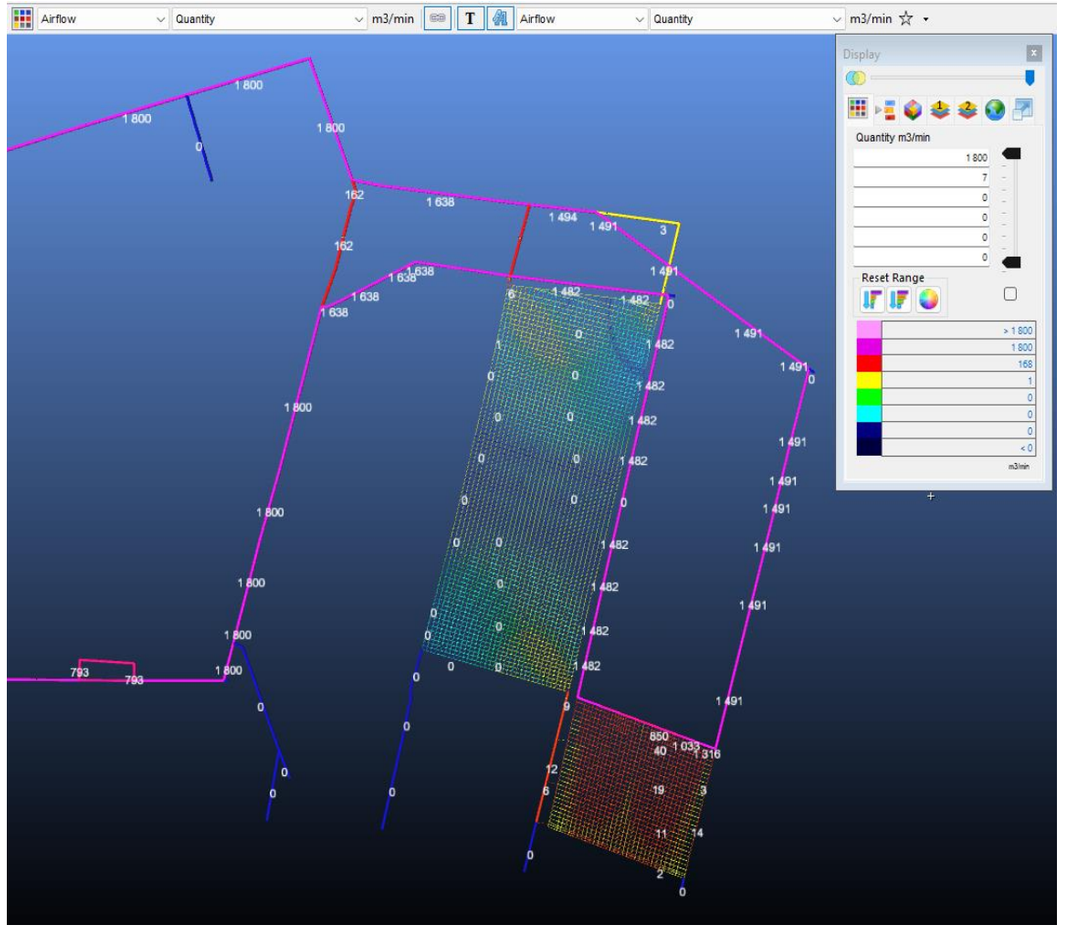
- Element of the working grid of the VentSim program





Airflow in goaves for different stages





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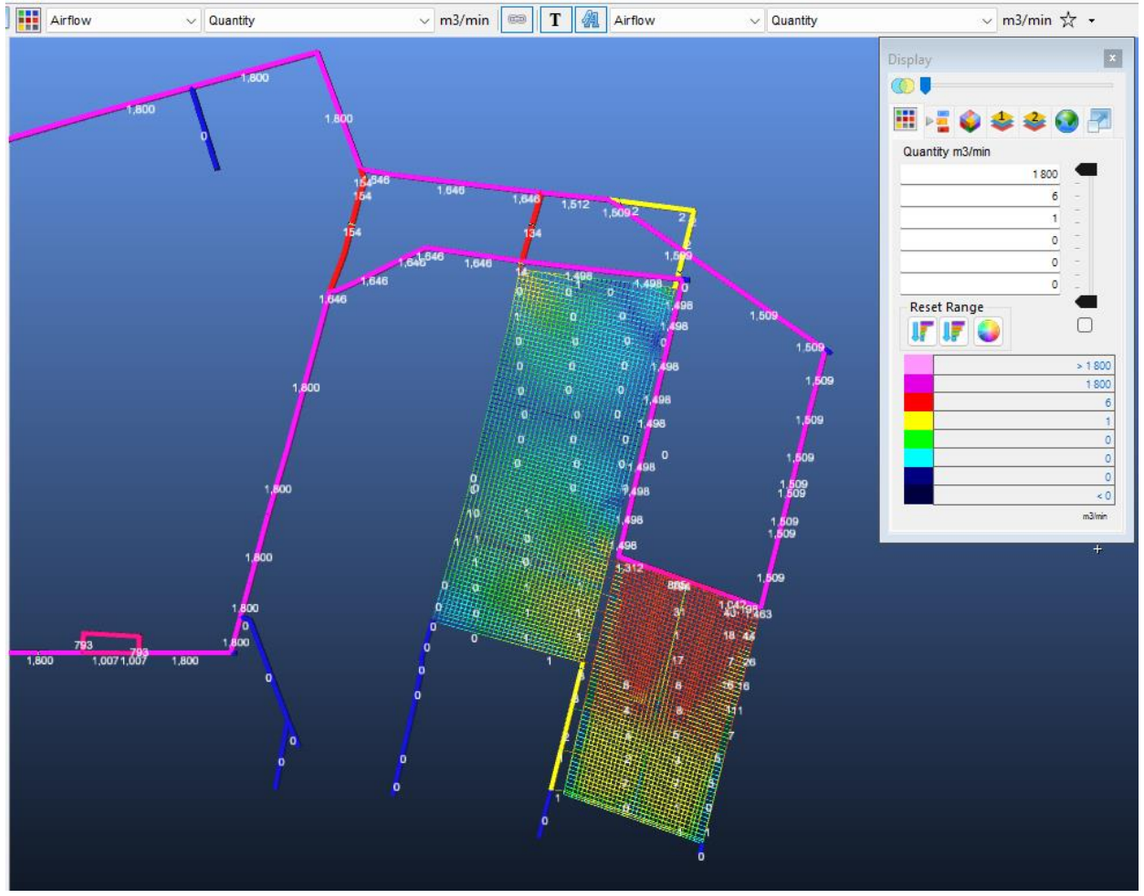
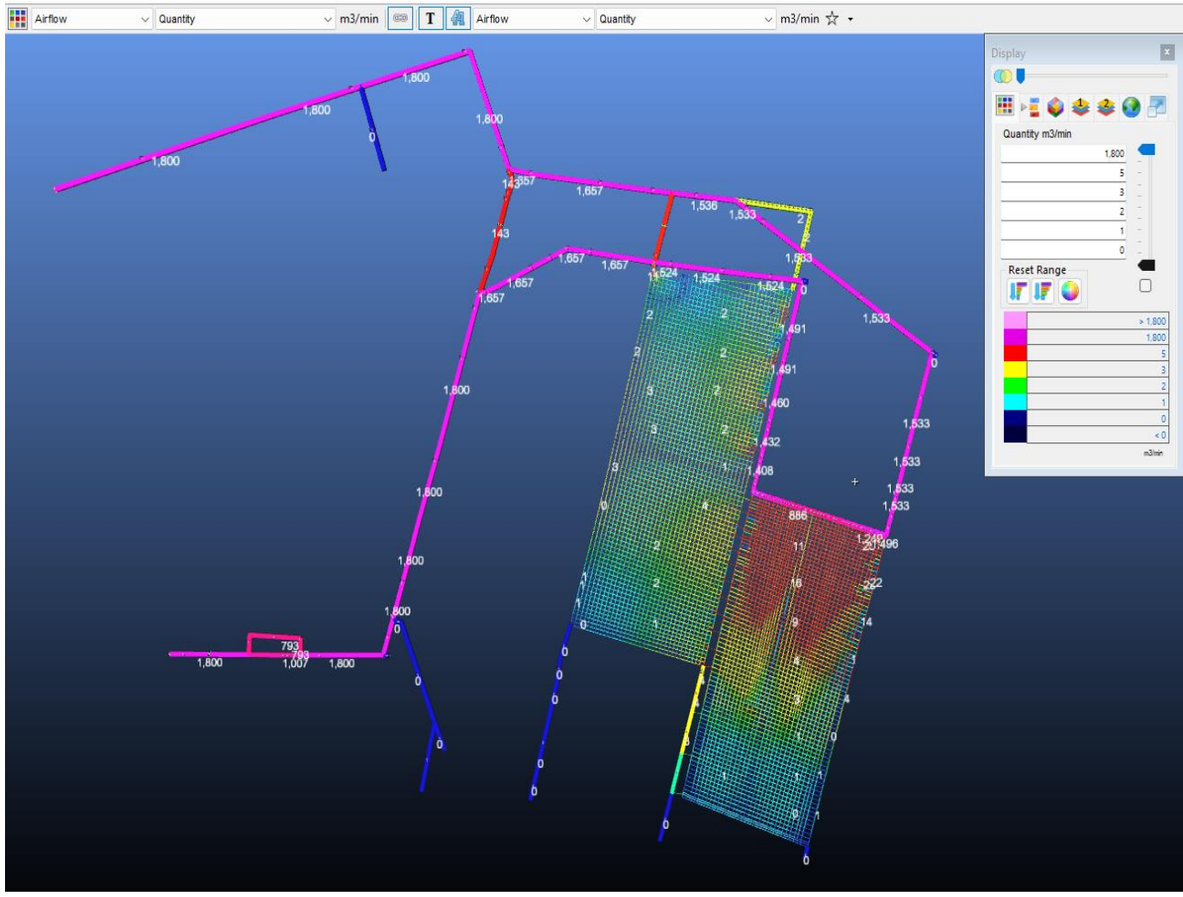




Underground sources of methane emissions

The amount of methane released into mining excavations, in particular into the mining excavation, depends on:

- methane emitted from the mined seam, both from the mined and transported coal and the exposed coal bed of the face or face,
- methane released from adjacent seams located in the ceiling and floor, which are within the operational influence.

