Optimizing barrier placement for lava flow hazard and risk mitigation

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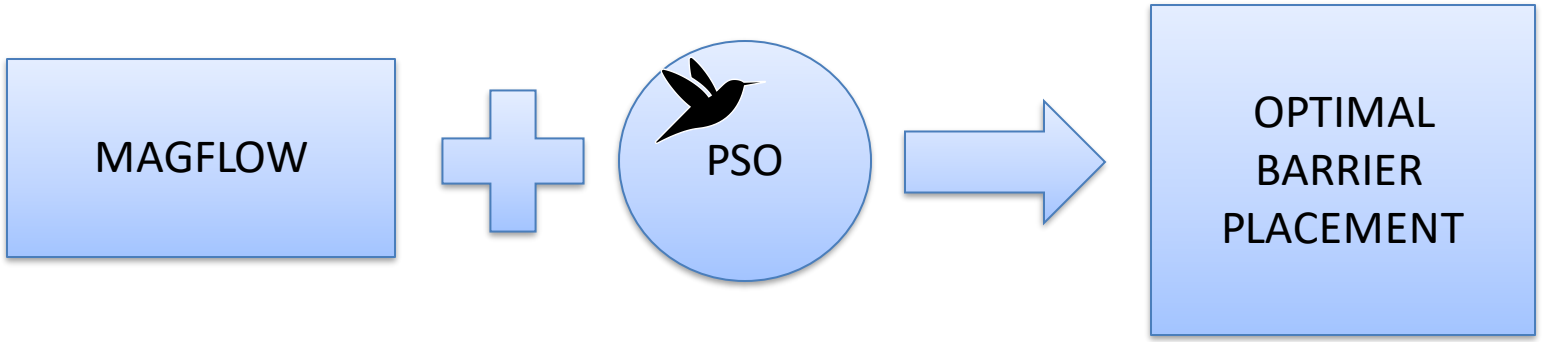
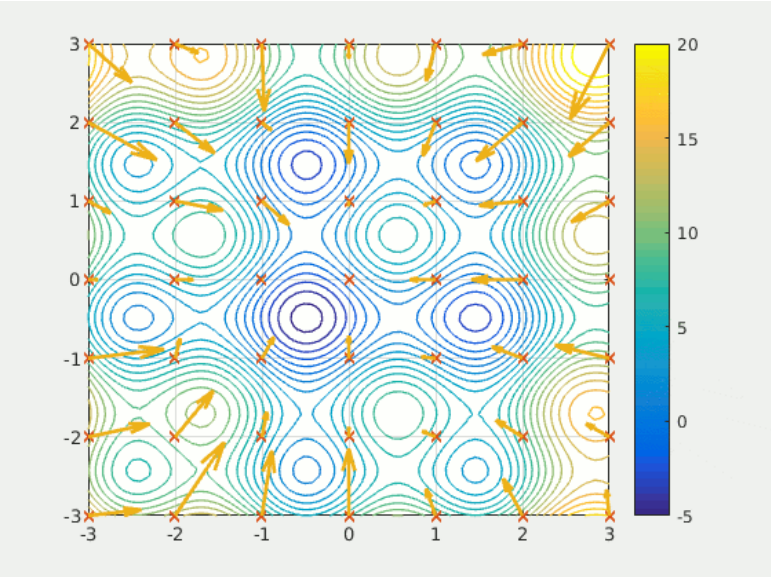


We show the application of **particle swarm optimization** (**PSO**), supported by the MAGFLOW lava flow simulation model, to find the optimal location of geometry of artificial barriers for lava flow risk mitigation.

