

Flow123d tutorial 3 – “2D tunnel”

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1 Description

The tutorial models the seepage site 23 m under the surface of the water treatment plant tunnel Bedřichov in the granite rock massif. This seepage site has fast reaction to the precipitation and measurements of various chemical values are available.

The user will learn how to:

- Prescribe time-dependent input data.

The geometry consists of a rectangle 500×300 m with a circular hole of diameter 3.6 m placed 23 meters under the surface, which represents a plane perpendicular to the tunnel.

2 Hydraulic model

The hydraulic model was fitted on the shape of the flux field, where it was assumed that the tunnel drains only a part of the model surface. In particular, the model was fitted on the estimated discharge of the seepage site.

We impose the following input data (see Figure 1):

- The hydraulic conductivity of the rock medium is set to $2.59\text{e-}2$ m/day ($= 3\text{e-}7$ m/s);
- On the surface we prescribe the annual precipitation $2.33\text{e-}3$ m/day ($= 852$ mm/yr);
- On the bottom part “base” we prescribe the pressure 270 m because of assumption of local groundwater flow;
- In the tunnel, the measured flux $-9.16\text{e-}2$ m/day ($= -1.06\text{e-}6$ m/s) is prescribed.

For convenience we use day as the unit of time. The corresponding YAML code is:

```
input_fields:
- region: rock
  conductivity: 2.59E-02
- region: .tunnel
  bc_type: total_flux
  bc_flux: -9.16E-02
- region: .base
  bc_type: dirichlet
  bc_pressure: 270
- region: .surface
  bc_type: total_flux
  bc_flux: 2.33E-03
```

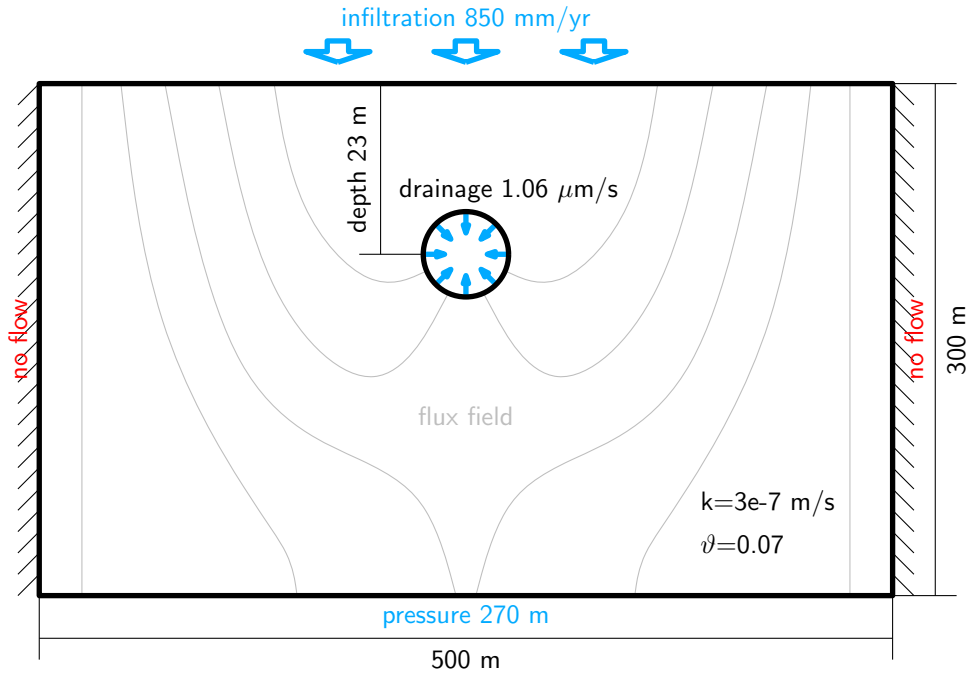


Figure 1: Geometry and boundary condition of model.

The results are shown in Figure 2, where the flux field and the pressure is shown. In the unsaturated layer the piezometric head is depicted.