The extent and amount of rock relaxation depend on both the method of roof management (backfilling, caving) and the nature of the rocks (rigid, ductile rocks).

Methane emission to exhausted goaf spaces

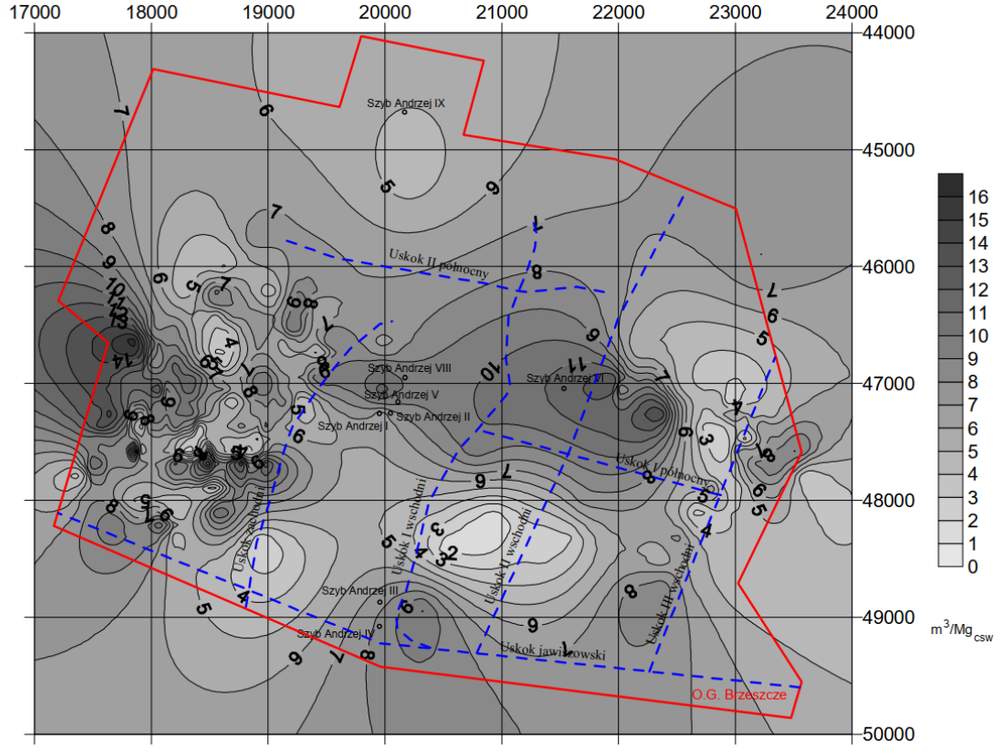
- Under the influence of coal seam exploitation, methane is released, which will be released into the workings and accumulate in the selected working area.

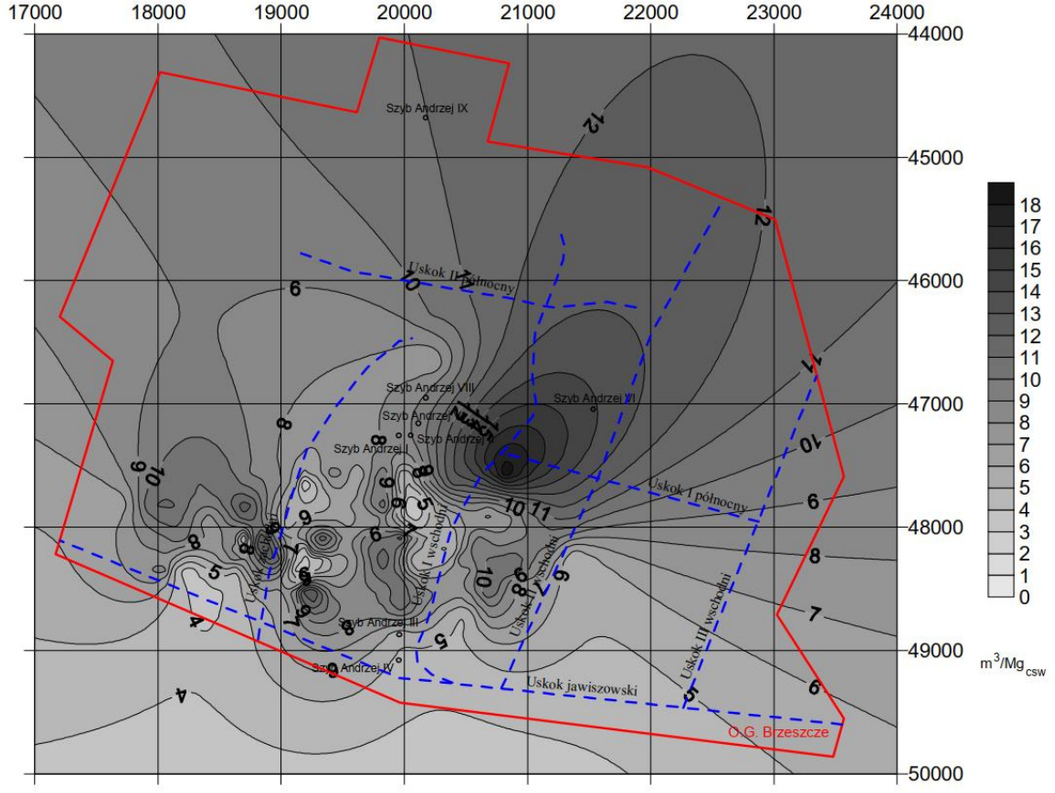
Methane emission and flow in the rock mass and mining excavations

At a given point (place) in a rock mass/mining excavation, three sources influence each other to varying degrees:

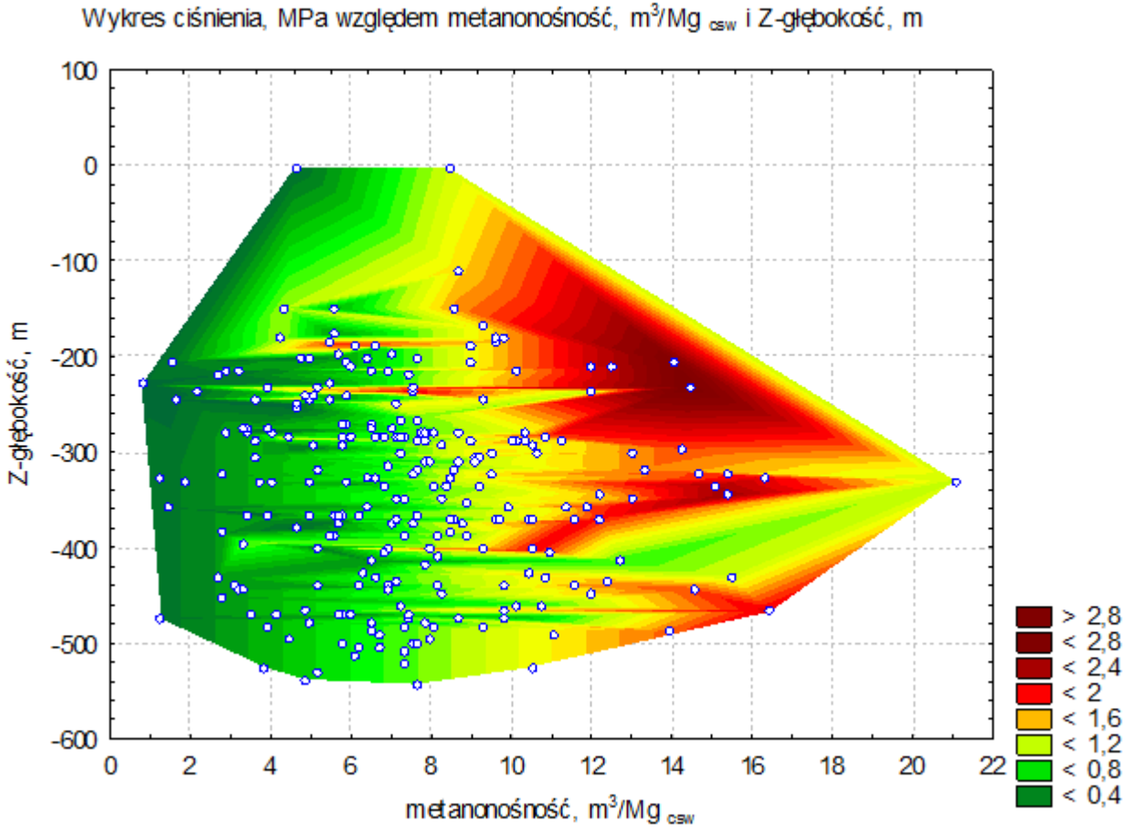
- Methane formation pressure in the coal seam (for 8 m^3/Mg_{csw} -> ~1.0 MPa),
- Negative pressure in the methane drainage network generated by the methane drainage station (SO-> ~0,4 MPa; O -> 0.006 MPa),
- Negative pressure in the mine ventilation network created by the main fans (W-> ~0,004 MPa; W -> 0.001 MPa),
- Atmospheric pressure 0.1 MPa (reference).