Particle Swarm Optimization (PSO)

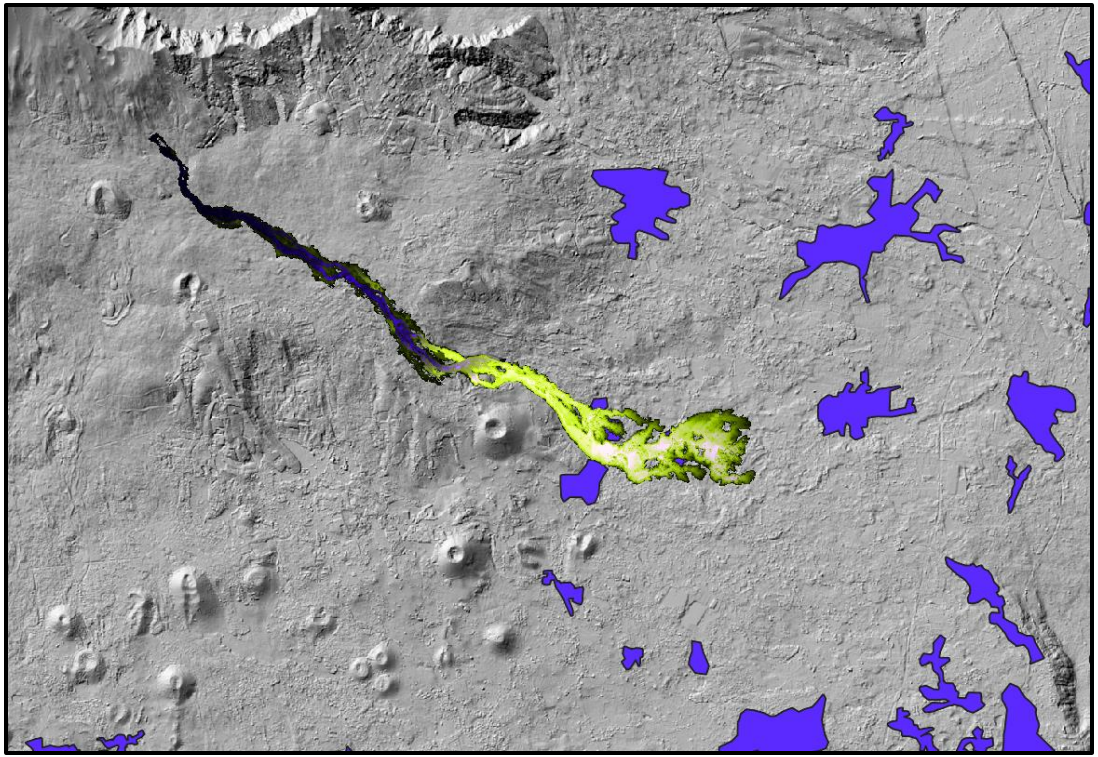
PSO seeks the optimal solution to a problem by iteratively trying to improve a set of candidate solutions with respect to a given measure of quality.



At each step, the candidate solutions, called *particles*, move around in the search-space, in the direction of the best solution found so far by the whole system.

