MATHEMATICAL SIMULATION MODEL OF SEEPAGE FLOW AND CONTAMINATES TRANSPORTATION THROUGH EARTH DAMS

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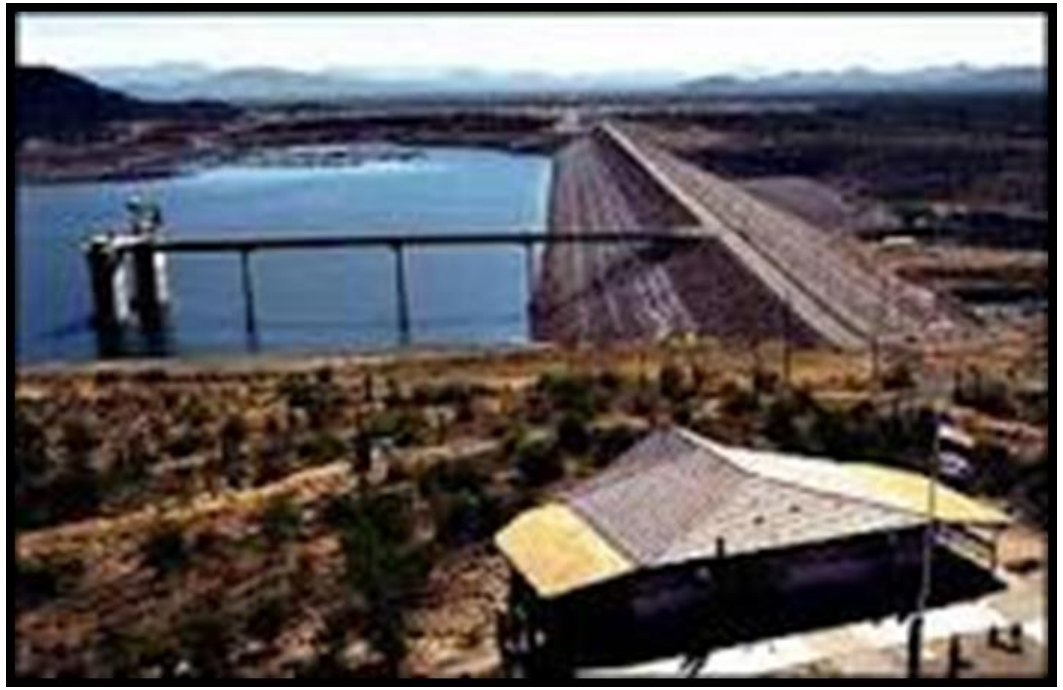
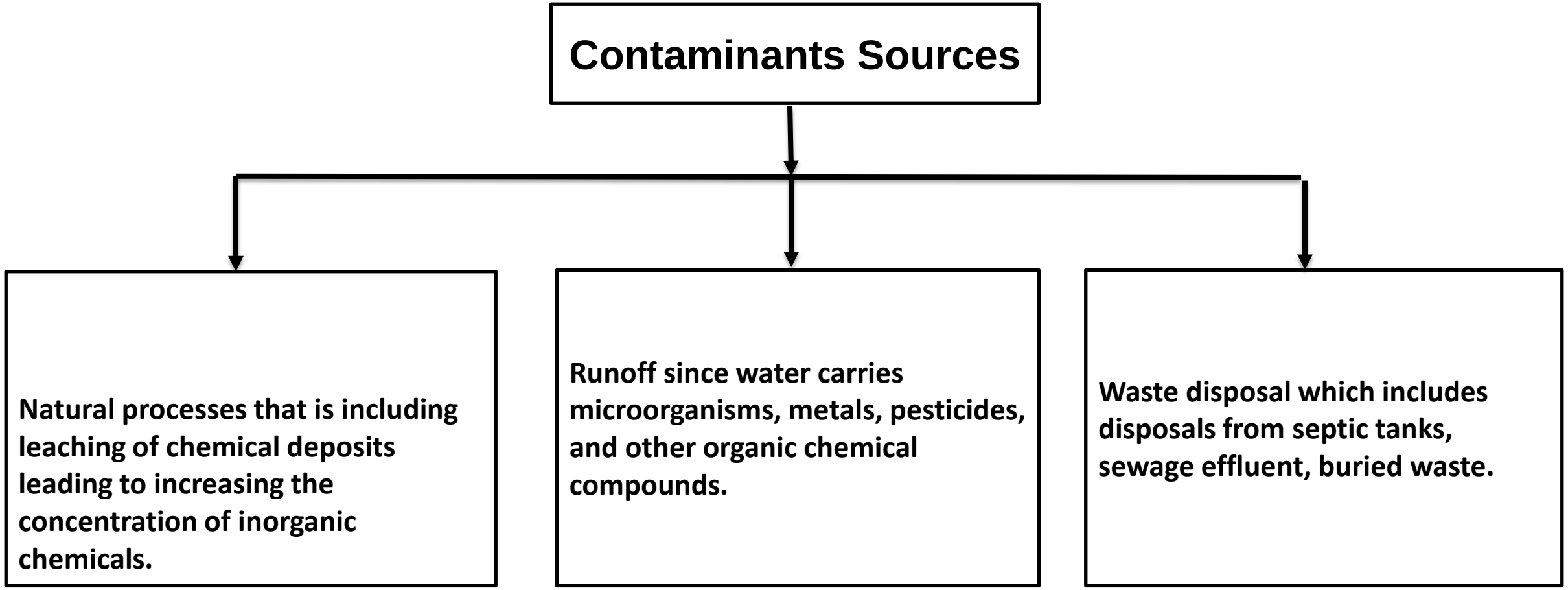
- **Earth dams** are structures constructed from natural material. Dams are employed for storing water, production of energy, flood control and planet-irrigation purposes.