3 Transport of real isotopes

The stable isotope O-18 was sampled in monthly steps in precipitation at nearby experimental catchment Uhlirská and at the seepage site 23m depth. The measured values are used for the boundary condition on the surface in the transport model as well as reference values in the tunnel.

3.1 Input

We use the value 0.067 for porosity. The initial concentration of O-18 is set to -10.5 kg/m^3 :

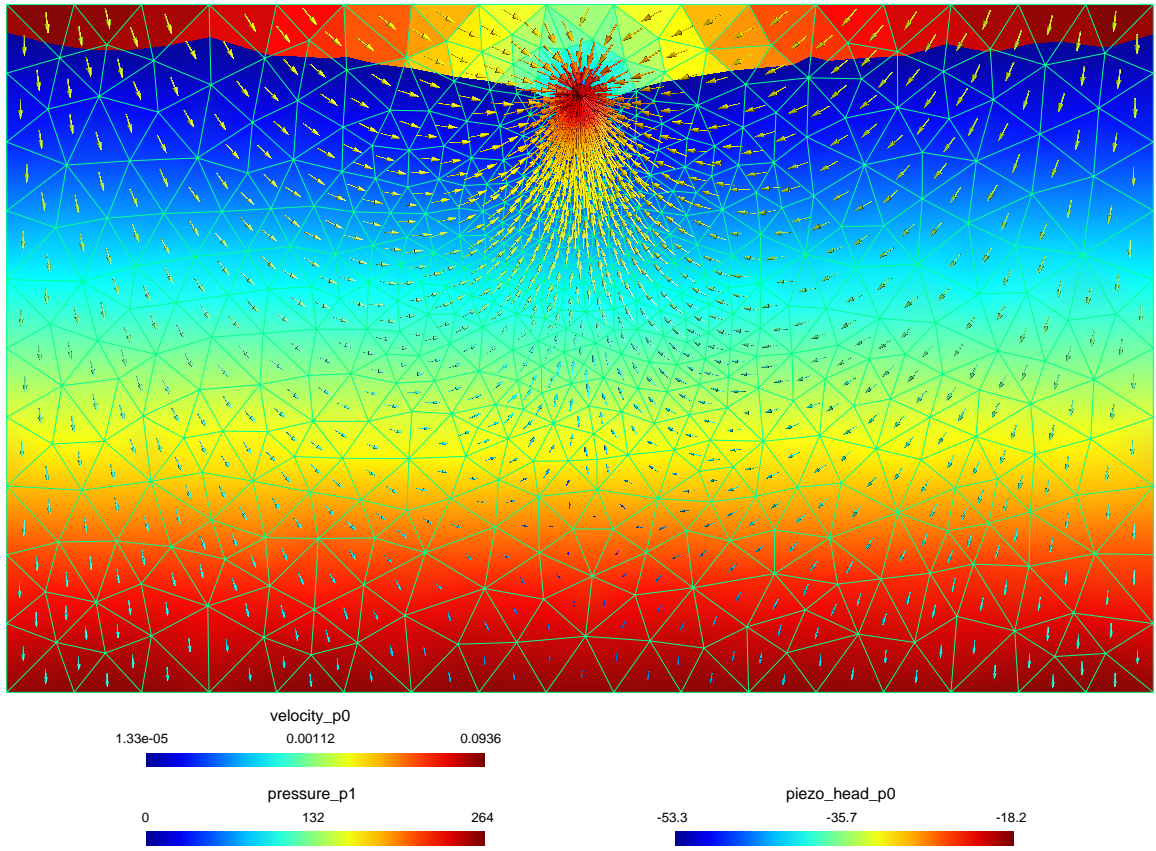


Figure 2: Pressure, boundary of water level and piezometric head in unsaturated zone and flux field.

```

transport: !Solute_Advection_FV
input_fields:
  - region: rock
    porosity: 0.067
    init_conc: -10.5

```

The monthly measured values of $\delta^{18}\text{O}$ [per mil V-SMOW] on the surface from the period 1/2006 till 6/2013 are supplied as the boundary condition:

```

- region: .surface
  bc_conc: -12.85443
  time: 11
- region: .surface
  bc_conc: -14.00255
  time: 42
- region: .surface
  bc_conc: -12.80081
  time: 72
- region: .surface
  bc_conc: -12.34748
  time: 103
...

