Induced Seismicity Consortium (ISC)

Semi- Annual Project Review Meeting

Upward Migration of Hydraulic Fracturing Fluid through Cement-Wellbore Interface

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Los Angeles, CA
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Problem Statement

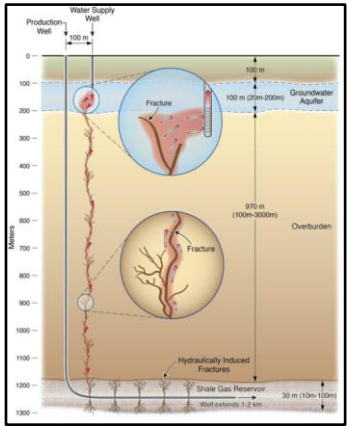
How to evaluate the possibility of groundwater contamination by hydraulic fracturing fluid through Cement-Wellbore Interface?

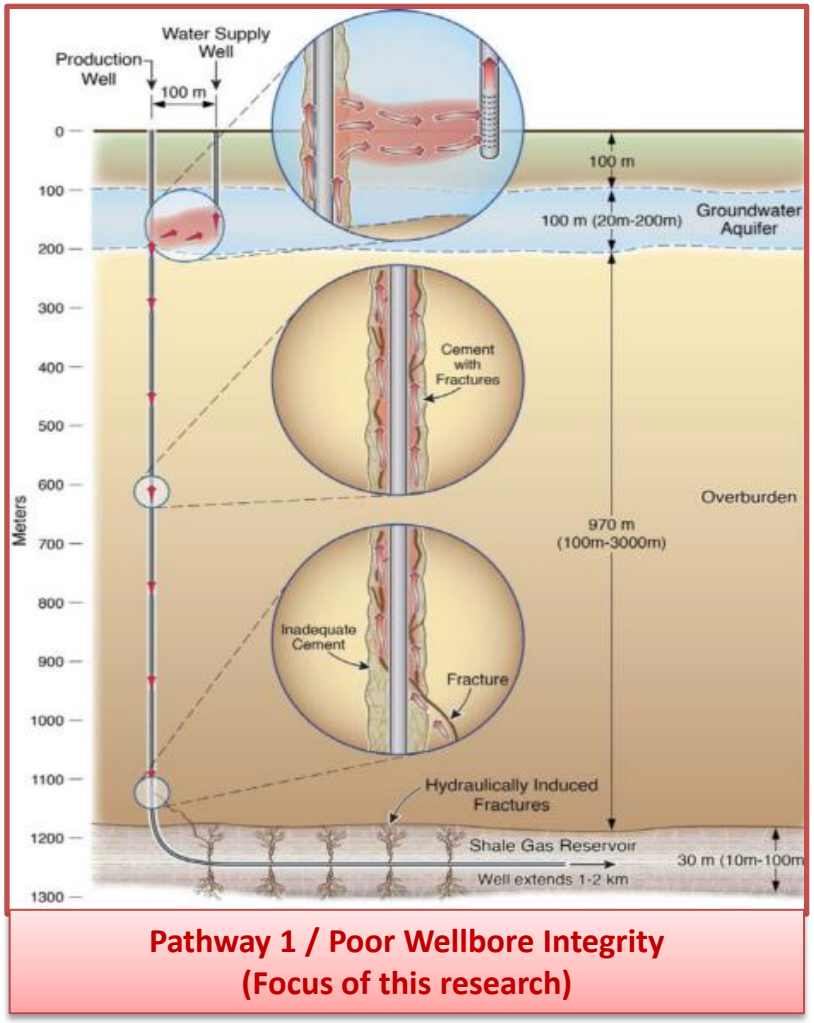
Research Objective

Evaluating the possibility of groundwater contamination by hydraulic fracturing fluid through Cement-Wellbore Interface.

Four pathways for the upward flow migration, suggested by EPA

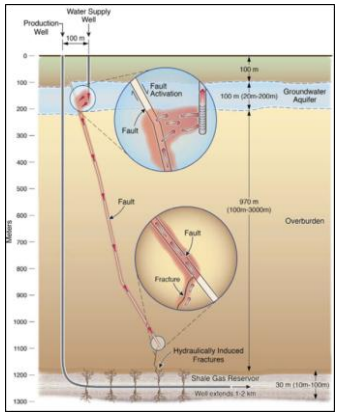
Pathway 2 Fracture Growth



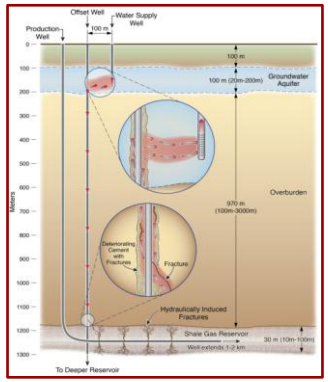


Pathway 1 / Poor Wellbore Integrity (Focus of this research)

Pathway 3 Fault



Pathway 4 Abandoned Well



Previous Studies

Most studies on the “Groundwater contamination as a result of hydraulic fracturing” are done using:

- Case studies - Sampling wells and nearby waters
- Monitoring wells
- Risk Analysis