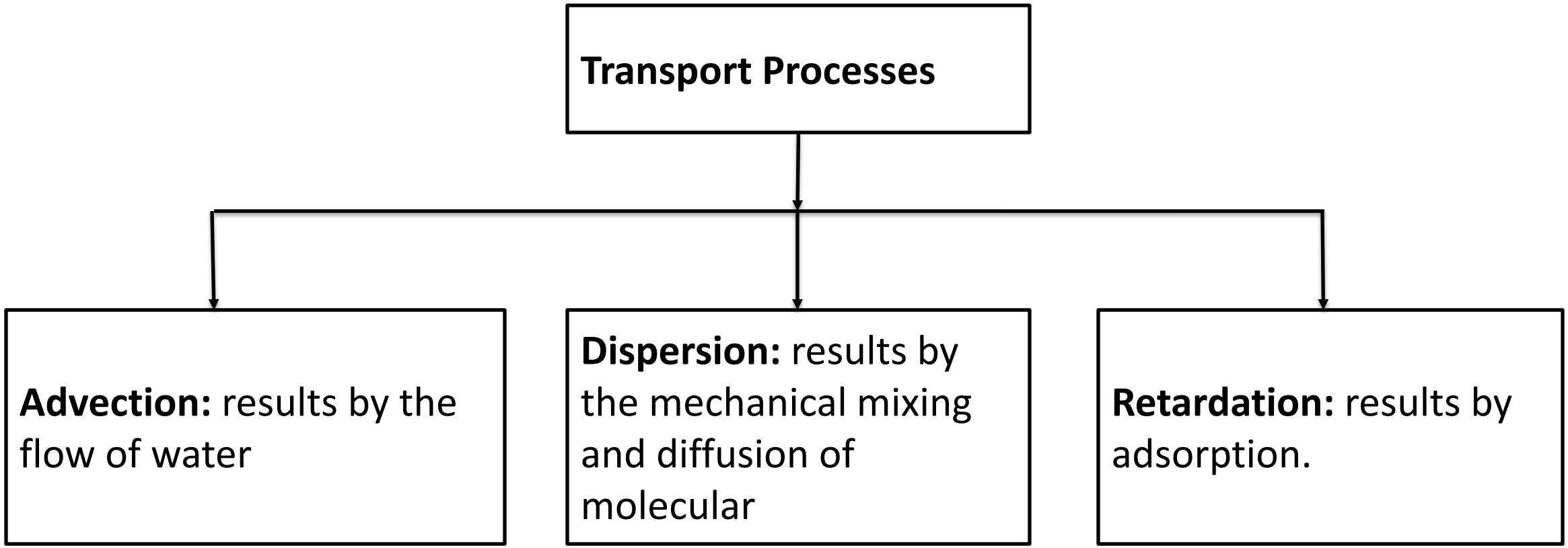


- **Seepage** is a strategic factor that has to be carefully studied on earth dam designing since it is the main reason for dam failure. The seepage flow of water through porous media depends on the soil material, type of the dam, properties of the liquid and hydraulic gradient. Many methods have been developed to study seepage flow; these methods can be classified as analytical, experimental and approximate methods.

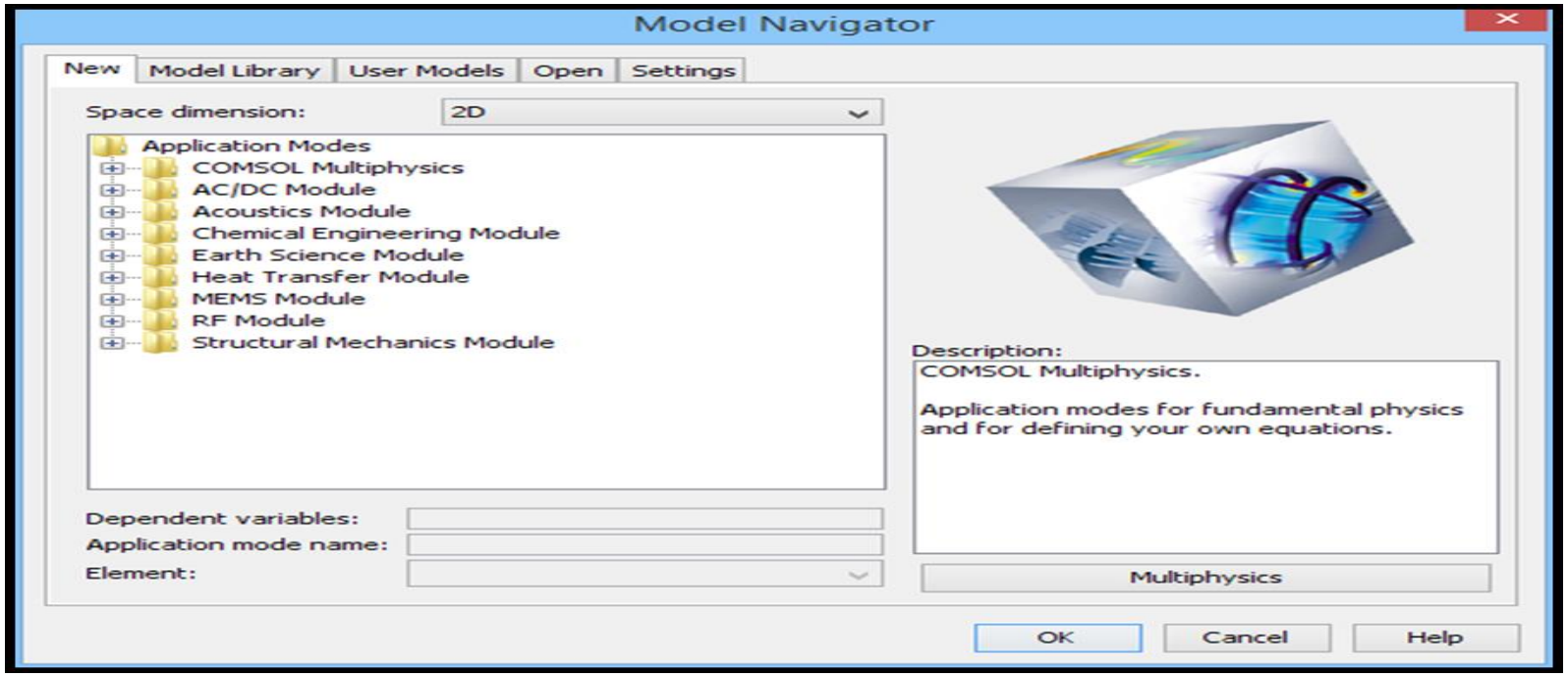
Types of water contaminants' sources:



Transportation of Contaminants:



- **COMSOL Multiphysics (version 4.2)** also can be used for analyzing and predicting the seepage flow and the contaminants' transportation with its sub-programs named Free and Porous Media Flow and Species Transport through Porous Media. Free and Porous Media Flow was used to determine the phreatic lines, the amount of seepage from the dam, the pressure head. Species Transport through Porous Media was used to determine the amount of contaminants that transport through the dam.



The present study was designed to:

- Analysis of the seepage of flow and transportation of contaminants through the body of a homogeneous Dam..

- Verification of the above is set up by the COMSOL program for studying and analyzing the free surface seepage line, the discharge of flow, pressure head, and the amount of contaminants and its movement through the body of the dam.