```

3.2 Results

In Figure 3, the computed mass flux through tunnel is compared to the measured data. The evolution of the transported substance is depicted in Figure 4.

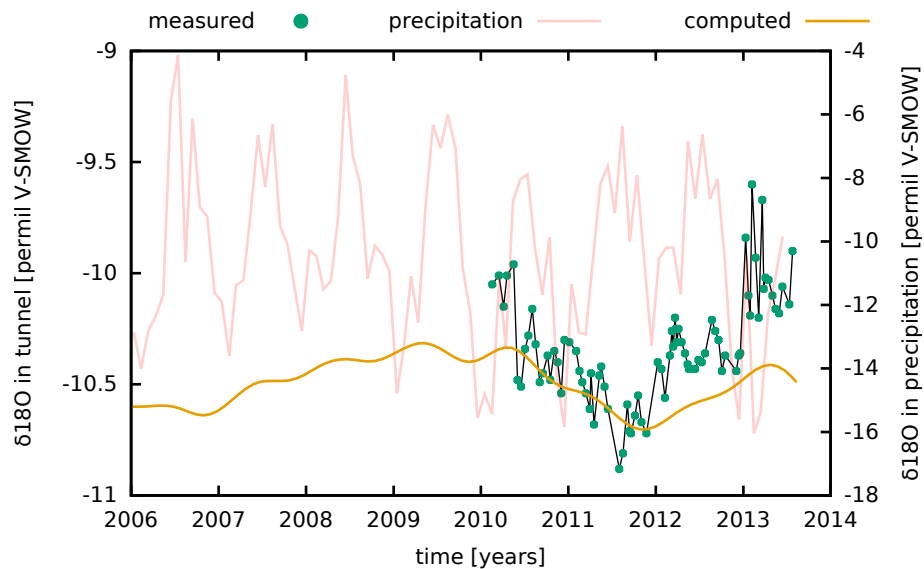


Figure 3: Concentration of O-18 on the seepage site 23m under the surface.

4 The control file

Below is the complete YAML source.