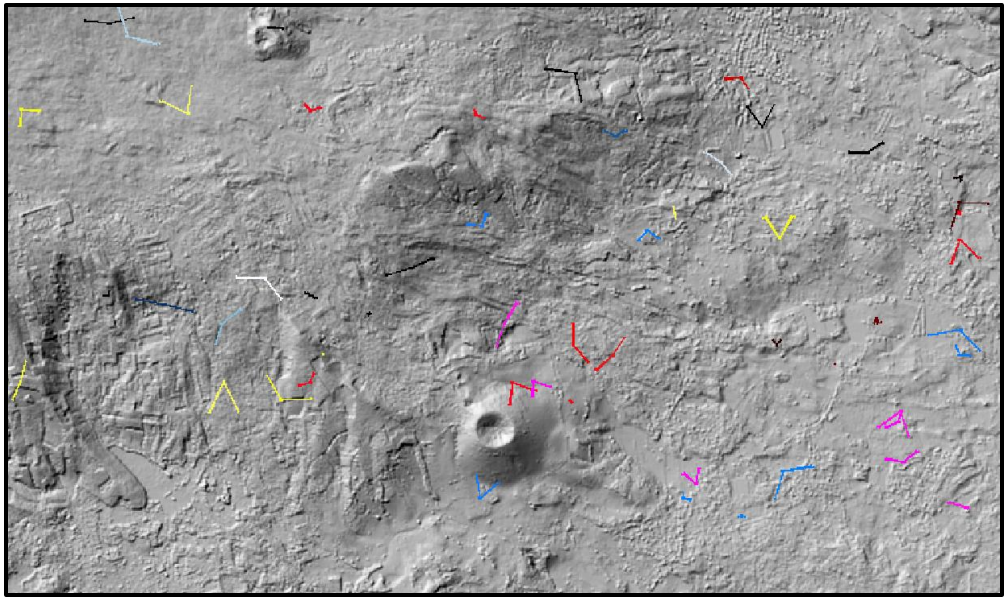
MAGFLOW

MAGFLOW is a physical-numerical model for the simulation of the spatio-temporal evolution of lava flows, based on the cellular automaton formalism.
Input parameters: lava rheology, topography (DEM), mass flux rate over time.
Optional barriers can be included in the simulation, described as a polyline with an assigned height and width; they are realized as changes to the topography in the cells corresponding to their location.



Main Elements for PSO

- ***Barrier:*** The *barriers* are the basic elements, defined by their positions and geometry.
- ***Particle:*** The particle is a single configuration in our search space and it is defined by a given number of barriers.
- ***Swarm:*** The *swarm* is a collection of a given number of particles



Section of the swarm.
Each color represents a single particle.

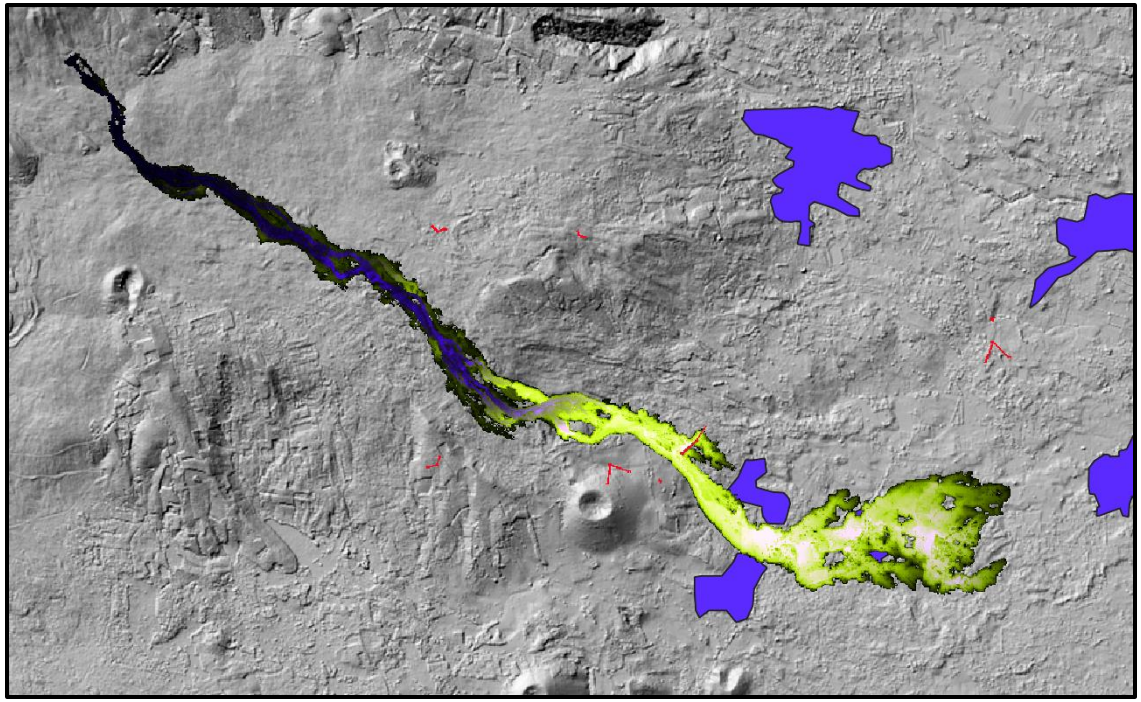
PSO + MAGFLOW

PSO: generate several barrier configurations ("particles").