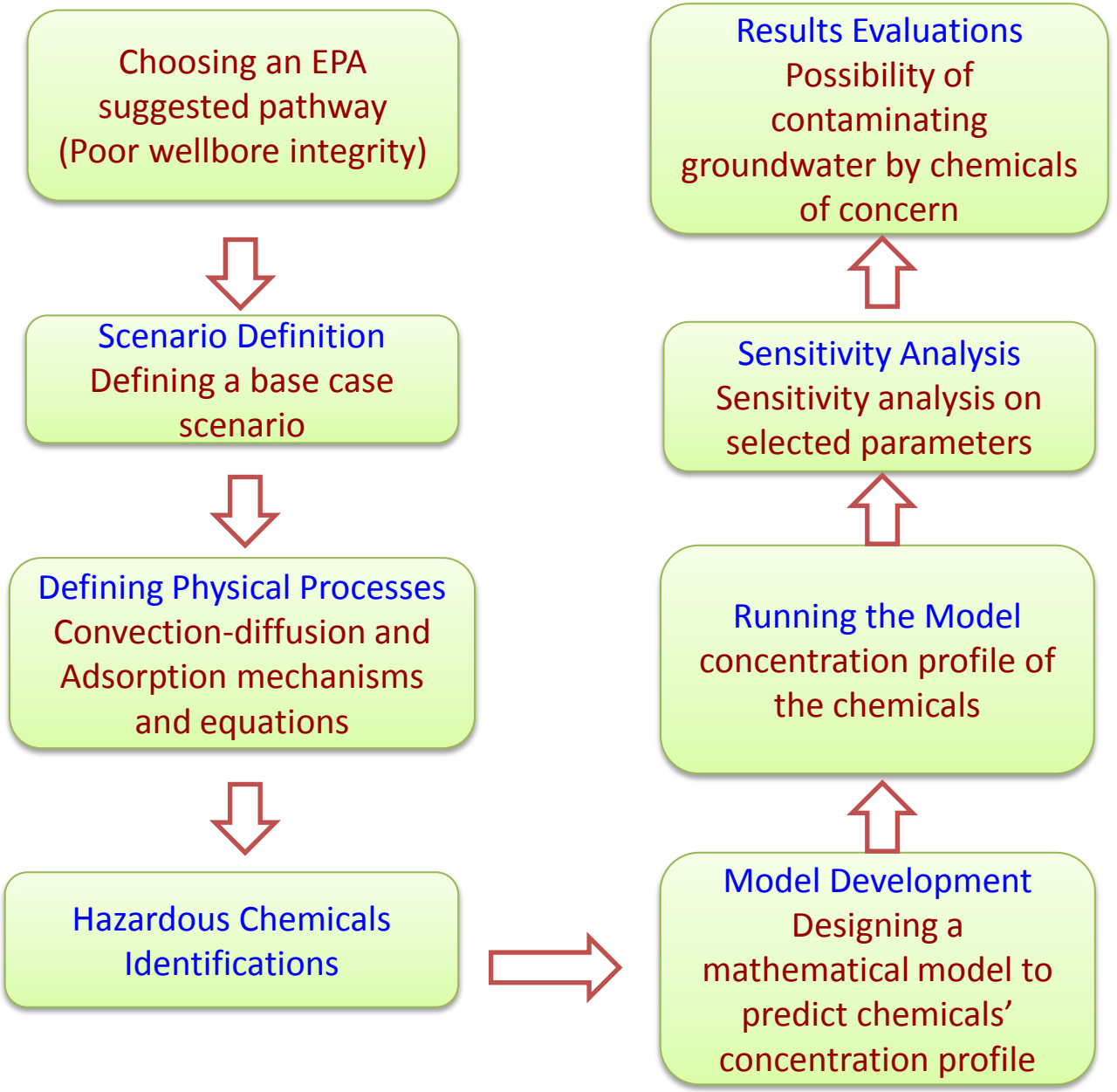
The challenges of above-mentioned approaches are:

- Detecting the actual source of contamination
- Lack of a predicting approach

Suggested Methodology

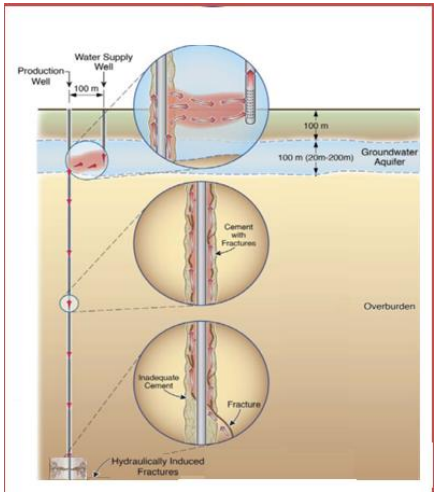
Main objective of this research:

Evaluating the possibility of groundwater contamination by chemicals of hydraulic fracturing fluid through a cracked cement.



Scenario Definition

- A damaged part of the cement, imaginary extended and considered as a pathway all the way through the underground water.
- Characteristics of the pathway inside the cement (apertures size).
- Concentration profile of chemicals is predicted along the length of the well (9000 ft) during the period of hydraulic fracturing process (one day).
- Miscible displacement of the hydraulic fracturing fluid with water inside cement crack.
- Vertical well depth, fracturing job pressure and fluid properties of a specific job are given.
- Chemicals used in the fluid are identified.



Scenario Definition

⇩

Defining Physical Processes

⇩

Hazardous Chemicals Identifications

⇩

Model Development

⇩

Running the Model

⇩

Sensitivity Analysis

⇩

Results Evaluations

Assumptions and Equations

- To model the fluid flow and calculate the mean velocity of the fluid in aperture, “Cubic Law” (Witherspoon et al, 1980) have been utilized.

$$\frac{Q}{\Delta h} = C(2b)^3 \qquad C = \left(\frac{W}{L}\right)\left(\frac{\rho g}{12\mu}\right)$$

- To predict the concentration profile inside the imagined aperture in the cement, solution to the Convection- Diffusion equations (C-D equations), by Brigham, have been used.

$$C' = \frac{1}{2}\,\mathrm{erfc}\left(\frac{x-ut}{2\sqrt{Kt}}\right) + \frac{1}{2}\,e^{ux/K}\,\mathrm{erfc}\left(\frac{x+ut}{2\sqrt{Kt}}\right) \quad \ldots (19)$$