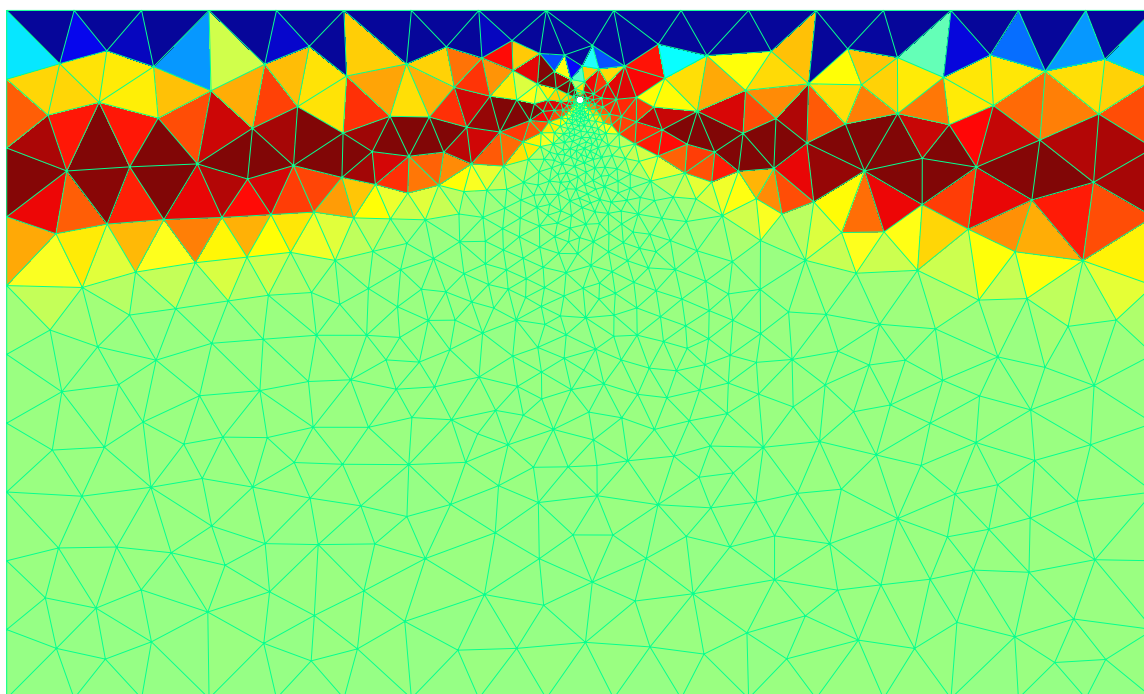


Figure 4: Transport of isotopes in two-dimensional model.

```

flow123d_version: 1.8.9
problem: !Coupling_Sequential
  description: Example 2 inspired of real locality - 2D model of the tunnel with transport
  mesh:
    mesh_file: 03_mesh.msh
  flow_equation: !Flow_Darcy_MH
  nonlinear_solver:
    linear_solver: !Petsc
    a_tol: 1.0e-15
    r_tol: 1.0e-15
  input_fields:
    - region: rock
      conductivity: 2.59E-02
    - region: .tunnel
      bc_type: total_flux
      bc_flux: -9.16E-02
    - region: .base
      bc_type: dirichlet
      bc_pressure: 270
    - region: .surface
      bc_type: total_flux
      bc_flux: 2.33E-03
  balance: true
  output:
    output_stream:
      file: flow.msh
      format: !gmsh
      variant: ascii
    output_fields:
      - piezo_head_p0
      - pressure_p0
      - pressure_p1
      - velocity_p0
  solute_equation: !Coupling_OperatorSplitting
  transport: !Solute_Advection_FV
  input_fields:
    - region: rock
      porosity: 0.067
      init_conc: -10.5
    - region: .surface
      bc_conc: -12.85443
      time: 11
    - region: .surface
      bc_conc: -14.00255
      time: 42
    - region: .surface
      bc_conc: -12.80081
      time: 72
    - region: .surface
      bc_conc: -12.34748
      time: 103
    - region: .surface
      bc_conc: -11.69056
      time: 134

```

- region: .surface
bc_conc: -5.57036
time: 166
- region: .surface
bc_conc: -4.12469
time: 196
- region: .surface
bc_conc: -10.64047
time: 227
- region: .surface
bc_conc: -6.13211
time: 257
- region: .surface
bc_conc: -8.91885
time: 287
- region: .surface
bc_conc: -9.2128
time: 318
- region: .surface
bc_conc: -11.60327
time: 348
- region: .surface
bc_conc: -11.90417
time: 379
- region: .surface
bc_conc: -13.59872
time: 410
- region: .surface
bc_conc: -11.38297
time: 438
- region: .surface
bc_conc: -11.22253
time: 469.5
- region: .surface
bc_conc: -9.12168
time: 499
- region: .surface
bc_conc: -6.64882
time: 530.5
- region: .surface
bc_conc: -8.28722
time: 560
- region: .surface
bc_conc: -6.29825
time: 591
- region: .surface
bc_conc: -9.52325
time: 622
- region: .surface
bc_conc: -10.06889
time: 652.5
- region: .surface
bc_conc: -11.45036
time: 683