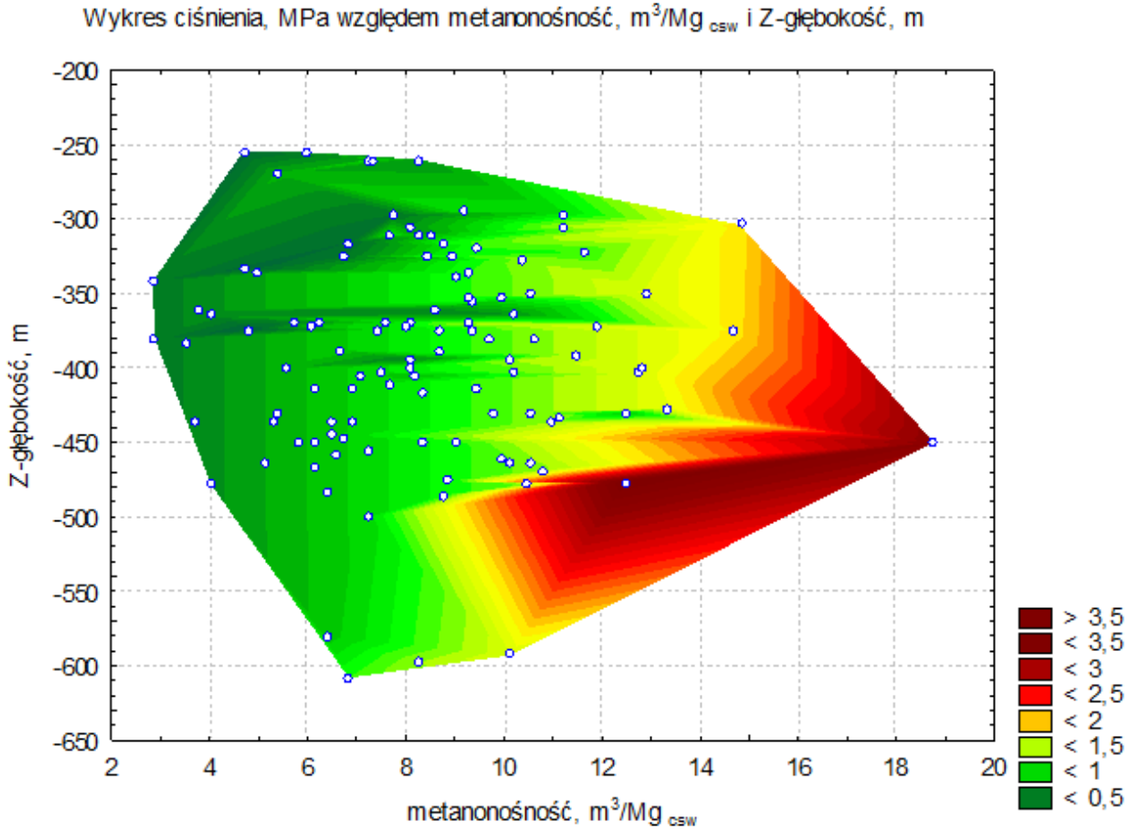
Isoline map of methane content in seams 364 and 510