- Langmuir isotherms have been used to assess the adsorption of Xylene (one of the chemicals , used in the hydraulic fracturing jobs) by cement, based on a research, in which the adsorption of Xylene in a solutions of water and on a surface composed of cement and some other material analyzed (Reference 14 /M. Houari et al.).

$$Q = \frac{K\,A\,C}{1+K\,C}$$

K_{eq} = The equilibrium constant
C = equilibrium concentration,
A = total adsorbent capacity,
Q = equilibrium adsorption,

Scenario Definition
Defining Physical Processes
Hazardous Chemicals Identifications
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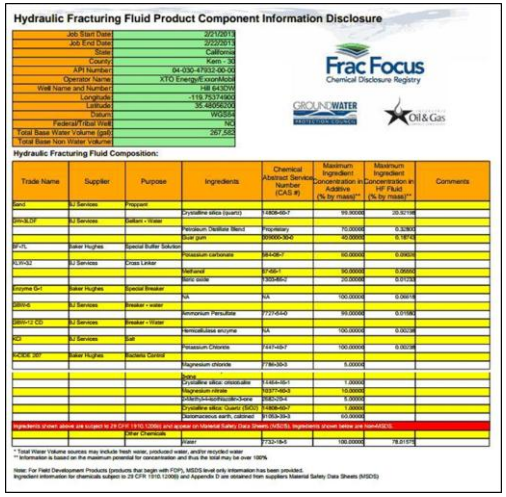
The process of identifying hazardous chemicals - California

Extracting the list of all chemicals from FracFocus database

Evaluating the hazardousness of chemicals using EPA regulations

Identifying chemicals of concerns


Hydraulic Fracturing Fluid Product Component Information Disclosure

Hydraulic Fracturing Fluid Composition:

Obtaining the maximum allowable limits for the concerned chemicals from EPA

Obtaining the frequency of the usage and the concentration of the concerned chemicals from FracFocus

- Scenario Definition
- Defining Physical Processes
- Hazardous Chemicals Identifications
- Model Development
- Running the Model
- Sensitivity Analysis
- Results Evaluations

Model Development

Developed a model to predict the concentration profile of the chemicals in one of the EPA suggested scenarios (Pathway 1: Poor wellbore integrity)

Input

- Well bore / cement characteristics (Well depth/Aperture size)
- Defining the hydraulic fracturing job (Pressure)
- Hydraulic fracturing fluid properties
- Identifying the chemical of concern
- Adjusting C-D equation and Adsorption Parameters

Model

- Run the Mathematical Model

Output

- Chemicals Concentration profile
- Sensitivity Analysis Results

Scenario Definition

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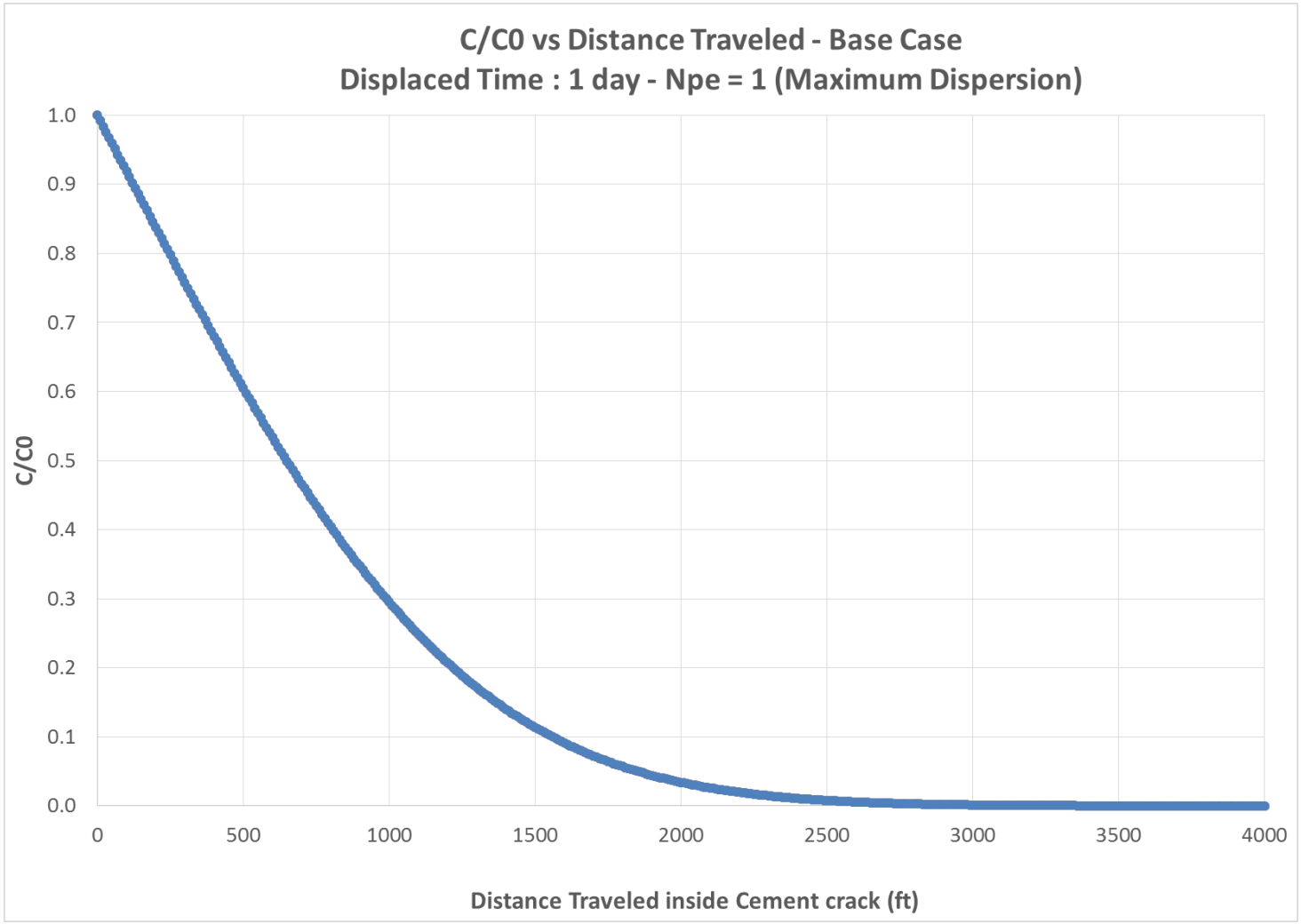
Results – Base Case