Dam in COMSOL Multiphysics

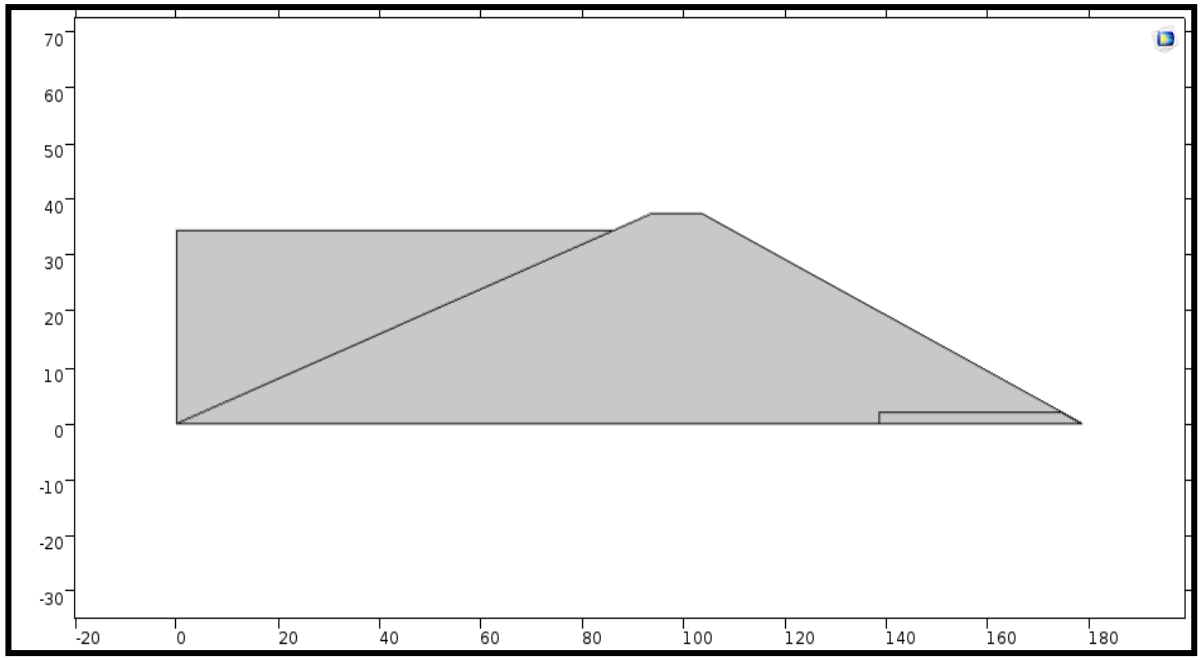


Figure (A) Cross-section of the dam

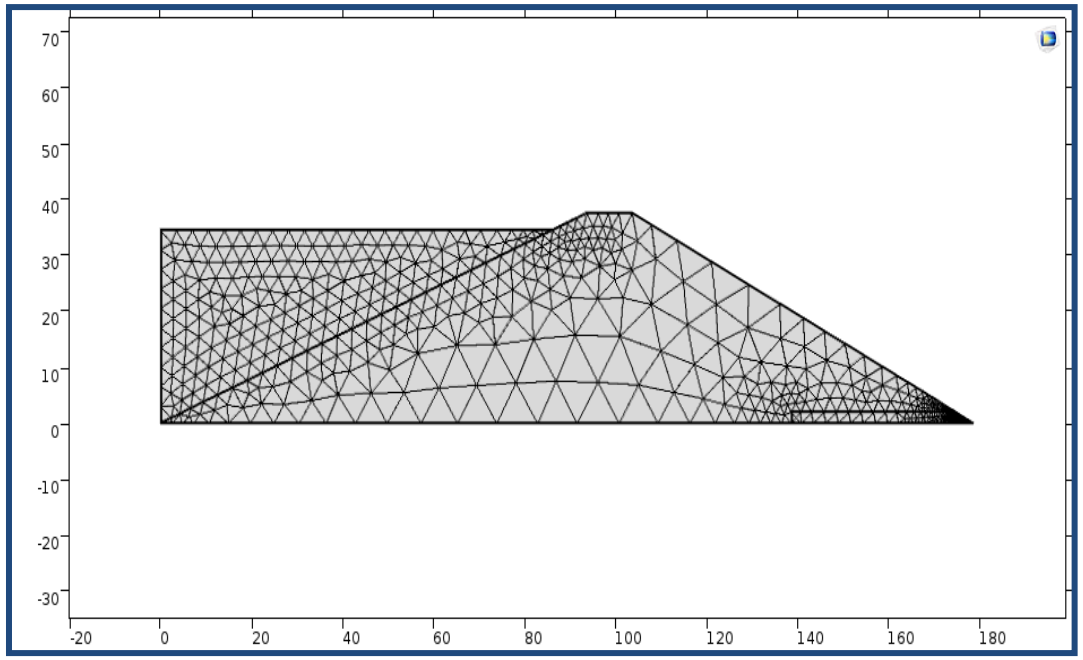
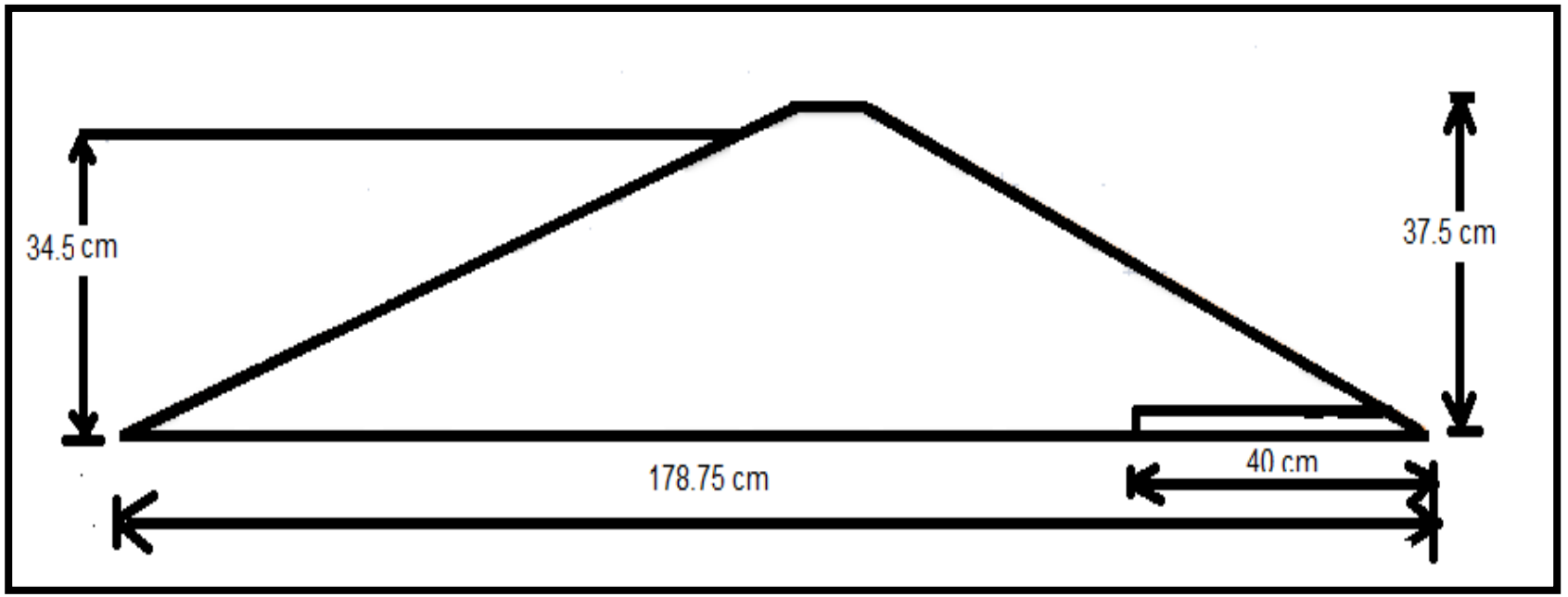


Figure (3-10) Finite element mesh.