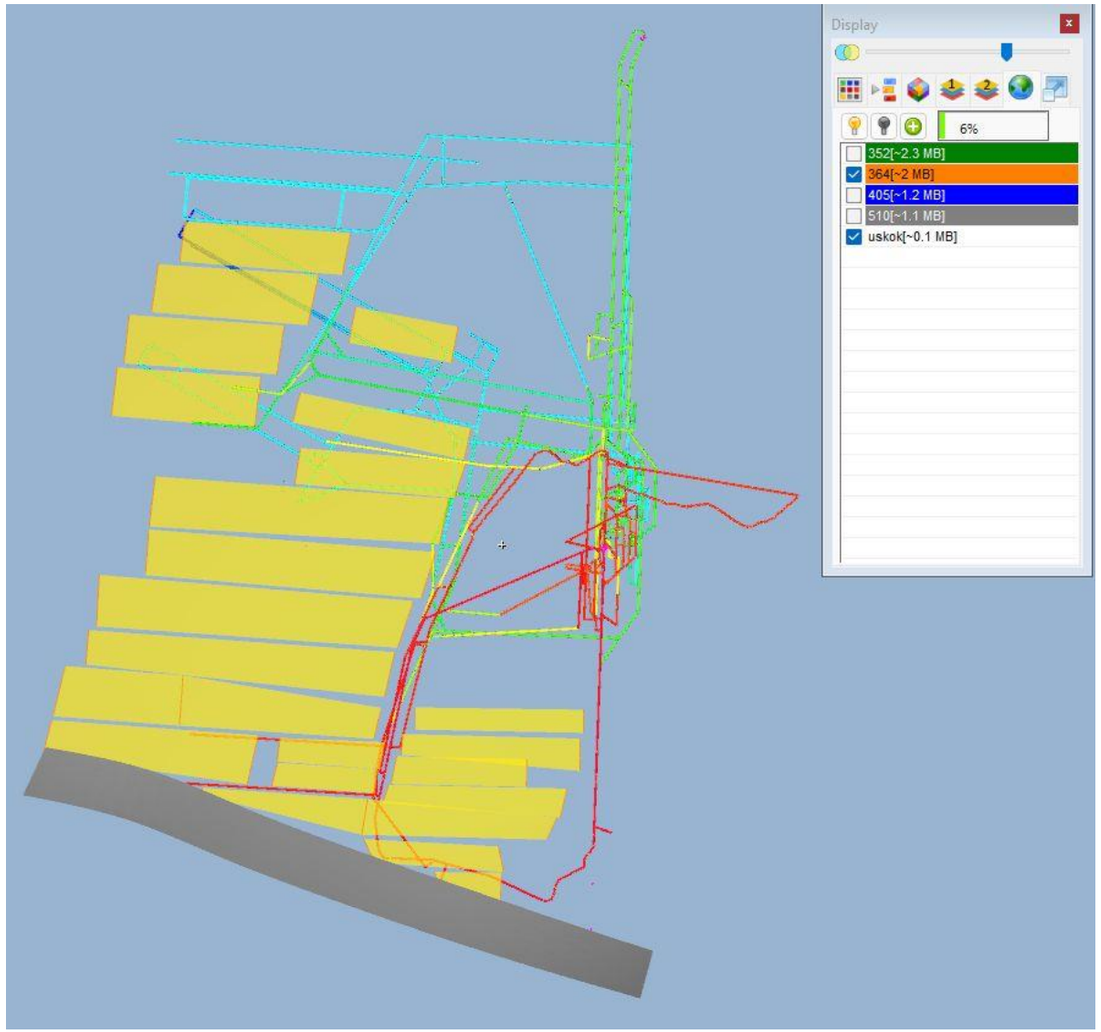


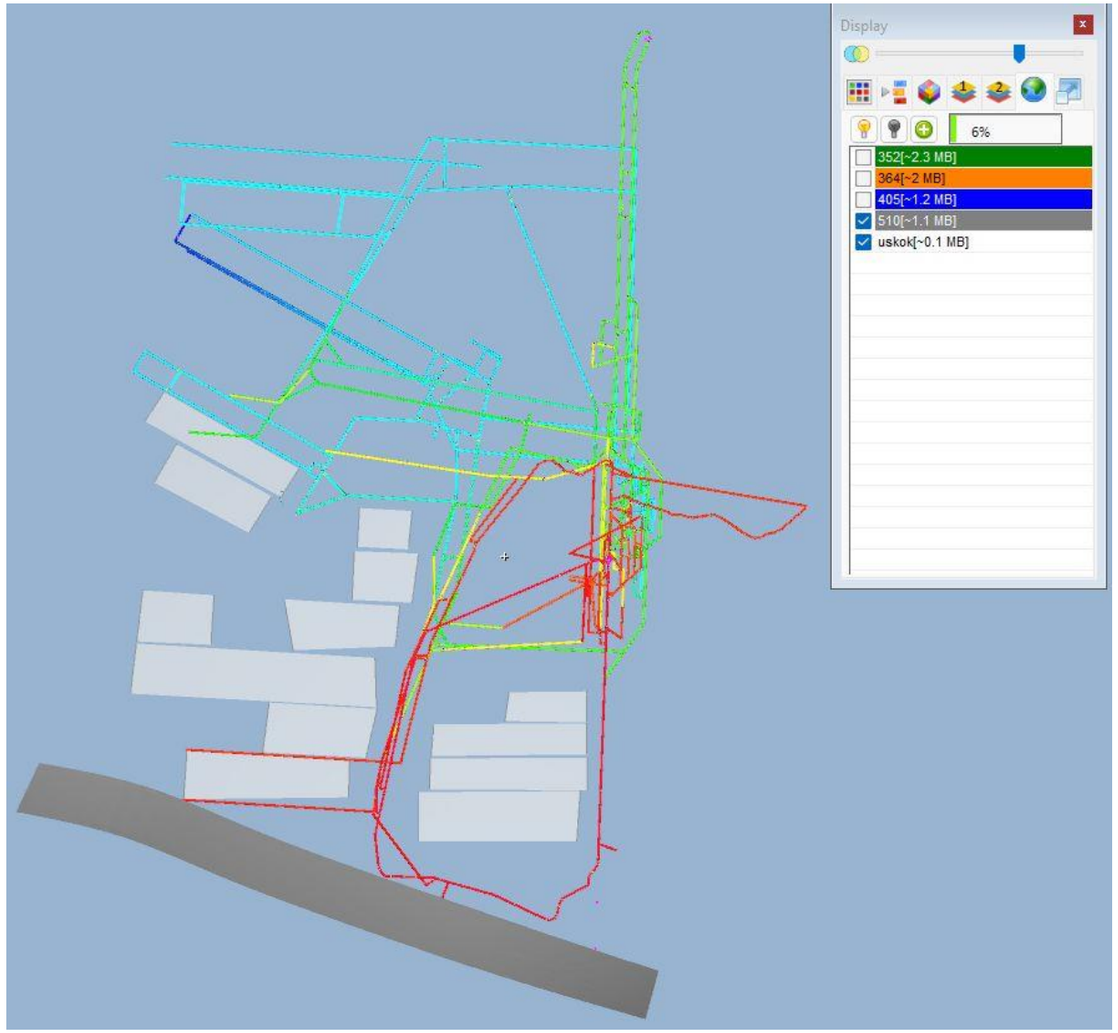
"Waffle" plot of reservoir pressure versus methane content and depth in seams 364 and 510



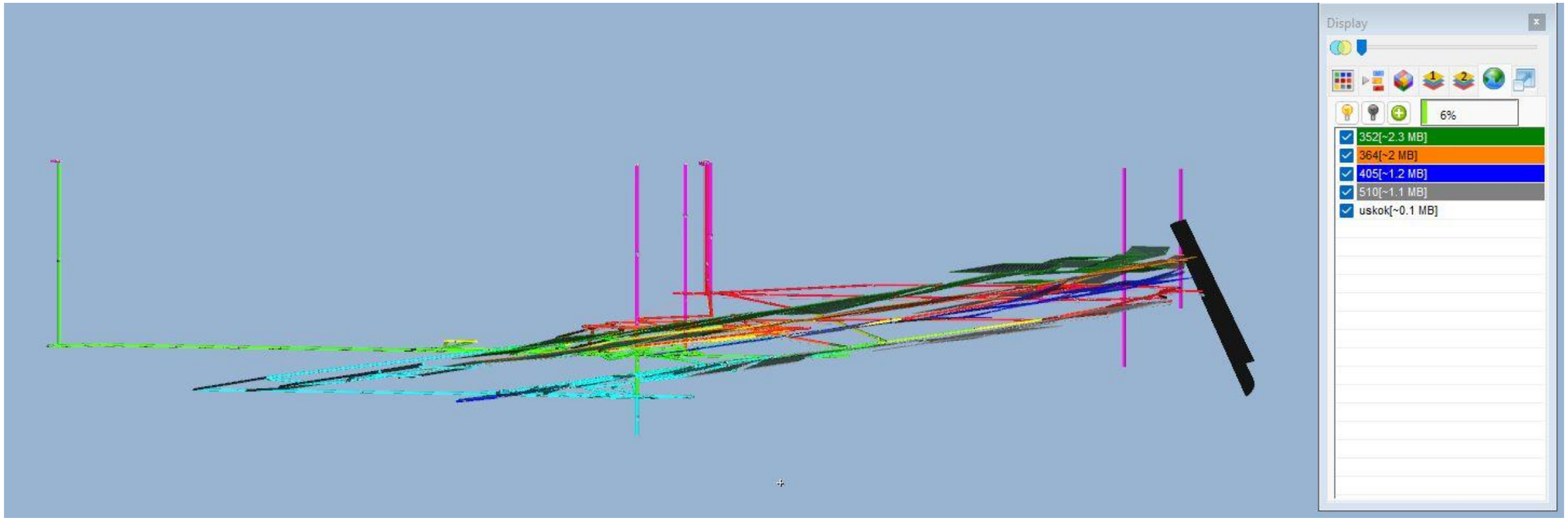


Projections of post-mining goaves in seams 364 and 510

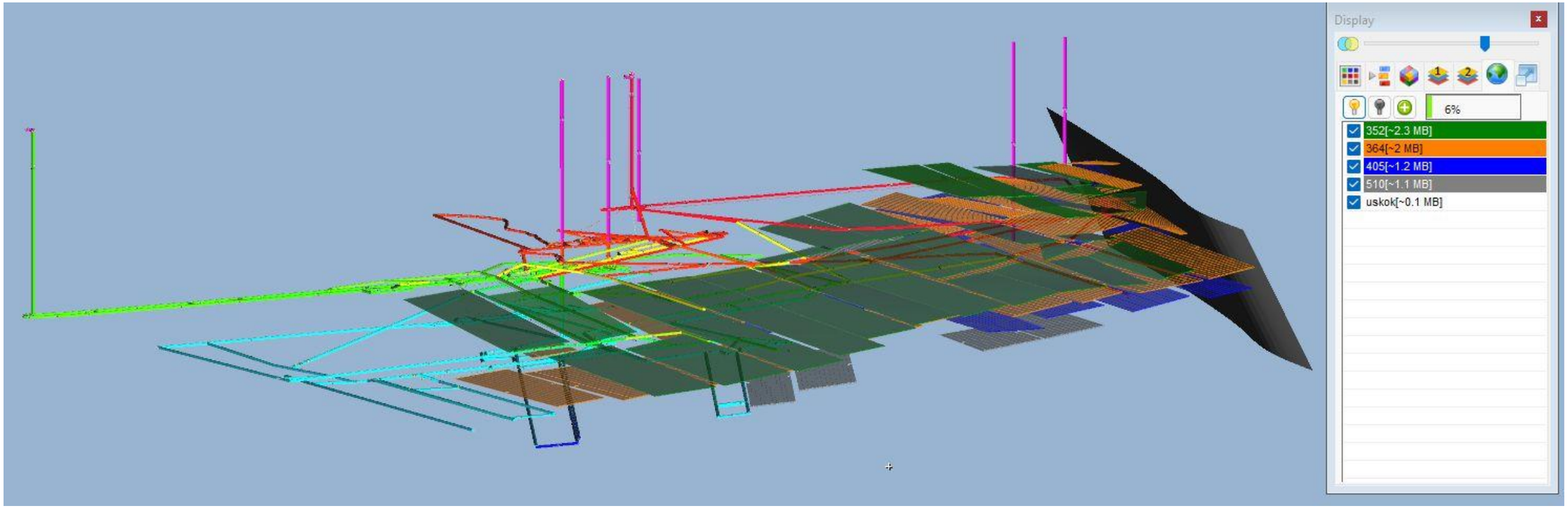




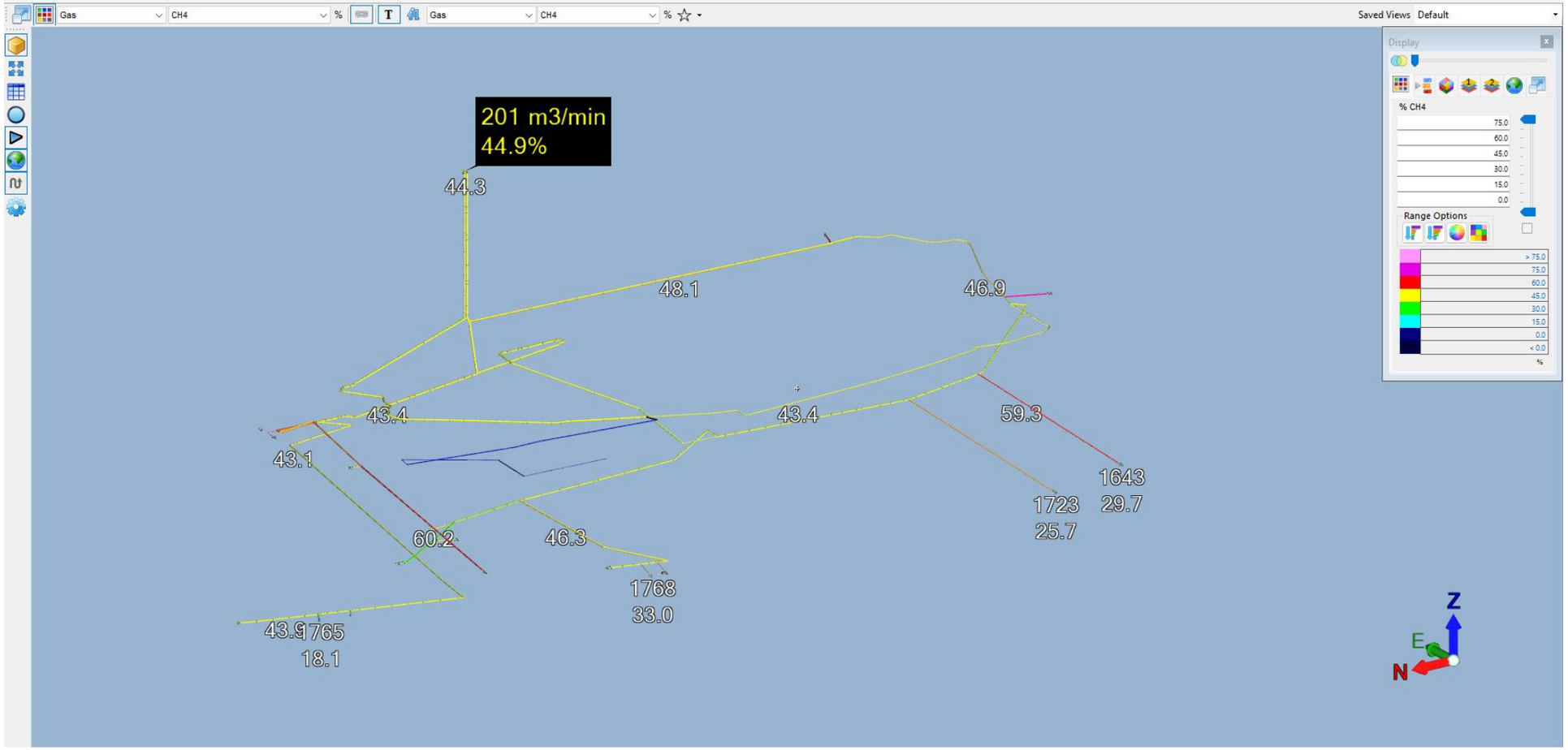
Vertical cross-section of the ventilation network and post-mining goaves in seams 364 and 510