- Scenario Definition
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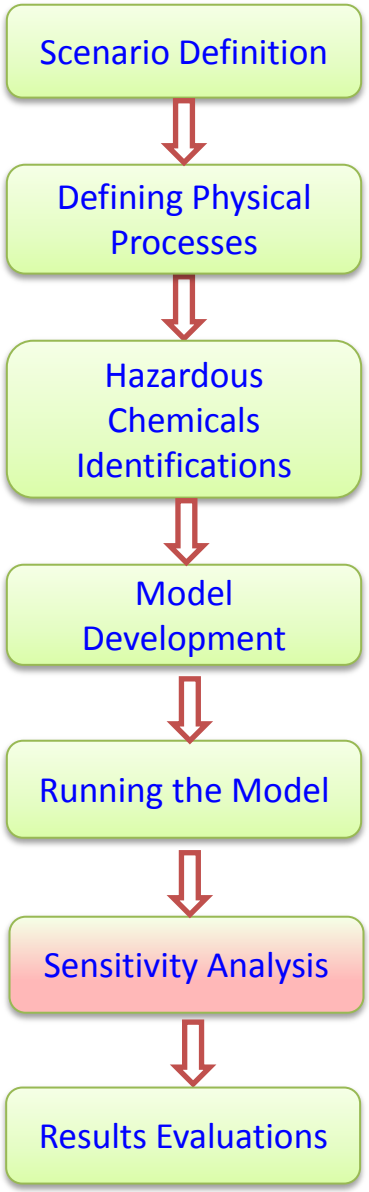
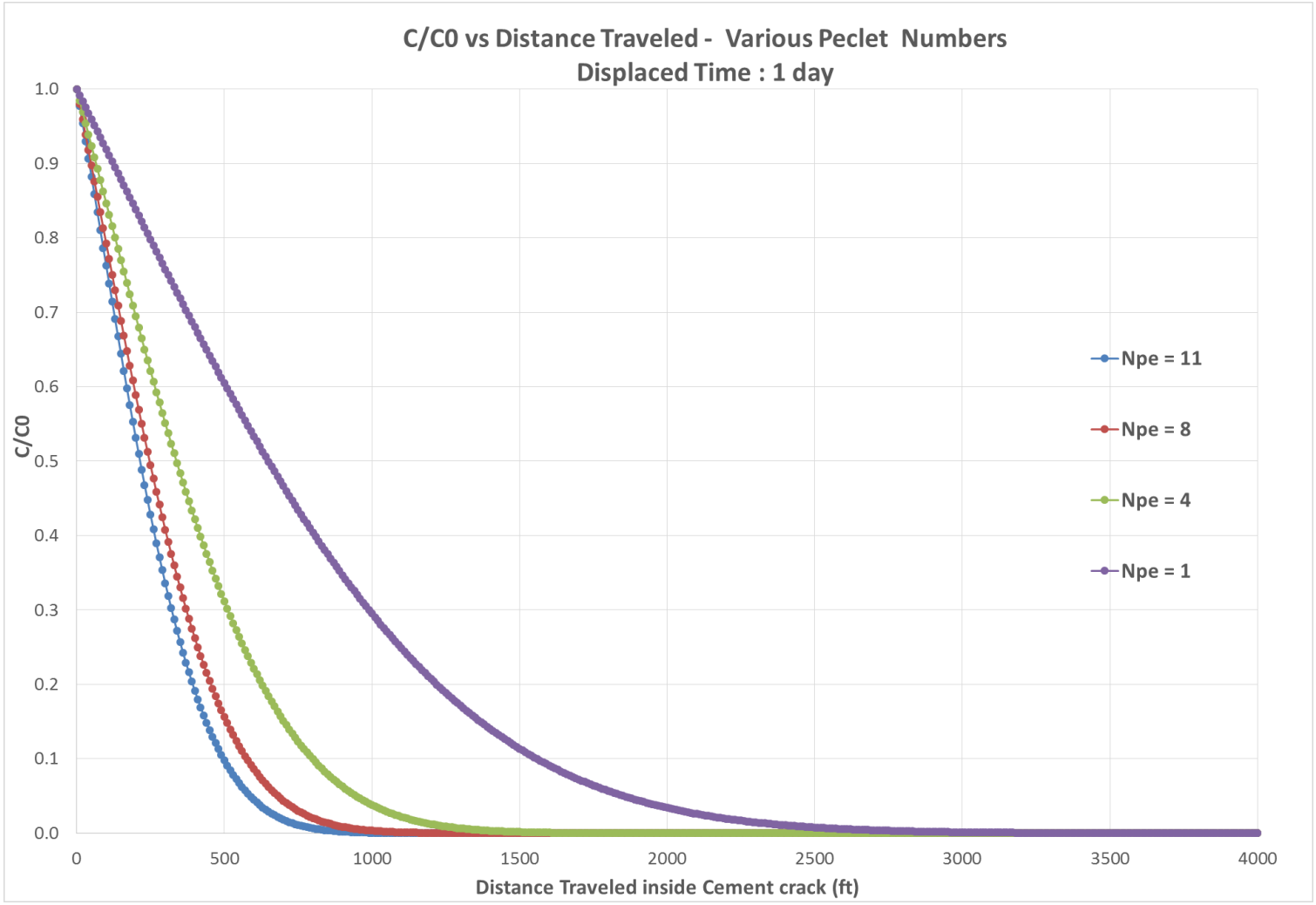
Sensitivity Analysis