- A number of elements are 1091, edge element is 212, vertex element is 10, minimum element size is 0.0536 cm, and the maximum element size is 12cm.



- The dam composed of homogeneous sand material. A horizontal drainage blanket system, of the form of a horizontal drain, is provided. The upstream side of the dam is flatter than the downstream side. The dam had an upstream side slope 2.5H: 1V, downstream slope 2H: 1V. The drain size is 40 cm length, 2cm height and 53cm width composed of fine gravel, very coarse sand and coarse sand.

Horizontal drainage blanket with piezometer pipes

The homogeneous earth dam

The homogeneous earth dam with piezometer pipes

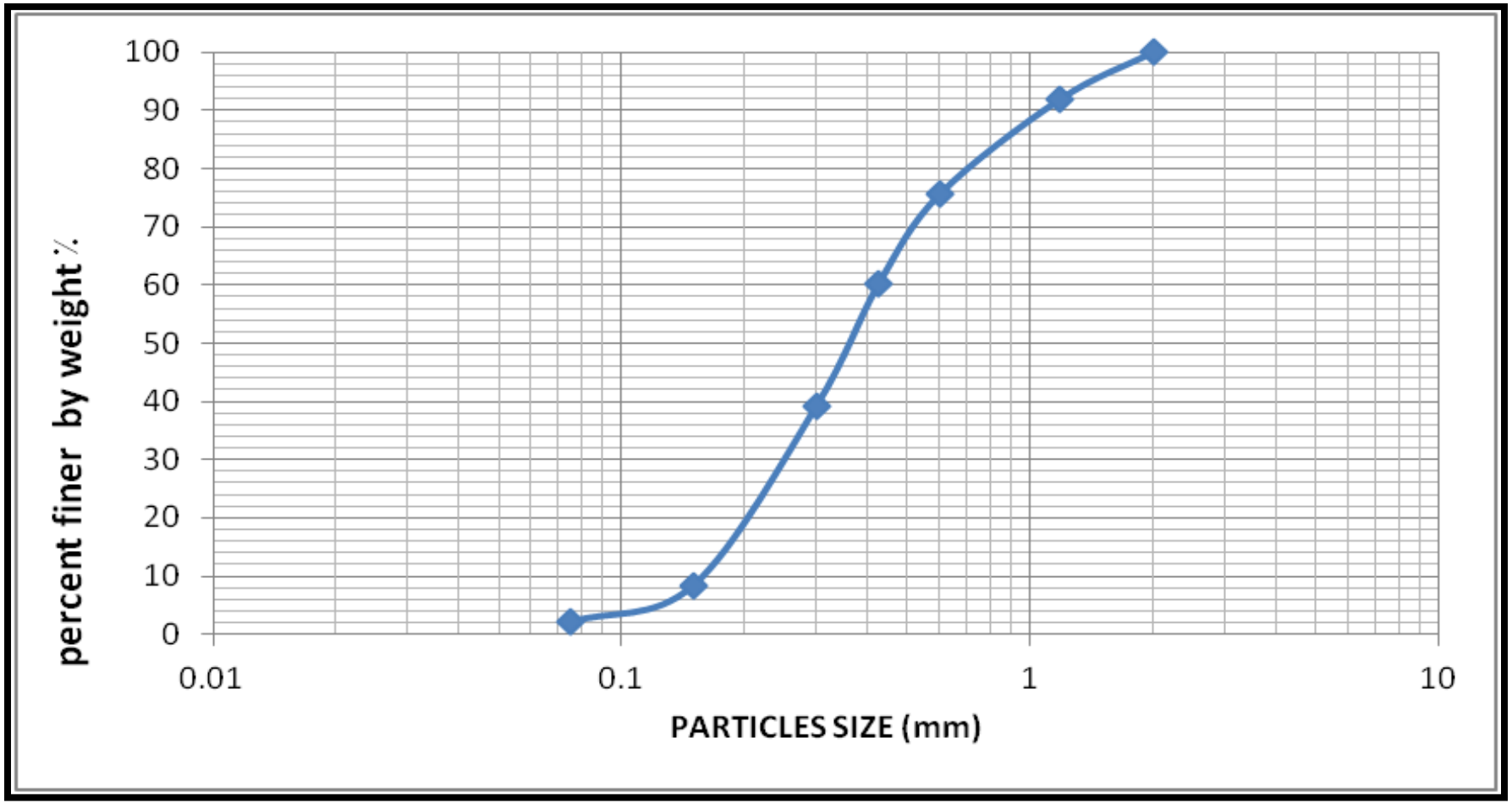
The specifications of the dam:

Type of Dam	Homogeneous Earth dam
Dam	Height: 37.5cm; Length: 178.75cm; Width: 53cm.
U/S Water level	34.5 cm
Type of Material	Sandy Soil
Volume (cm^3)	187570
Slope of the dam	Upstream: 2.5:1; Downstream: 2:1
Thickness of Filter	2 cm
Volume of the Filter	4240 cm3

Properties of the soil material of the dam:

Tests	Value
bulk density of soil, compacted soil	1600 (kg /l), 1720 (kg /l)
Porosity, void ratio	40%, 66.7%
Gravimetric Water content Volumetric water content	12% 22.7%
Saturated degree	56.6%
Surface Area	4.6543 (m^2/g)
Hydraulic Conductivity	9.07 m/day= 0.01 cm/s

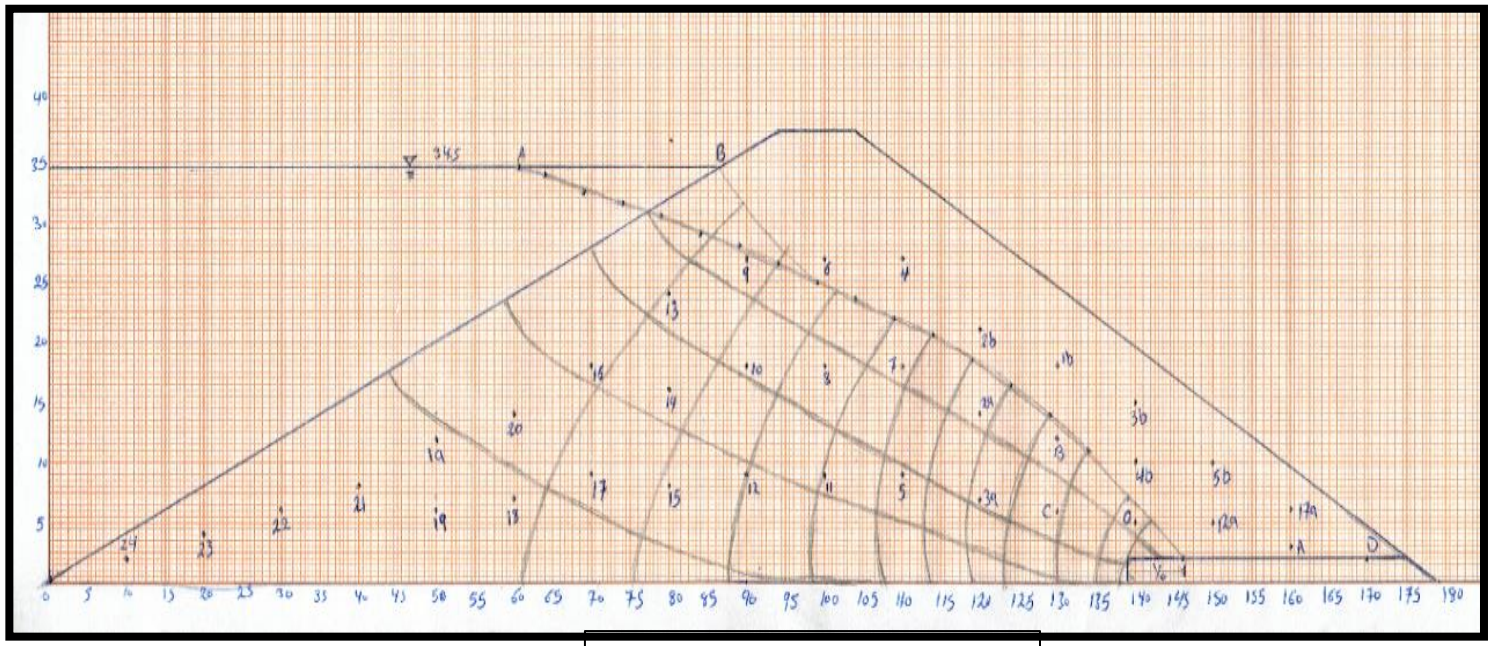
The percentage of soil particles shown in the following figure are as follows: Silt &clay (2%), fine sands (28%), medium sands (38%), coarse sands (20%) and very coarse sands (12%).