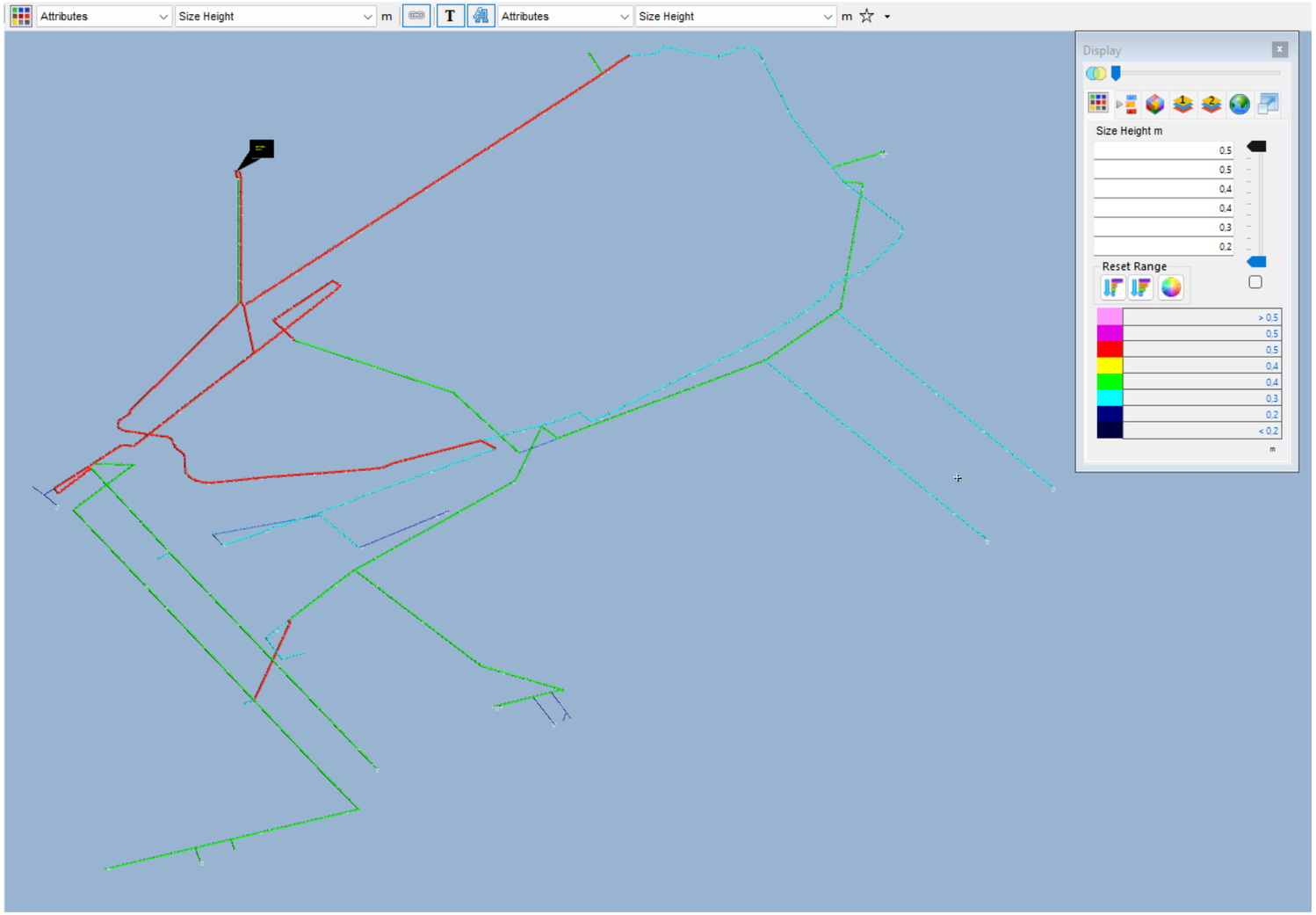
Isometric projection of the ventilation network and post-mining goaves in seams 364 and 510



Projection of isometric methane drainage networks with methane concentrations in methane drainage pipelines