- region: .surface
bc_conc: -12.81734
time: 713.5
- region: .surface
bc_conc: -10.28309
time: 744
- region: .surface
bc_conc: -10.45338
time: 774.5
- region: .surface
bc_conc: -11.5138
time: 804
- region: .surface
bc_conc: -11.23509
time: 835.5
- region: .surface
bc_conc: -9.20653
time: 865
- region: .surface
bc_conc: -4.75257
time: 896.5
- region: .surface
bc_conc: -7.29354
time: 926
- region: .surface
bc_conc: -8.18397
time: 957.5
- region: .surface
bc_conc: -11.17229
time: 988
- region: .surface
bc_conc: -10.13945
time: 1018.5
- region: .surface
bc_conc: -10.41511
time: 1049
- region: .surface
bc_conc: -10.92845
time: 1079.5
- region: .surface
bc_conc: -14.78398
time: 1110
- region: .surface
bc_conc: -13.24067
time: 1141.5
- region: .surface
bc_conc: -11.10512
time: 1169
- region: .surface
bc_conc: -12.54885
time: 1199.5
- region: .surface
bc_conc: -8.90522
time: 1230

- region: .surface
bc_conc: -6.32787
time: 1261.5
- region: .surface
bc_conc: -7.05611
time: 1292
- region: .surface
bc_conc: -6.0089
time: 1323.5
- region: .surface
bc_conc: -7.05956
time: 1355
- region: .surface
bc_conc: -10.84582
time: 1385.5
- region: .surface
bc_conc: -12.256
time: 1417
- region: .surface
bc_conc: -15.56566
time: 1447.5
- region: .surface
bc_conc: -14.80394
time: 1477.9
- region: .surface
bc_conc: -15.43502
time: 1508.3
- region: .surface
bc_conc: -11.08503
time: 1538.7
- region: .surface
bc_conc: -13.34144
time: 1565
- region: .surface
bc_conc: -8.72689
time: 1595
- region: .surface
bc_conc: -8.04992
time: 1626
- region: .surface
bc_conc: -7.87742
time: 1656
- region: .surface
bc_conc: -10.21281
time: 1687
- region: .surface
bc_conc: -11.67132
time: 1718
- region: .surface
bc_conc: -9.86934
time: 1748
- region: .surface
bc_conc: -14.29788
time: 1779

- region: .surface
bc_conc: -15.83779
time: 1809
- region: .surface
bc_conc: -11.34214
time: 1840
- region: .surface
bc_conc: -12.86511
time: 1871
- region: .surface
bc_conc: -12.93357
time: 1899
- region: .surface
bc_conc: -10.51149
time: 1930
- region: .surface
bc_conc: -8.19156
time: 1960
- region: .surface
bc_conc: -7.615
time: 1991
- region: .surface
bc_conc: -9.10695
time: 2021
- region: .surface
bc_conc: -6.36307
time: 2052
- region: .surface
bc_conc: -10.0023
time: 2083
- region: .surface
bc_conc: -7.9214
time: 2113
- region: .surface
bc_conc: -10.62
time: 2144
- region: .surface
bc_conc: -13.28369
time: 2174
- region: .surface
bc_conc: -10.53405
time: 2205
- region: .surface
bc_conc: -10.18778
time: 2236
- region: .surface
bc_conc: -10.20346
time: 2265
- region: .surface
bc_conc: -11.66542
time: 2296
- region: .surface
bc_conc: -6.83685
time: 2326

```

- region: .surface
  bc_conc: -8.64656
  time: 2357
- region: .surface
  bc_conc: -6.62866
  time: 2387
- region: .surface
  bc_conc: -8.66687
  time: 2418
- region: .surface
  bc_conc: -8.02979
  time: 2449
- region: .surface
  bc_conc: -10.50304
  time: 2479
- region: .surface
  bc_conc: -14.00857
  time: 2510
- region: .surface
  bc_conc: -15.60331
  time: 2540
- region: .surface
  bc_conc: -10.49306
  time: 2571
- region: .surface
  bc_conc: -16.0443
  time: 2602
- region: .surface
  bc_conc: -15.3727
  time: 2630
- region: .surface
  bc_conc: -12.28302
  time: 2661
- region: .surface
  bc_conc: -11.15953
  time: 2691
- region: .surface
  bc_conc: -9.84281
  time: 2722
output_stream:
  time_step: 30
  file: transport.msh
  format: !gmsh
  variant: ascii
substances: 0-18
time:
  end_time: 2780
balance:
  cumulative: true

```