The experimental work include :

1- Calculate of the amount of seepage, the position of the phreatic line, the pressure head and head losses through the earth dam.

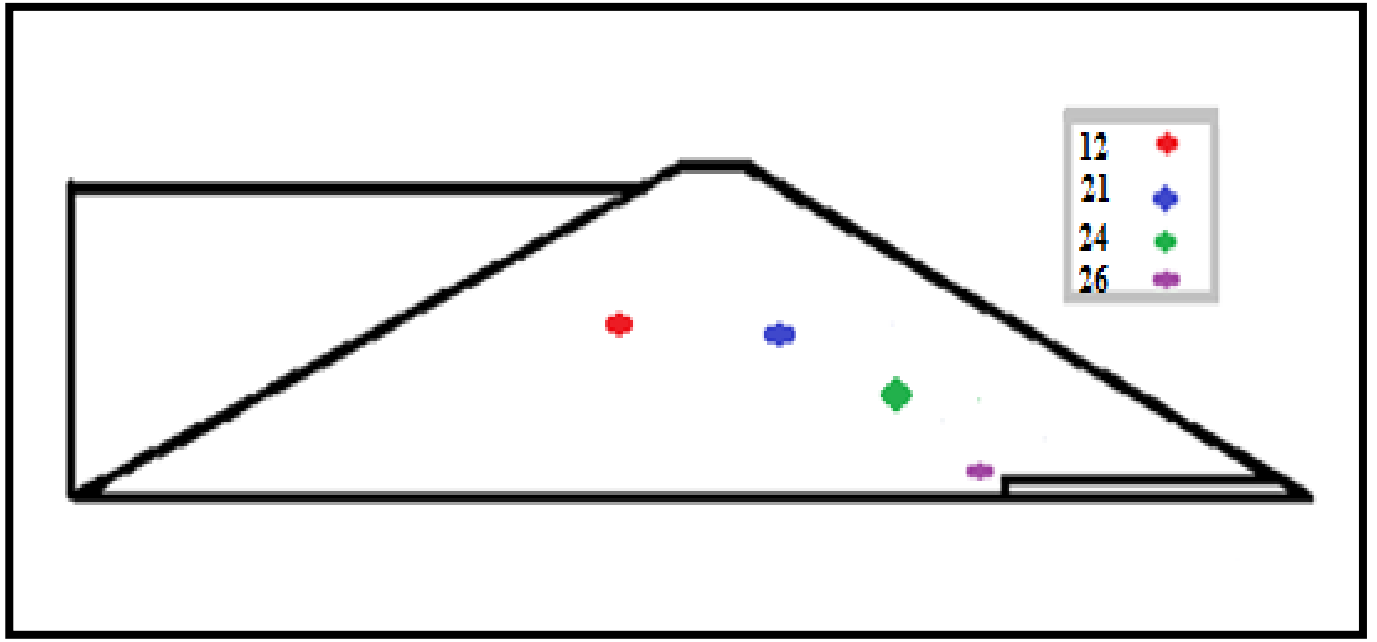
➢ The flow rate for the seepage was 0.83 (L/min), the position of seepage face was computed by two methods: The first method was flow net and the second method was numerically (COMSOL).



Flow Net

2- Study the contaminants behavior and its' transportation through earth dam and at the exit point.

- Four points were selected randomly through the dam from upstream to downstream which are: 12, 21, 24 and 26, for the purpose of measuring the concentration of contaminant.