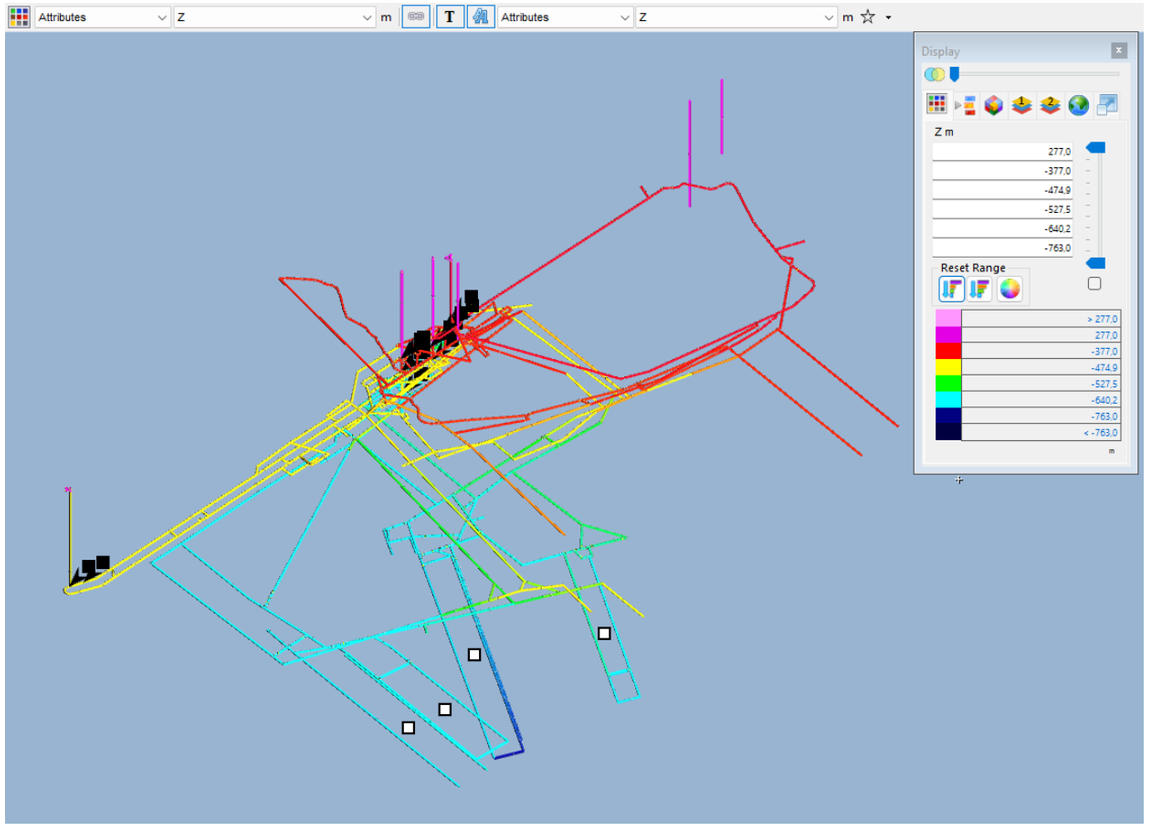


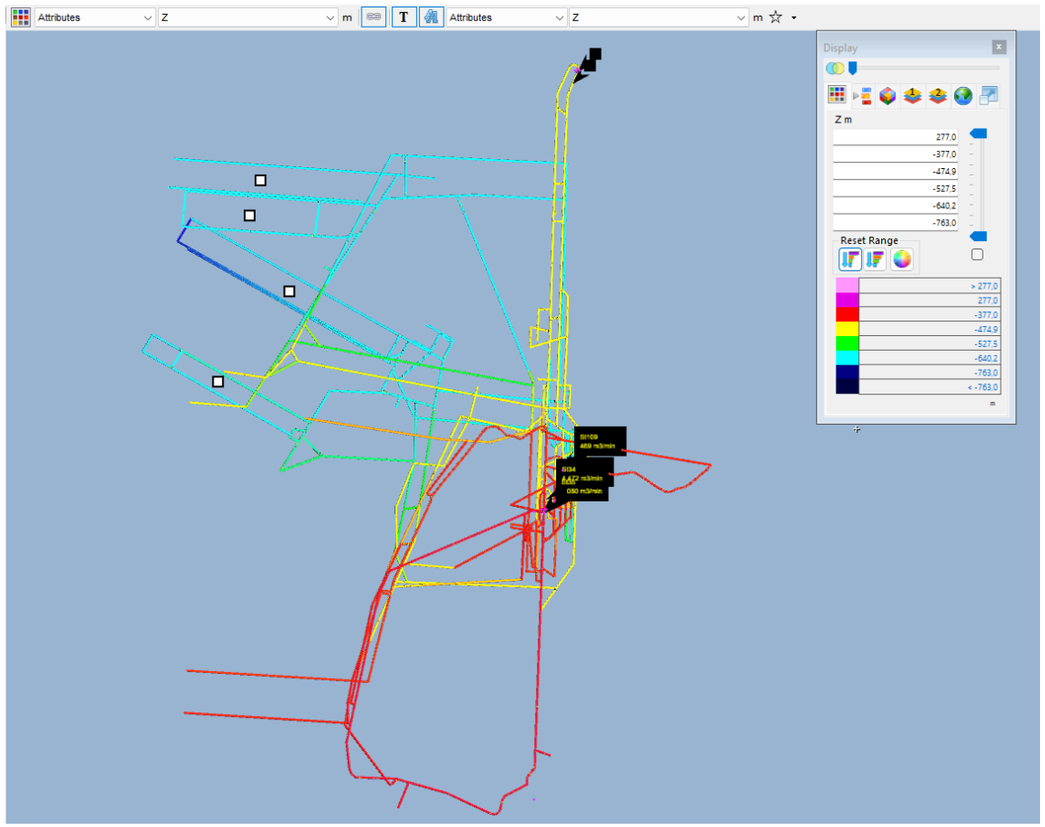
Diameters of methane drainage pipelines, isometric projection



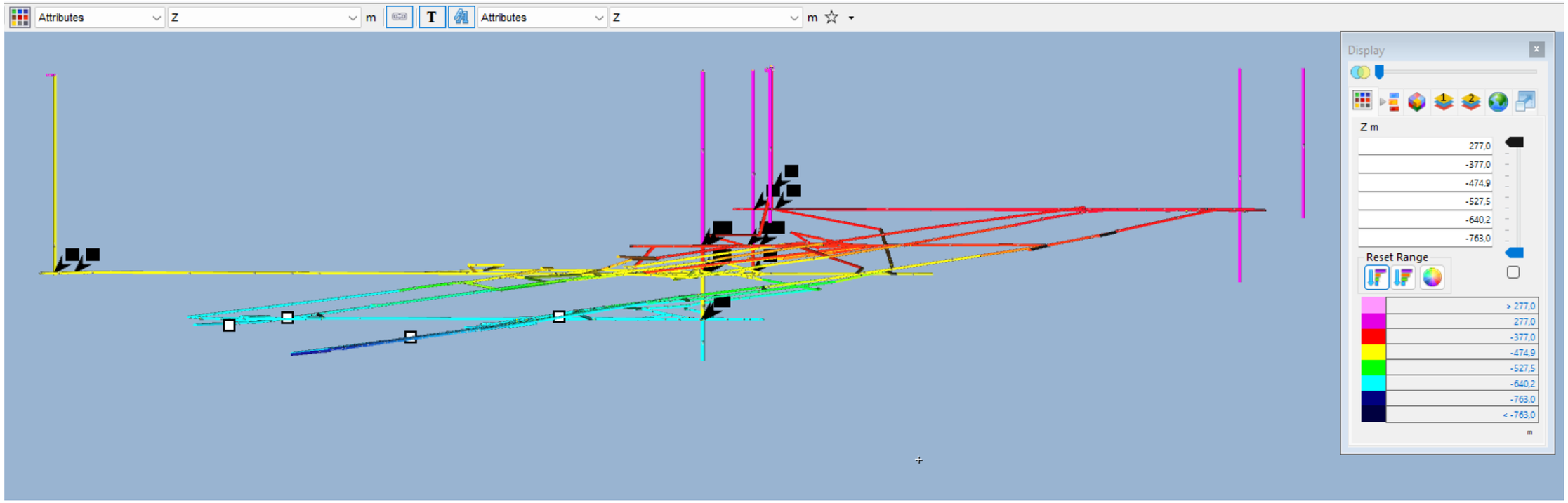
Diameters of methane drainage pipelines, vertical cross-section

The structure of the ventilation network with a color scale showing the depth of location of individual workings