- Peclet Number (Pe / Npe), reflecting dispersion coefficient K
- Aperture Size
- Displacement Period
- Adsorption
- Apertures with combination of sizes



Sensitivity Analysis – Pe Number



- Scenario Definition
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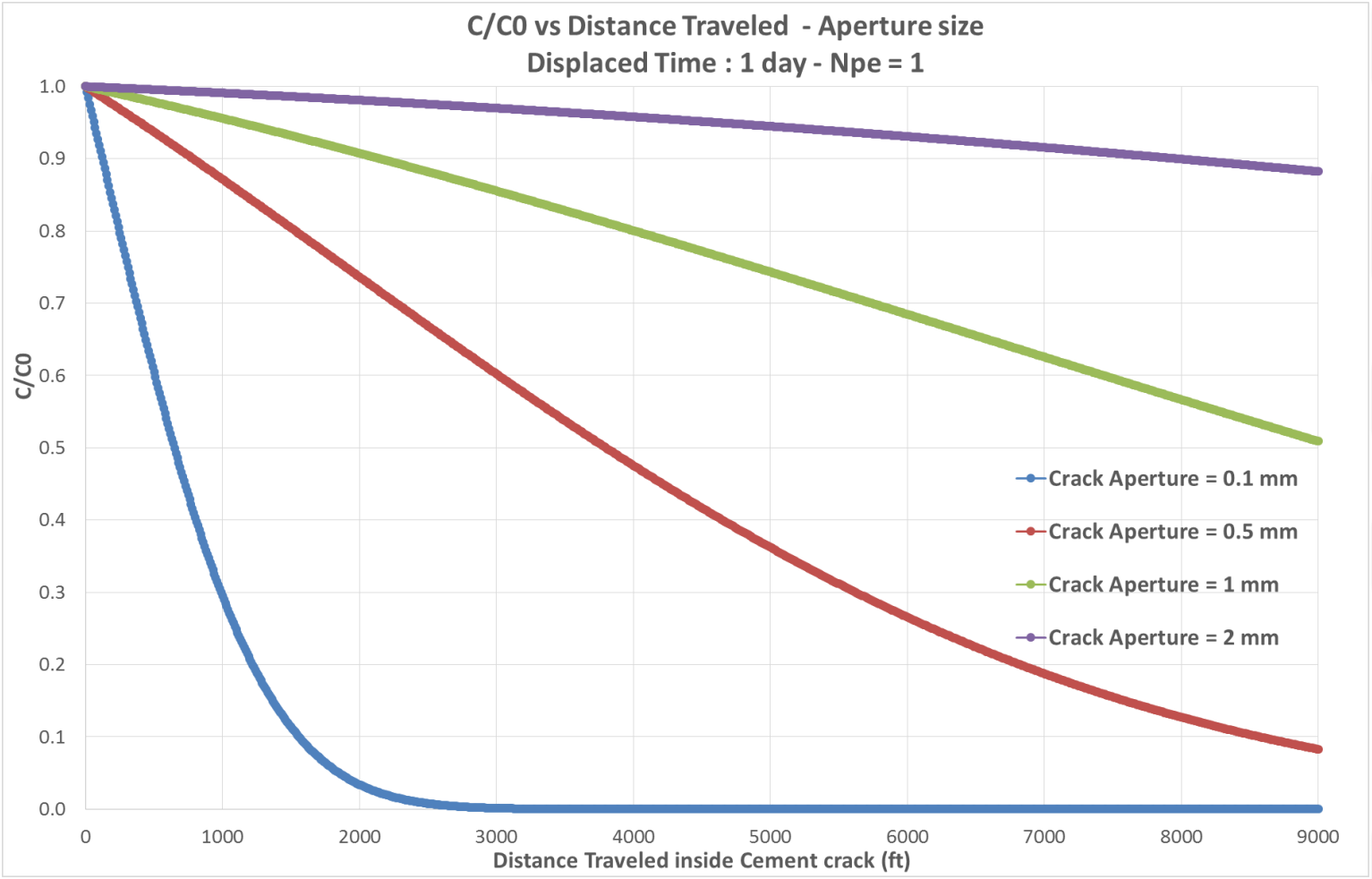
Sensitivity Analysis – Aperture Size