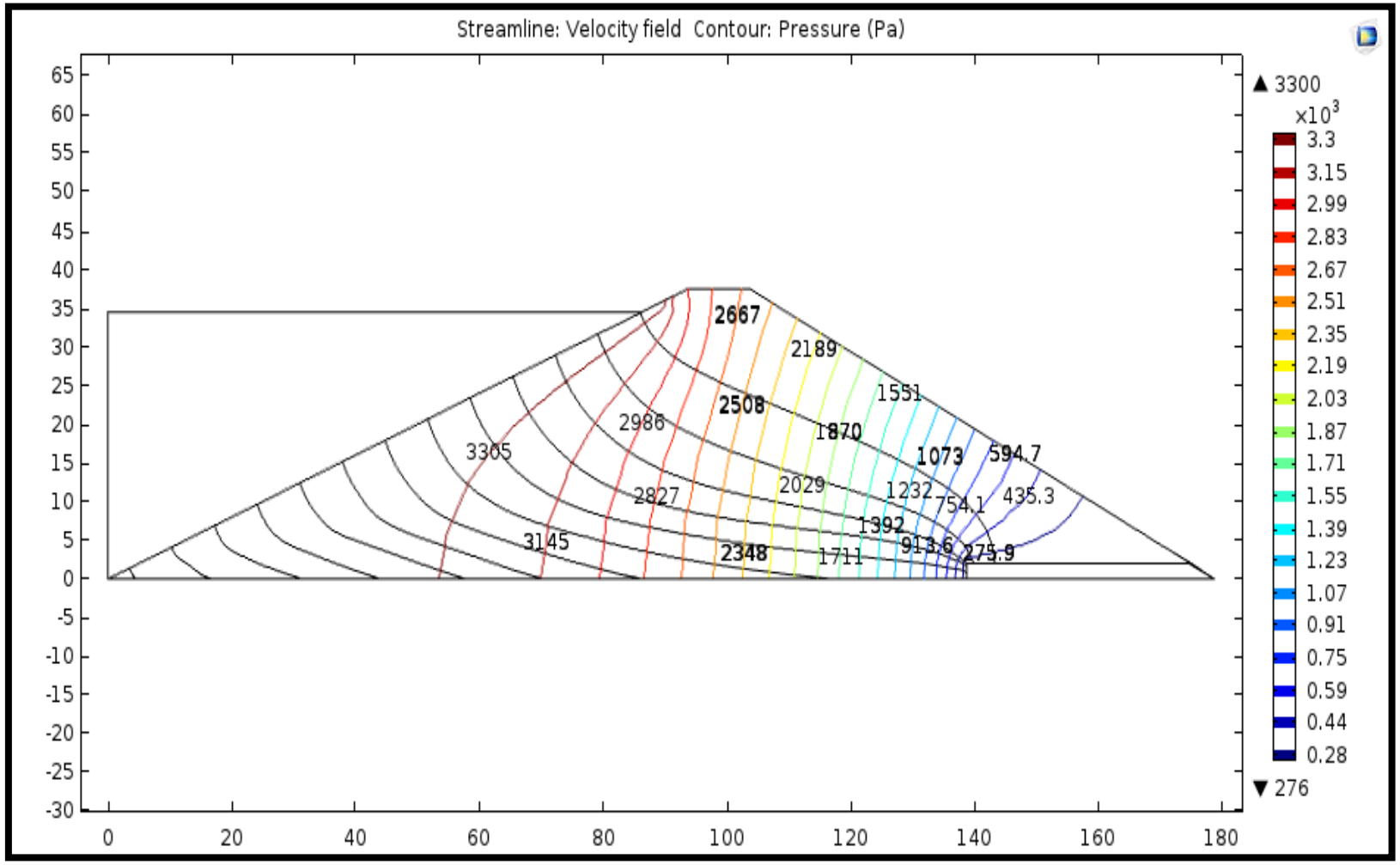


The steady state seepage flow through homogeneous earth dam:

Physical Model:

The phreatic line starts from the water surface level and drops throughout the dam until it passes through the horizontal drainage filter and exit at the dam toe.

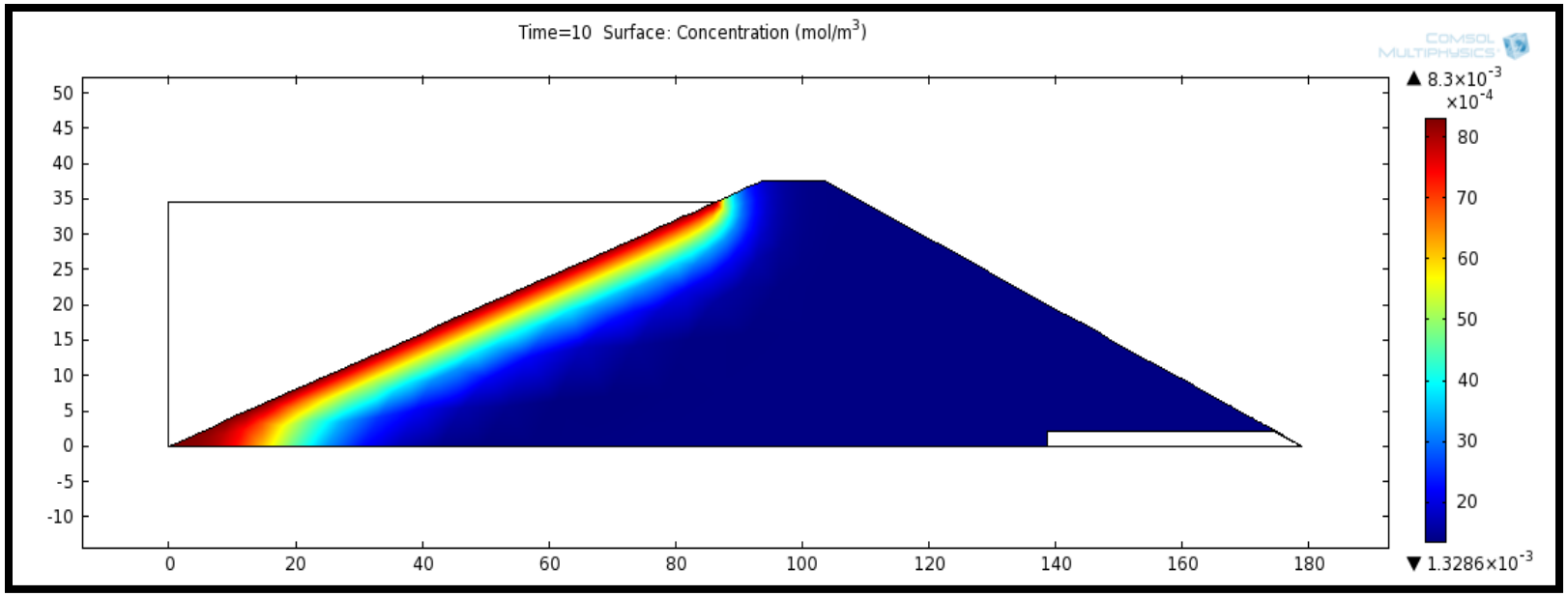
COMSOL Software:



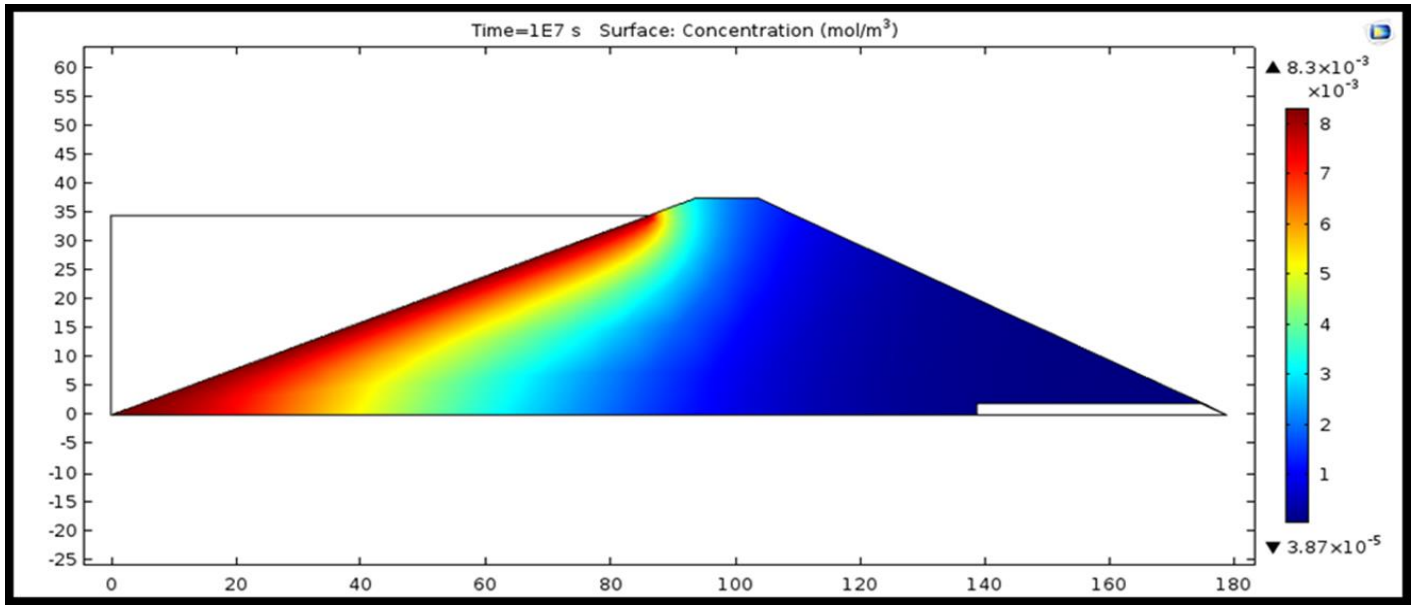
homogeneous earth dam with stream lines and equipotential lines