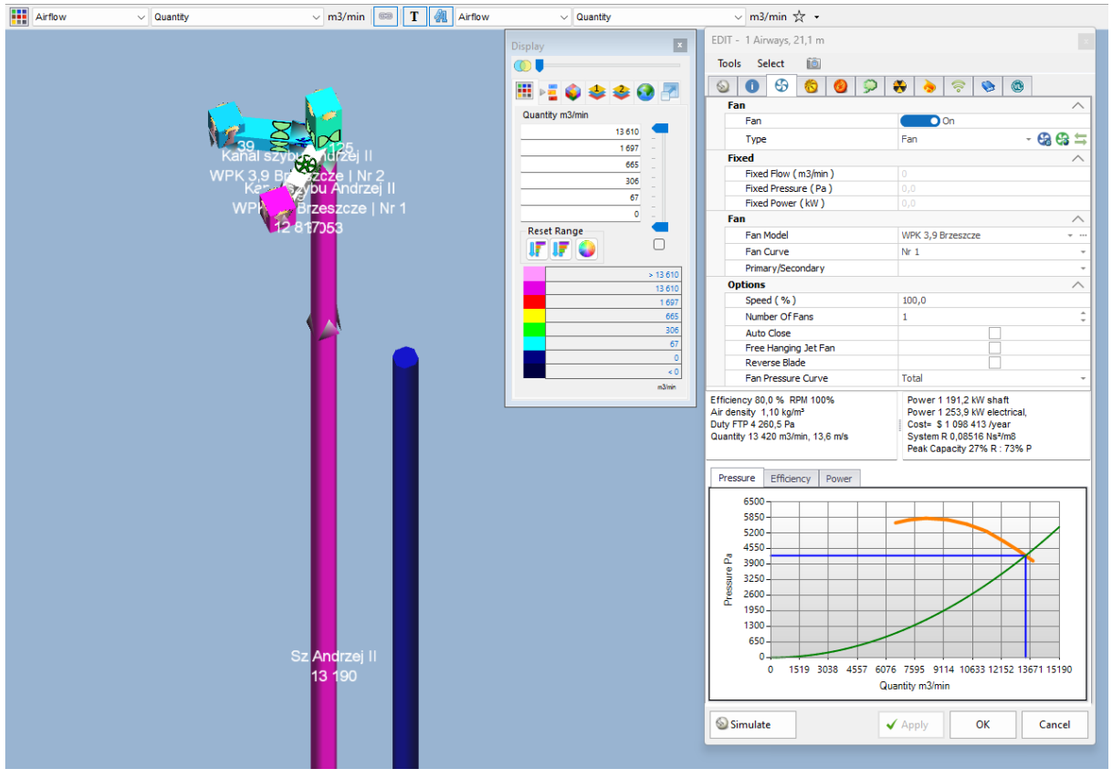


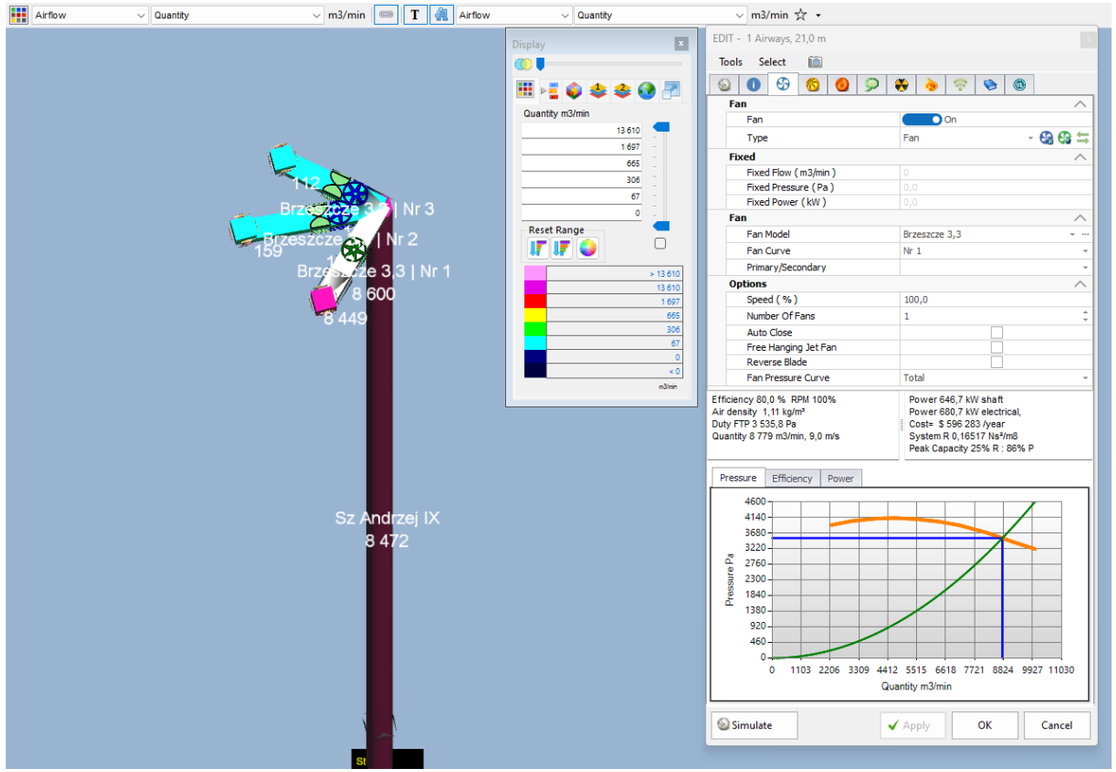


The structure of the ventilation network in the vertical section

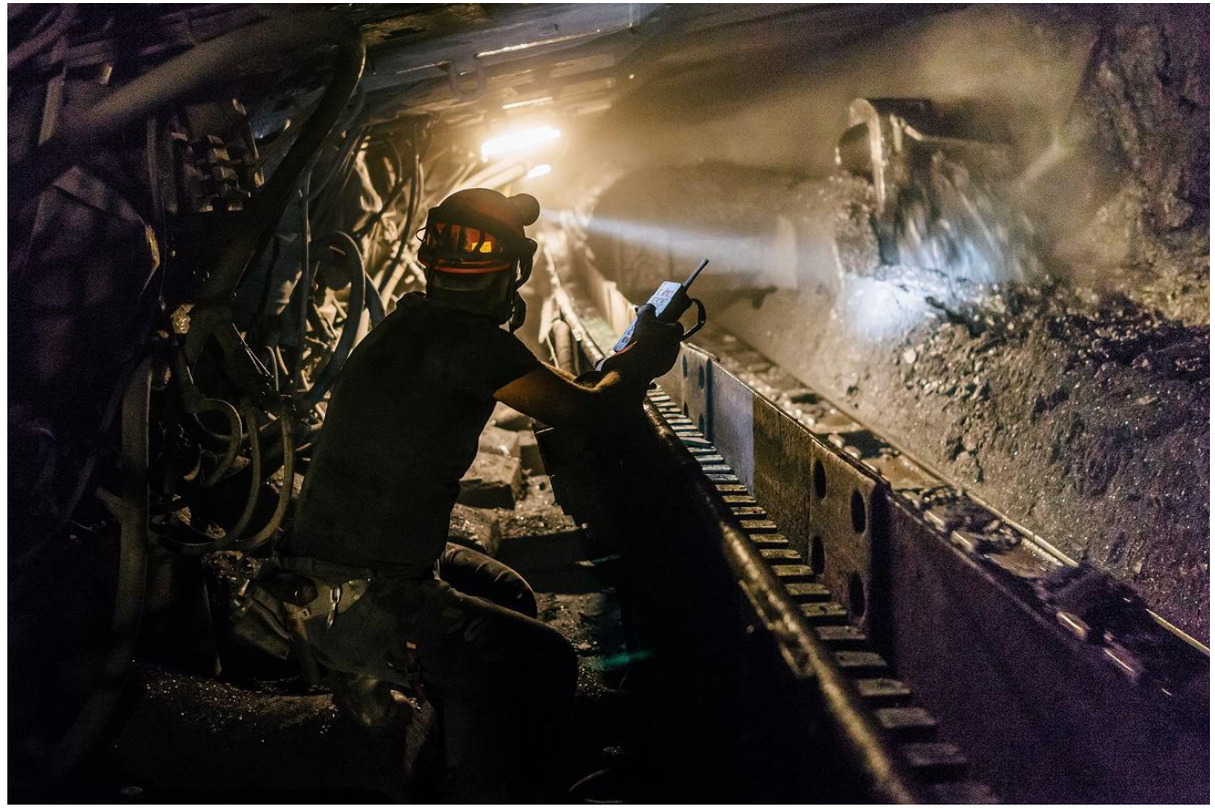


Characteristics of fans at ventilation shafts



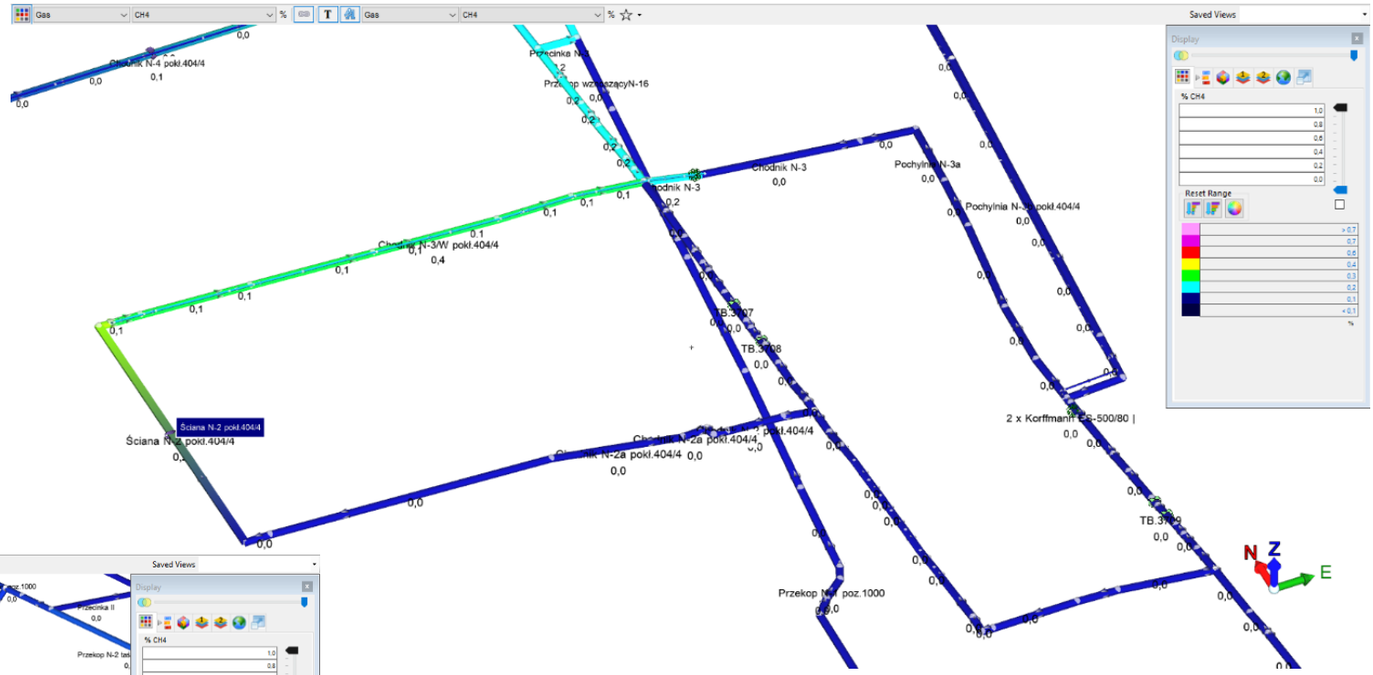


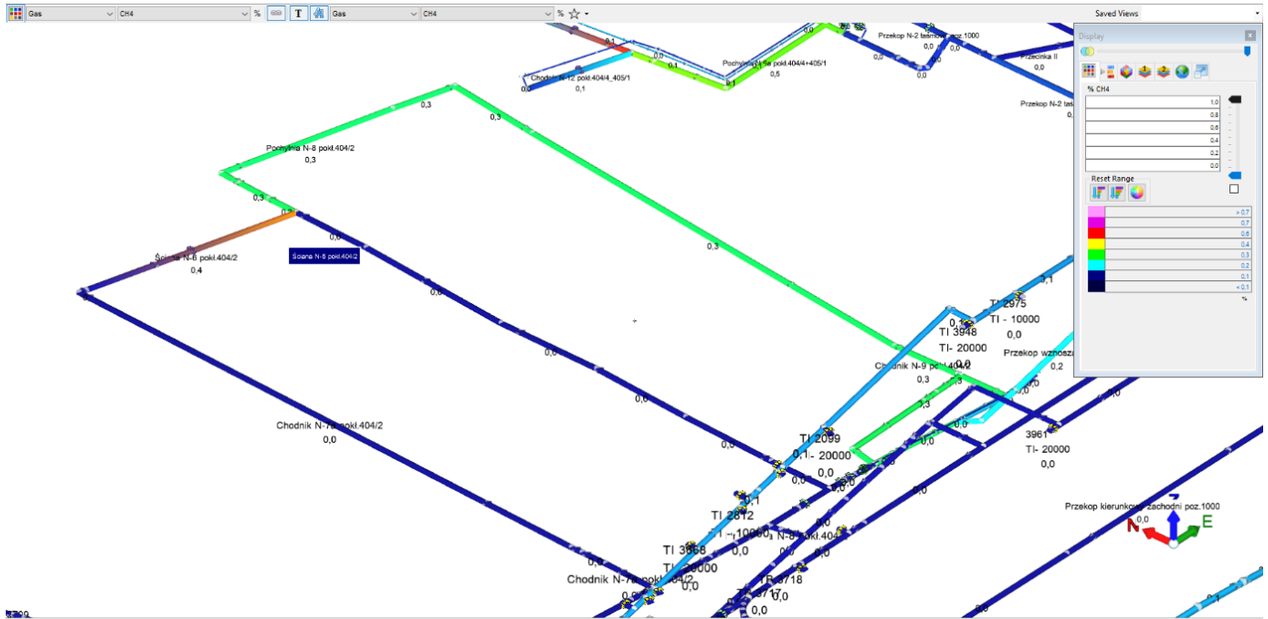
Forecasting air flow and methane emissions