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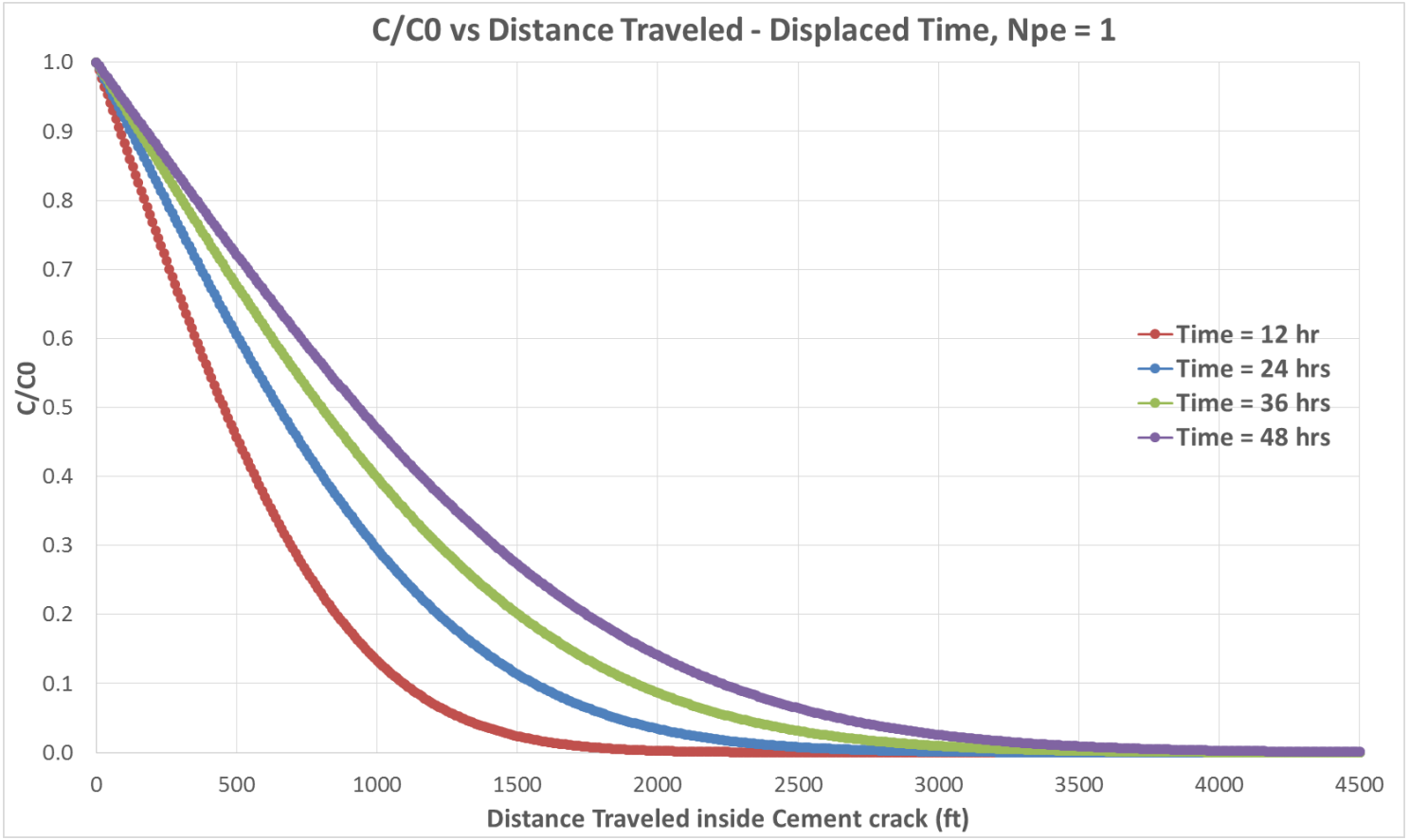
Sensitivity Analysis - Time



- Scenario Definition
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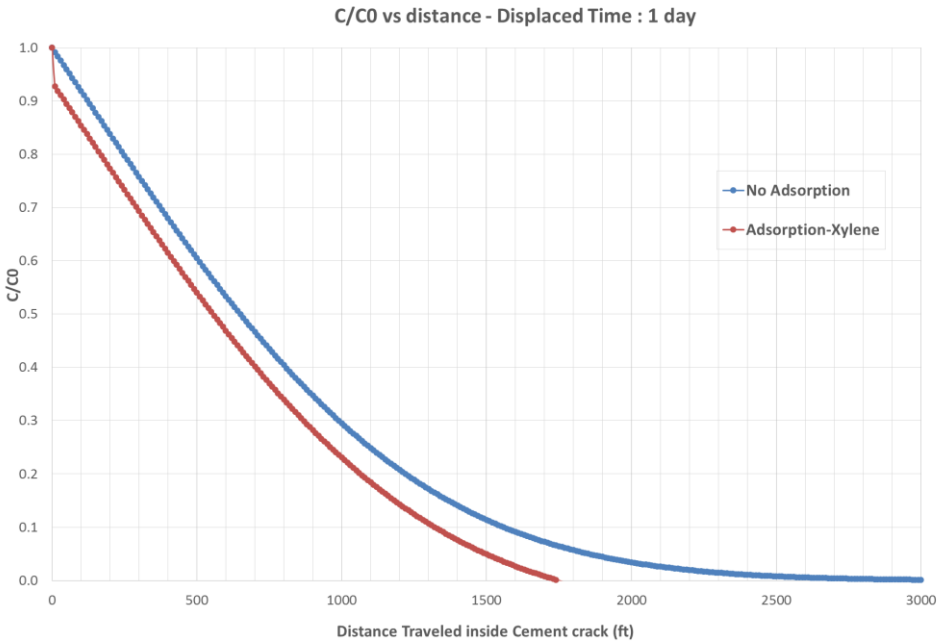
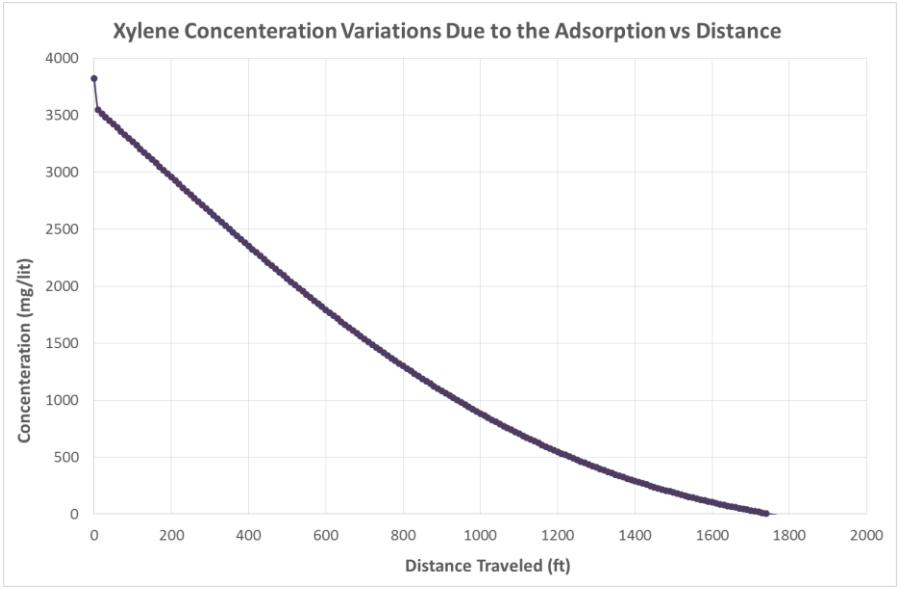
Sensitivity Analysis - Adsorption