MAGFLOW: run simulations with barriers defined by PSO.

PSO: compute score of each configuration (impact of emplaced lava flow).

PSO: update configurations, moving towards "particles" with minimal impact.



Optimality of the barrier placement is considered a minimization problem for the impact of lava flows, controlled by the barrier.

New velocities

We implemented a **variant** of the standard PSO update algorithm.

Each velocity component at step *t+1* gets updated by four weighted factors:

- previous barrier velocity ($v^d_{i,t}$);
- distance from the best particle position ($p^d_{i,t}$);
- distance from the best swarm position ($p^d_{g,t}$);
- **distance of the barrier from the flow** ($BFDist^d_t$).

For the best positions we **only consider barriers actually interacting** with the flow.

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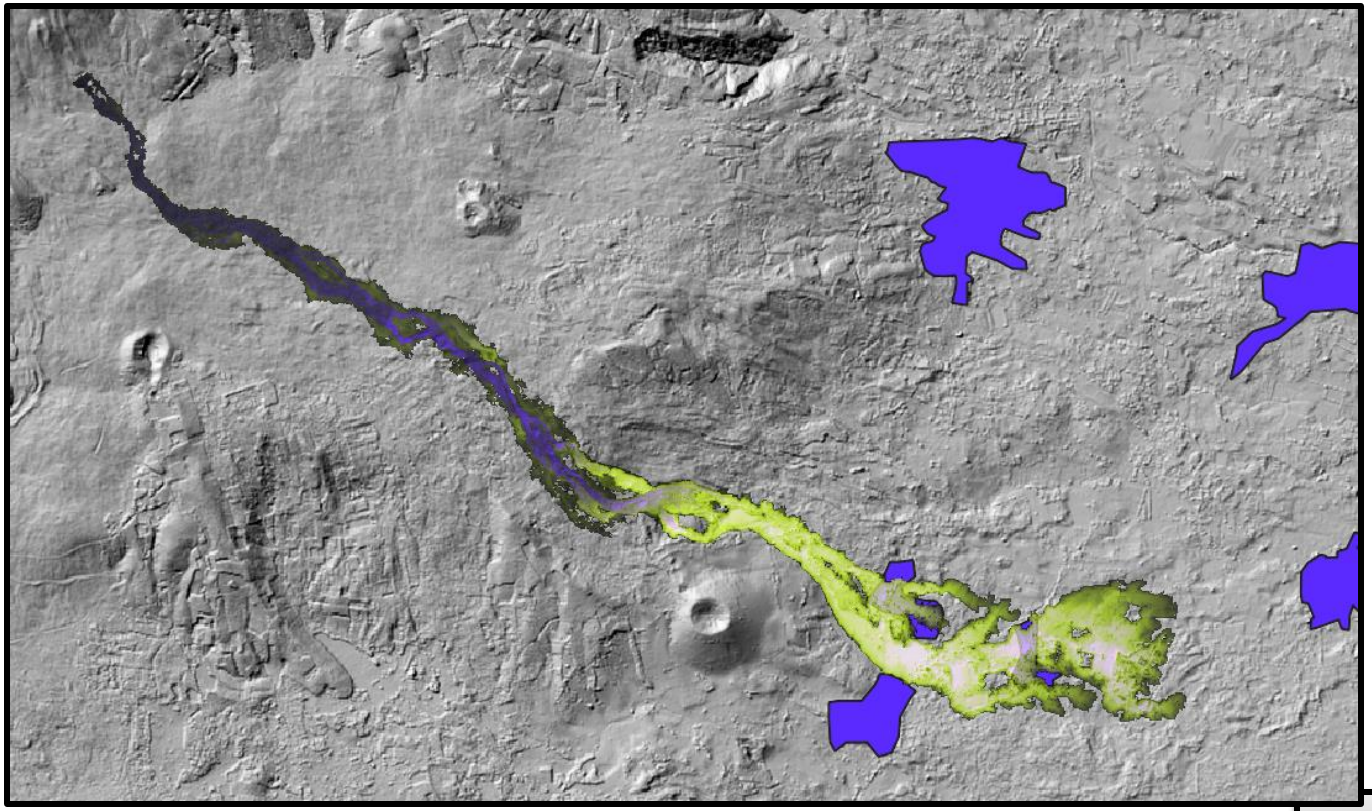
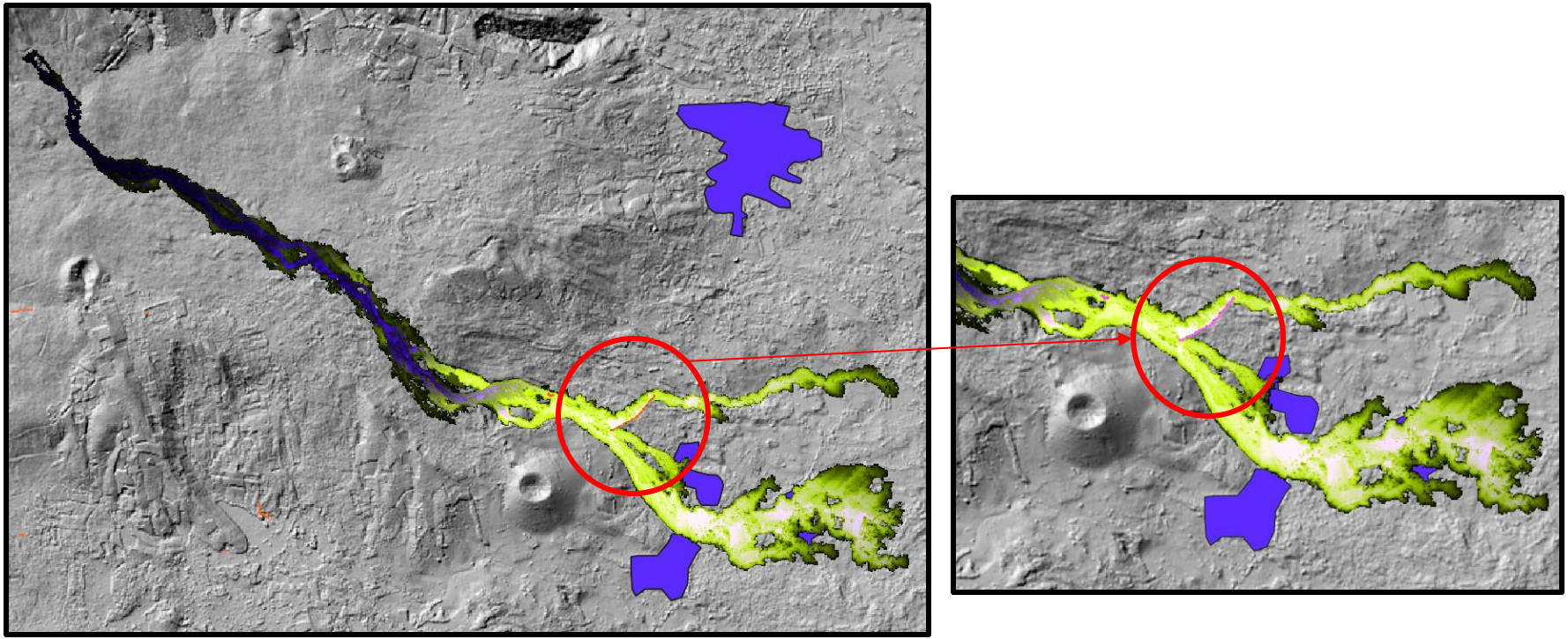
Simulation without barriers