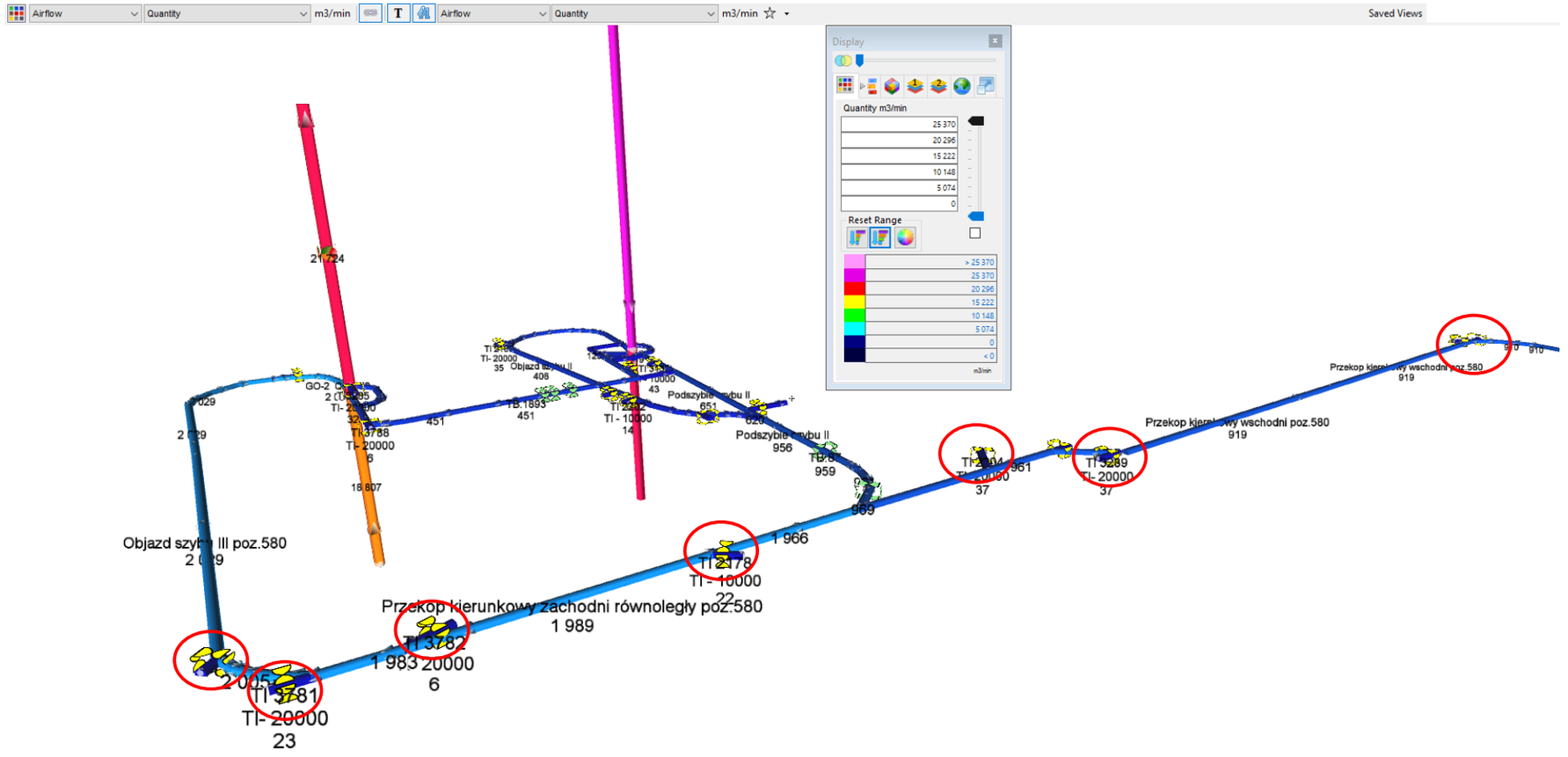
- Simulating airflow and methane emissions in hard coal mines is important to improve employee safety, environmental protection, and production efficiency.

Methane concentration in mining excavations

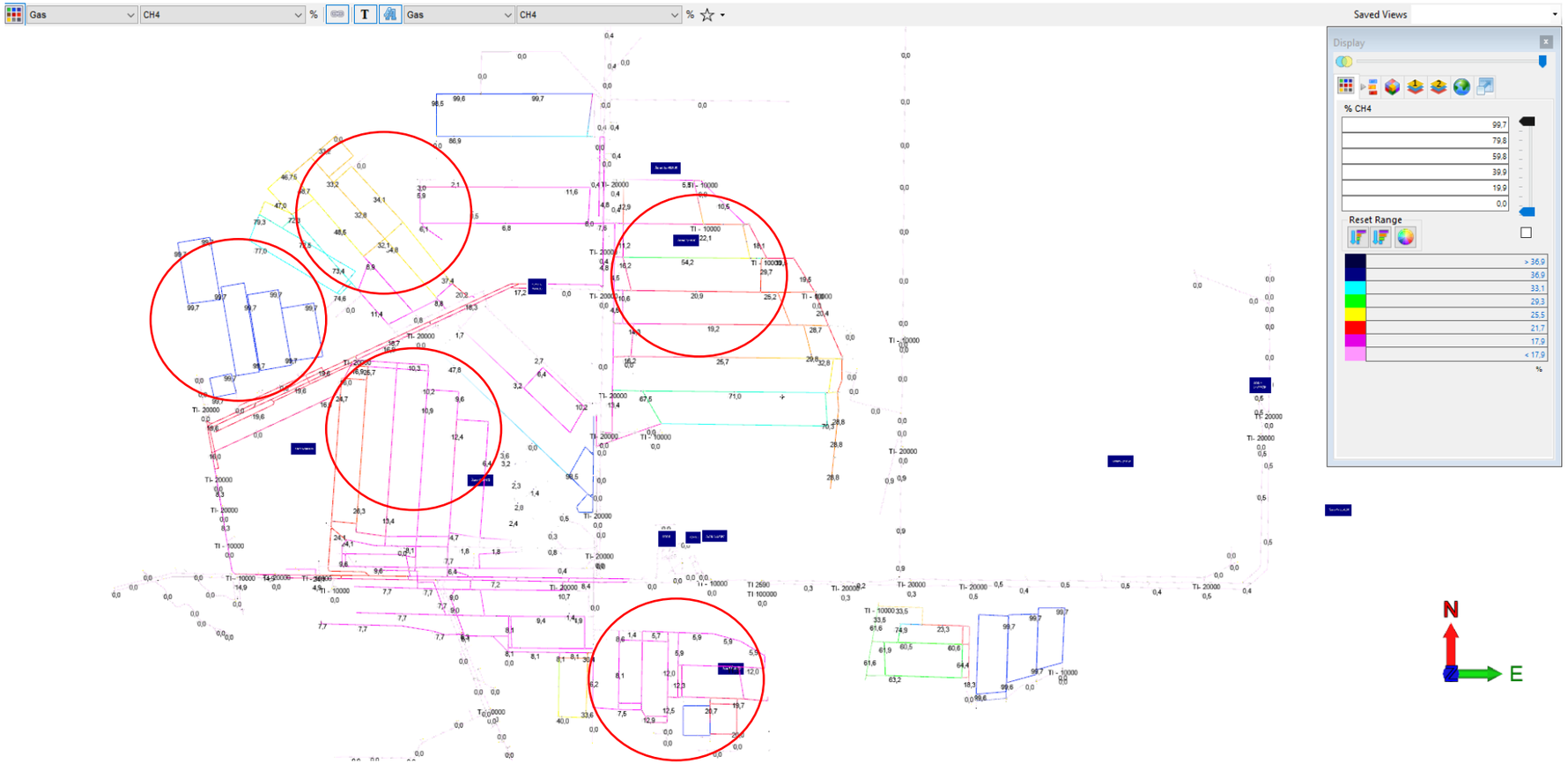




Methane emission to mine workings through isolation dams



Methane emission to selected goaf spaces



Summary

- Forecasting methane emissions using advanced software plays a key role in safety, environmental protection, production efficiency, and sustainable development.

Thanks to simulations, you can:

- effectively manage methane emissions, control and reduce VAM methane emissions more effectively,
- improve employee safety by identifying risk areas and optimizing ventilation,
- use the captured methane to produce heat and electricity.

Thank you for your attention