- Scenario Definition
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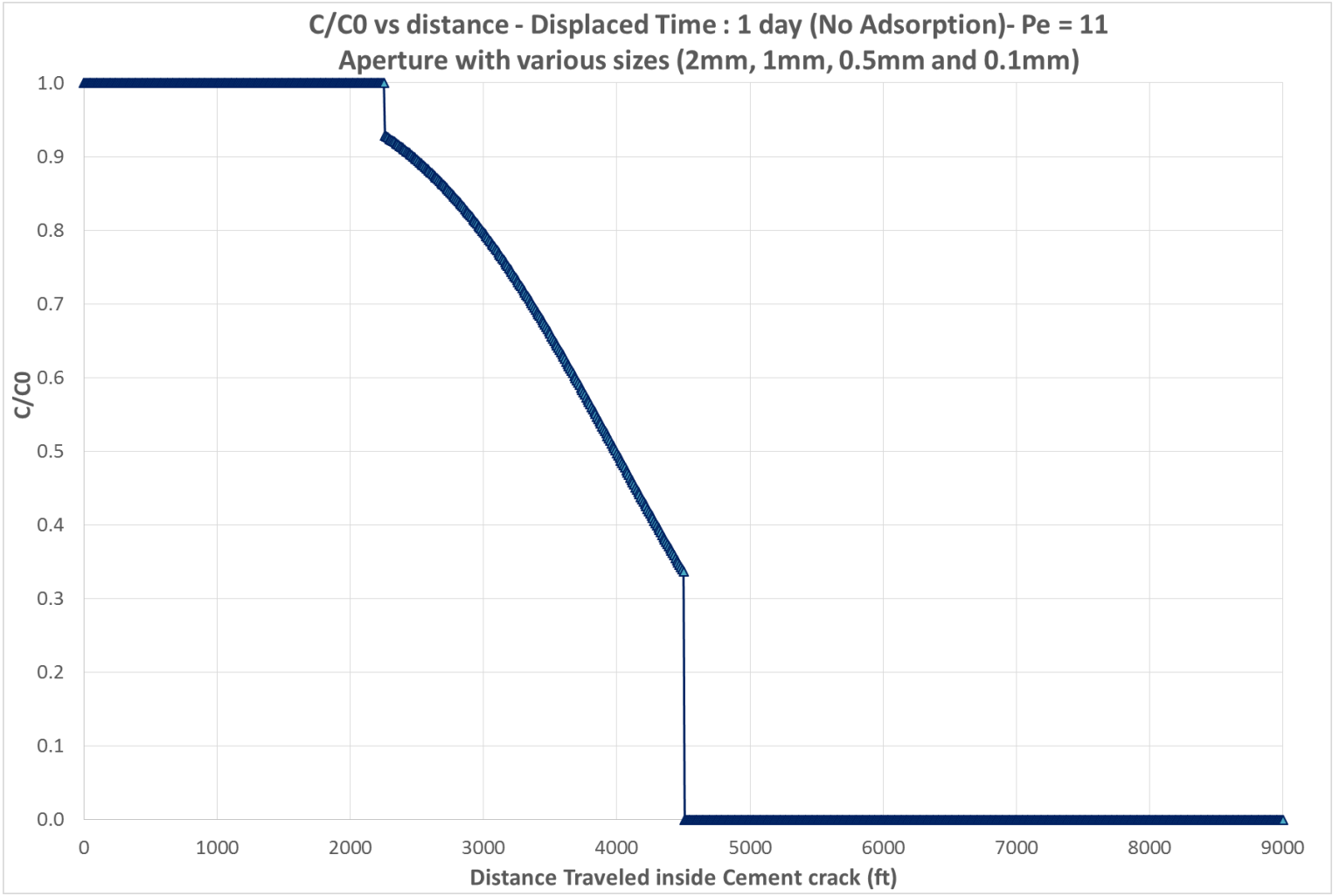
Sensitivity Analysis
Combined sizes of Apertures



- Scenario Definition
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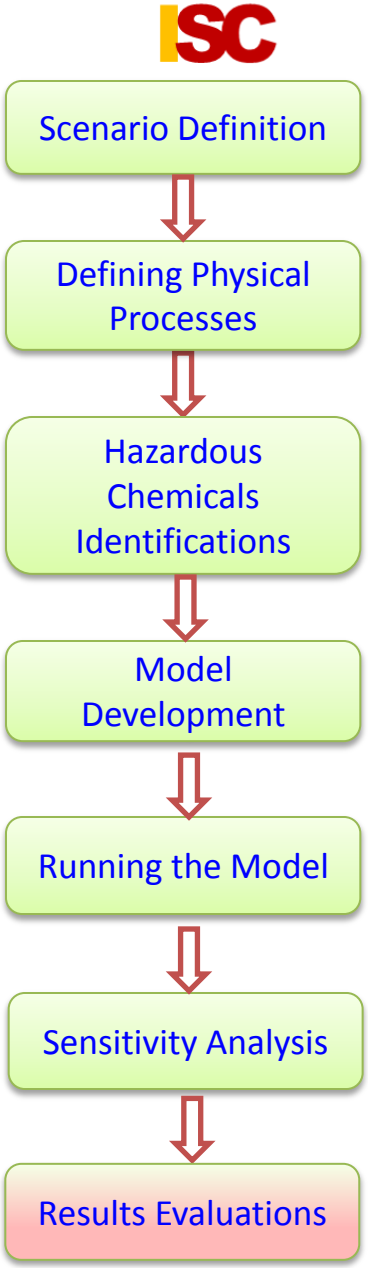
Results Evaluations

- The chemicals' concentration inside the aperture, approaching the ground water level, will be achieved considering the injected concentrations.
- The calculated concentration of chemicals should be compared to EPA suggested MCL (Maximum Contamination Level)
- Short term and long term affects of the ground water contamination to be evaluated.