Pressure head (Hp) through earth dam were measured by experimental work, graphical flow net and numerical model (COMSOL).
The result indicates that there is a good agreement between the physical model (experimental work), graphical solution of flow net and COMSOL software.

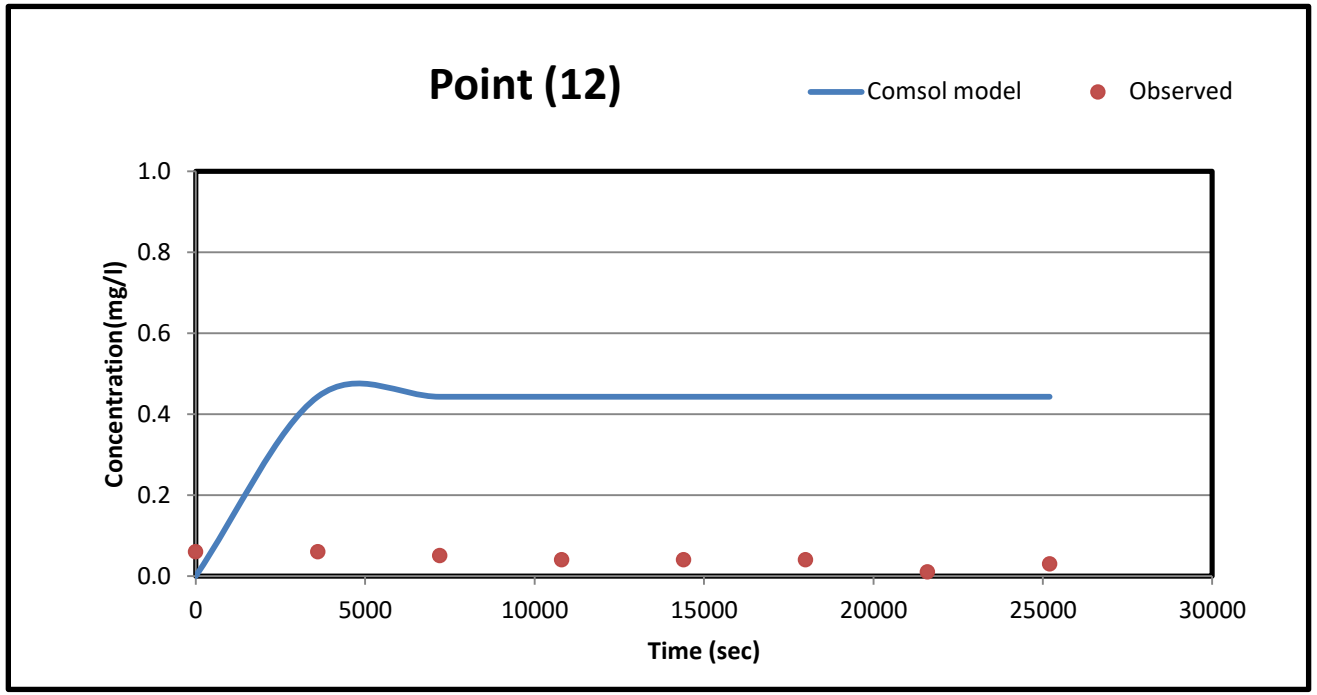
❖Numerical model; COMSOL software:



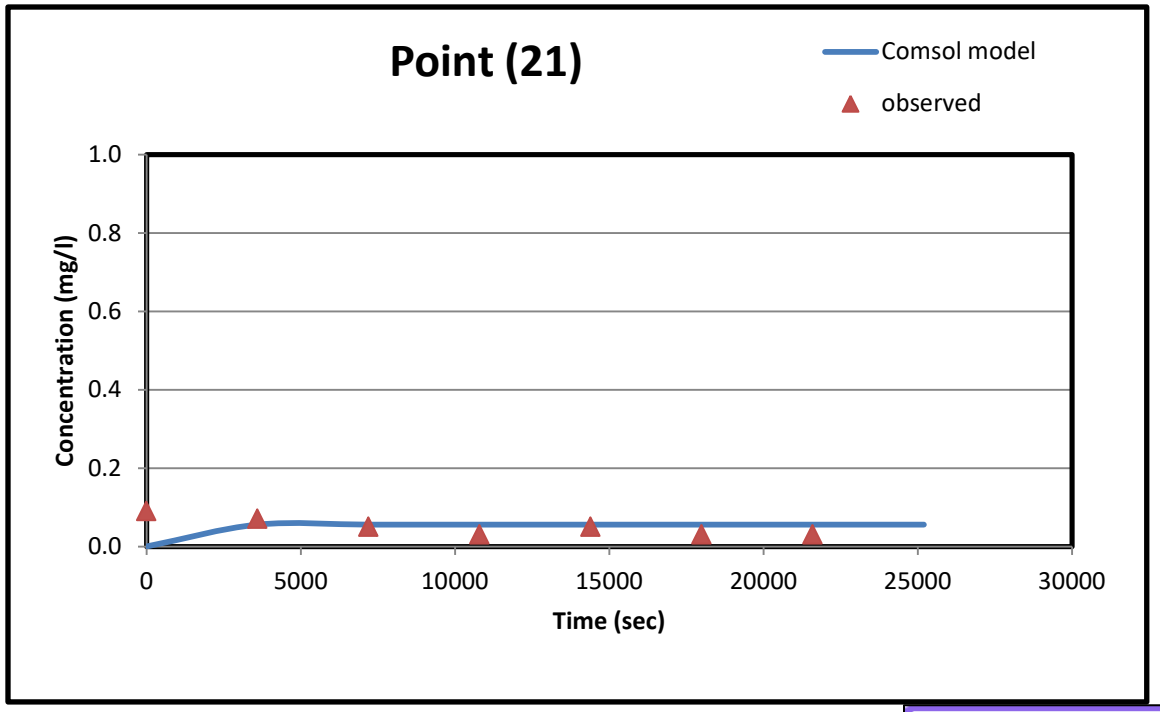
contaminate's transportation through the dam