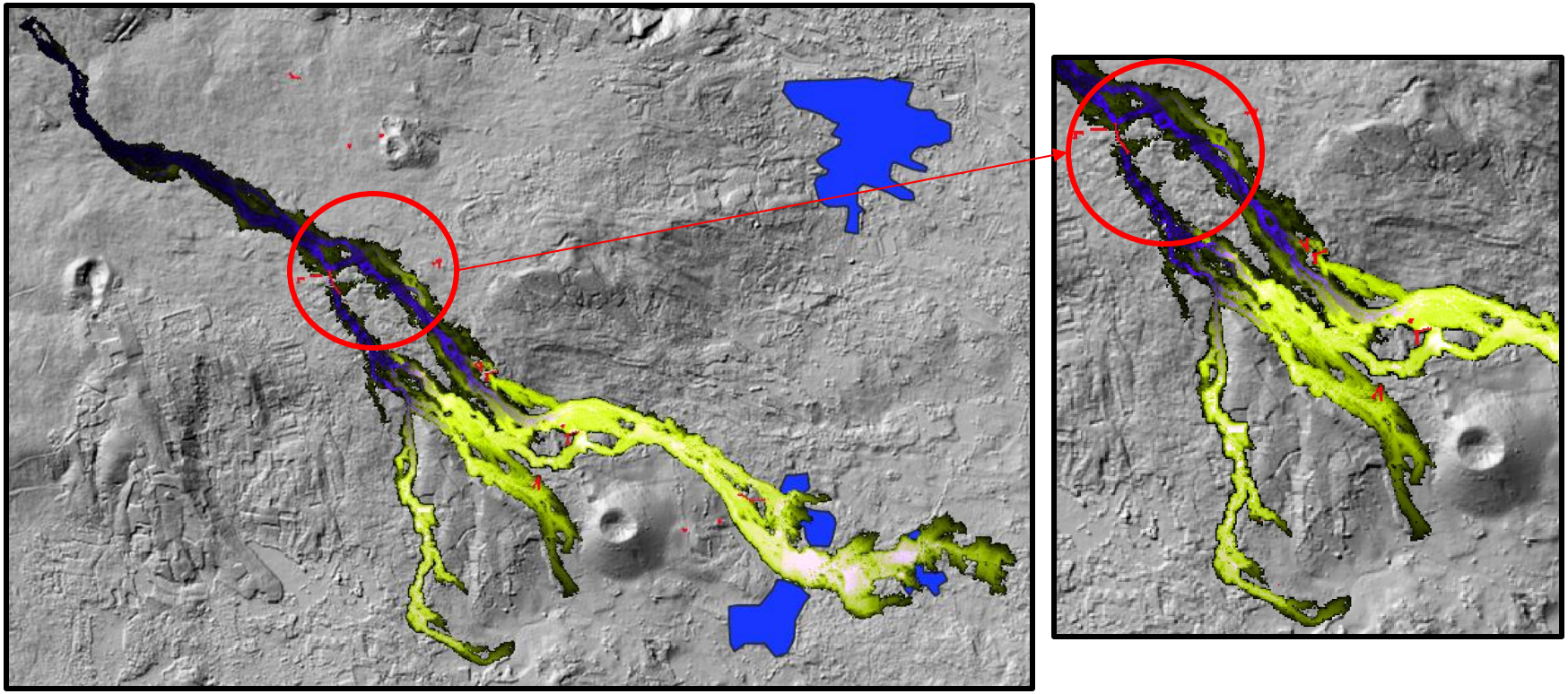
Score : 1737

Example of the effect of barriers



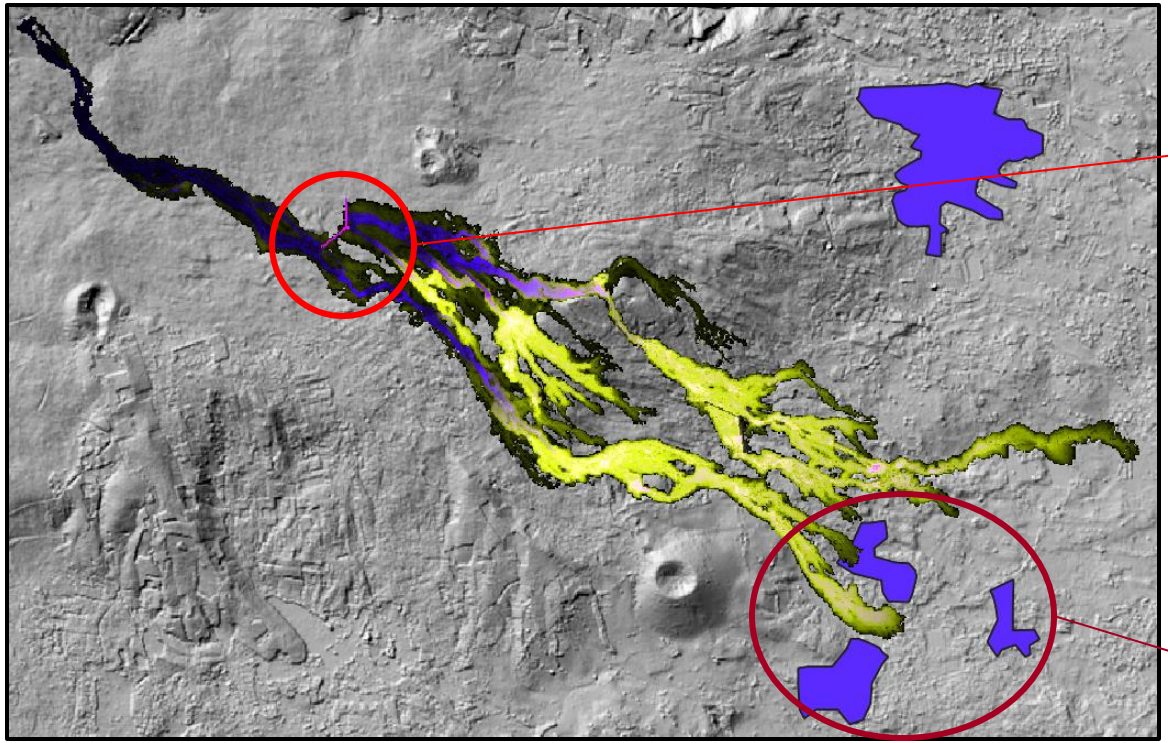
Configuration's Score : 779

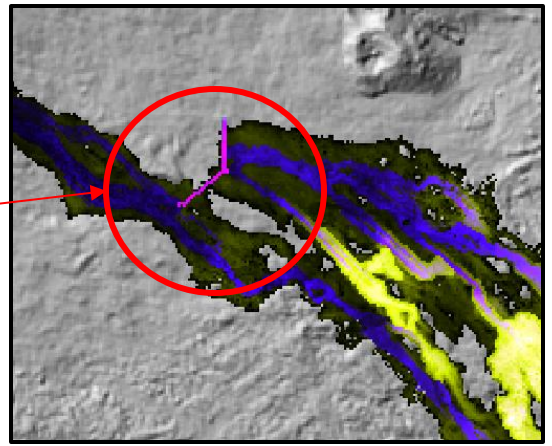
Example of the effect of barriers

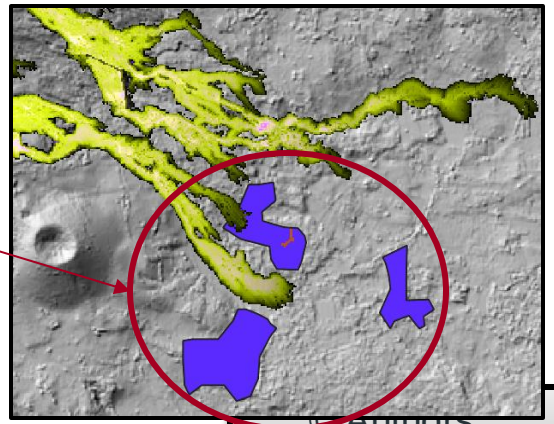


Configuration's Score : 1049

Example of the effect of barriers







Configuration's Score : 133