Possibility of contaminating groundwater by identified chemicals of concern



Conclusion

- We developed a model to predict the concentration profile of the chemicals in case of the poor well integrity.
- Some assumptions due to the limitations in the available input data.
- This study should be considered as preliminary steps to assess the hydraulic fracturing fluid migration inside the cement via mathematical methods.
- Results of the model should not be deemed as any other rigid conclusions.

To receive much better and more precise results:

Experimental lab tests and methodologies, especially for the following parameters:

- Npe (longitudinal dispersion coefficient)
- Langmuir isotherms
- Upscaling methods

Future Works

- Developing the tool to consider many more inputs for more complex scenarios and events.
- Updating the tool based on some real input data received from industry.
- Lab experiments to validate and update some of the considered parameters. (Might be part of the California-centric site-proposal)
- Working on the possibility of replacing concerned chemicals with safer alternatives.
- Studies on cement for evaluations and improvements, avoiding possible damages and further consequences.

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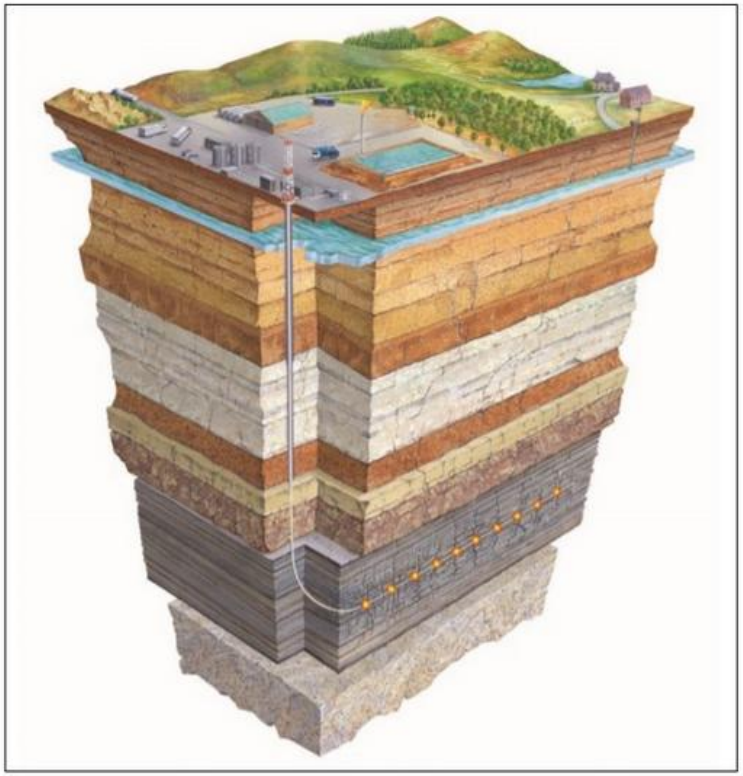
Thank you for your attention!



Fracking, the Environment, and Health. "American Journal of Nursing

Chemicals of concern (As of 2013 in California)

Back-up Slide

- 12 chemicals, used in hydraulic fracturing jobs in CA have been identified as being either carcinogen or toxic to human in certain levels.
- Result achieved following comparison of the chemicals used in CA and Drinking Water Standards and Health Advisories (DWSHA) tables.

						10kg Child			
No.	Chemical	CASRN #	Frequency of usage	Purpose	MCL (mg/L)	One-day (mg/L)	Ten-day (mg/L)	Life-time (mg/L)	Cancer Descriptor
1	Ethylbenzene	100-41-4	4	Acidizing	0.7	30	3	0.7	D
2	Ethylene glycol	107-21-1	342	Crosslinker	-	20	6	-	D
3	Formaldehyde	50-00-0	4	**Biocide	-	10	5	1	B1
4	Isopropylbenzene (cumene)	98-82-8	3	**	-	11	11	-	D
5	Naphthalene	91-20-3	24	Surfactant, Carrier fluid for the active surfactant ingredients		0.5	0.5	-	I
6	Trimethylbenzene (1,2,4-)	95-63-6	11		-	-	-	-	D
7	Trimethylbenzene (1,3,5-)	108-67-8	3		-	10	-	-	D
8	Xylenes	1330-20-7	3	Acidizing / Solvent	10	40	40	-	I
9	Chlorite	7758-19-2	7		1	0.8	0.8	0.8	D
10	Chloride	7647-14-5	32		250				
11	Sulfate	7757-82-6	8		250				
12	Bromate	7789-38-0	1		0.01	0.2		-	B2

Hydraulic Fracturing jobs in CA utilized Xylene

API	Date	Well Name	(% by mass)**	PPM	mg/lit
04-030-48153-00-00	10/13/2012	Paloma 31-11	0.38%	3792.4	3825
04-030-46641-00-00	6/6/2012	Twisselman 18-14W	0.32%	3216.5	3221
04-031-20484-00-00	6/14/2012	Kettleman 1-29	0.003162%	31.6154	31.824