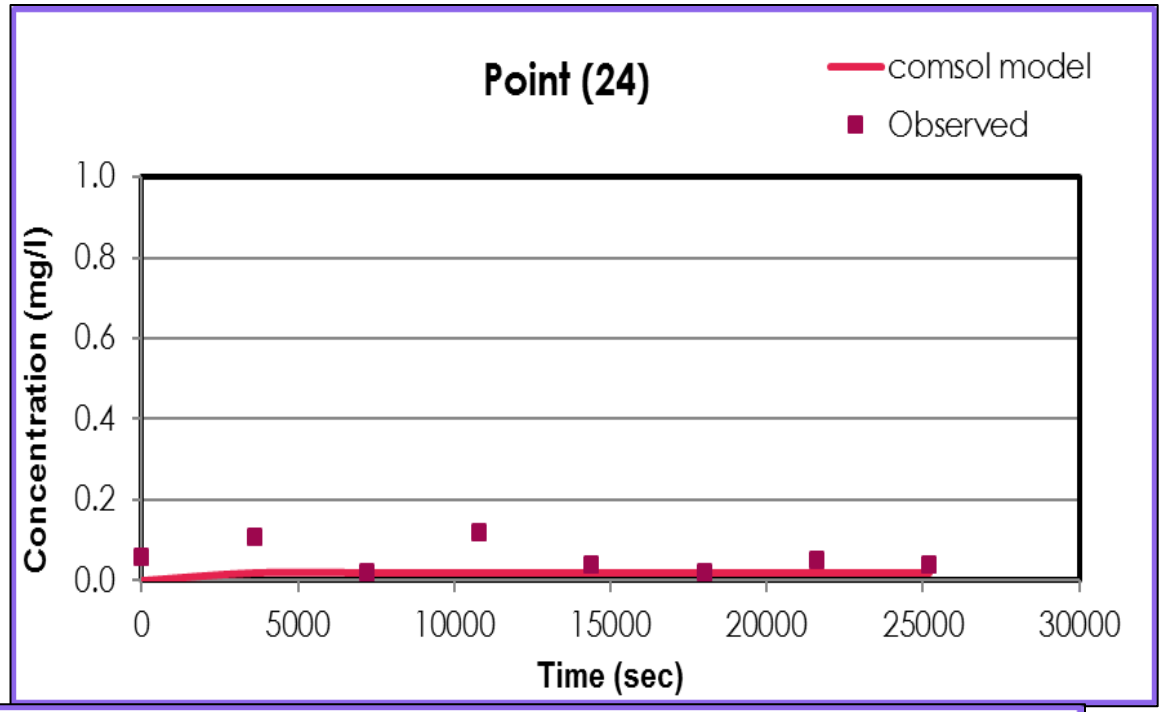


the observed and predicted values for contaminate at point (12)

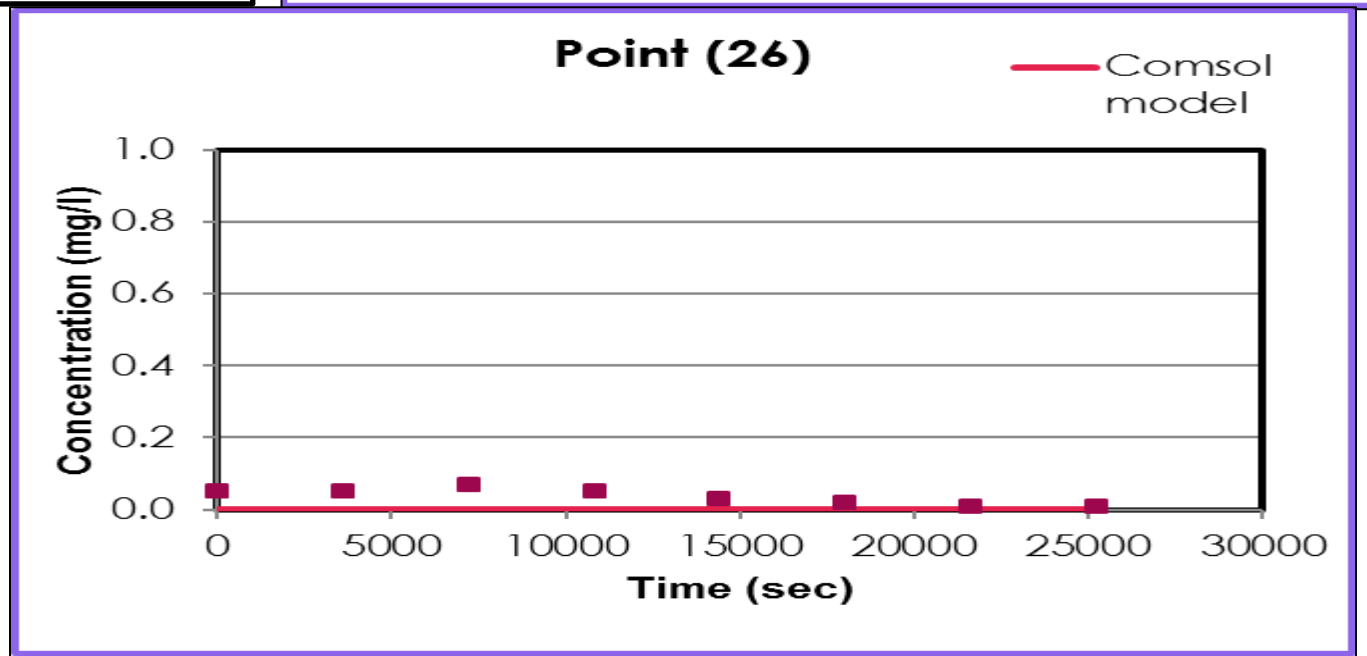


The measured values for the point 12 are not coinciding with the predicted values obtained from the COMSOL model. This is because the location of point 12 is near the upstream face of the dam where so much accumulation of sedimentations of the contaminate occurs at this face and on the bed of reservoir.





the observed and predicted values for contaminate at points (21,24,26).



Conclusion :

- The physical model of dam with sandy soil material and horizontal drainage blanket can be used to simulate and analyze the seepage flow and transportation of contaminants throughout the dam body.
- Flow-through porous media and transportation of the contaminate are also simulated by a two-dimensional finite element seepage flow models based on the basic equations of steady seepage flow of a homogeneous earth dam and definite conditions by using the COMSOL program.

- The results of pressure head between the physical model (experimental work), flow net and COMSOL software have a good agreement.

References:

[1] Abhilasha P. S and T. G. A. Balan, “Numerical Analysis of Seepage in Embankment Dams,” 2014, p. 13.

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[4] S. B. Patil and H. S. Chore, “Contaminant transport through porous media: An overview of experimental and numerical studies,” *Advances in environmental research*, vol. 3, no. 1, pp. 45–69, Mar. 2014.

[5] Comsol ab, “COMSOLMultiphysicsUsersGuide,” 2012. [Online]. Available: http://people.ee.ethz.ch/~fieldcom/pps-comsol/documents/User%20Guide%20and%20Examples/COMSOLMultiphysicsUsersGuide.pdf. [Accessed: 26-Jul-2019].