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Supplement of

Conceptual model development using a generic Features, Events, and Processes (FEP) database for assessing the potential impact of hydraulic fracturing on groundwater aquifers

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Tables

Table S1. The highest ranked features for the six focused scenarios.

List of Features	S1	S2	S3	S4	S5	S6
A. Features of the Natural System						
1. Hydrogeology						
1.1. Hydrocarbon bearing formation (Source)						
Rock / Petrophysical properties of the hydrocarbon bearing formation	4	4				
Lithology	4	4	4	4		4
Intrinsic permeability	4	4		4	4	
Relative permeability		4	4	5	4	
Entry pressure		4	4	4		
Stress and Mechanical properties	5					
Heterogeneity of the hydrocarbon bearing formation	4					
Fractures and faults within the hydrocarbon bearing formation	4	4	4	5	4	
Porosity of the fracture				4		
Intrinsic permeability of the fracture	4	4		4		
Relative Permeability of the fractures		4		4	4	
Fracture geometry		4		4		
1.2. Fluids						
Hydrocarbons			4			
Natural formation water			4			
Production fluids			4			
Pore fluid composition within the fracking reservoir			4			
Reservoir fluids			4			
Other fluids			4			
1.3. Overburden						
Porosity				4		
Fractures and faults within the overburden		4				
Relative Permeability of the fractures				4		
Fracture geometry		4		4		
Undetected features within the overburden					5	
2. Near surface environment (Receptors)						
2.1. Terrestrial environment						
Near-surface aquifers and surface water bodies					4	4
B. Unconventional Hydrocarbon Extraction						
1. Hydro-fracturing fluid						
1.1. Hydraulic injection fluid properties						
1.1. Hydraulic injection fluid properties			4			
1.2. Physical properties of injection fluid						
1.2. Physical properties of injection fluid			4			
3. Site operation						
3.1. Drilling and completion						
3.1. Drilling and completion						
Horizontal wells	4	4				
4. Site decommissioning						
4. Site decommissioning						
Abandoned wells				4		

Table S2. The highest ranked events for the six focused scenarios.

List of Events	S1	S2	S3	S4	S5	S6
1. Operational Events						
Hydraulic fracturing	5	4	4	4		
Out of zone / beyond pumping				4	4	4
Production		4	4	4		
Seal failure		4			4	
2. Natural events						
Earthquakes	4					
Cap rock failure		4		4		
3. Accidents and unplanned events						

Overpressuring	4	4	4	4		
Poor site characterization		4	4	4	4	
Incorrect chemical mix released into fracking fluid			4			
Cementation poorly undertaken (spaces left)		4	4	4		

Table S3. The highest ranked processes for the six focused scenarios.

List of Processes	S1	S2	S3	S4	S5	S6
2. Hydraulics / Fluid Pressure Dominated						
Fluid pressure exceeds rock fracking pressures generating new fractures	4	4		4		
Fluid exceeds fault sealing pressures	4	4		4		
Fluid pressure exceeds stability of part of the plant construction.	4	4				
Displacement of surrounding formation fluids		4		4	4	
Buoyancy-driven flow		4		4	4	4
Advection and co-migration of other gas			4			
Water mediated transport			4		4	
Advection			4	4	4	4
Dispersion				4	4	4
Diffusion			4			4
Hydraulic and production fluids and the associated contaminants release processes			4	4	4	4
3. Chemical						
Corrosive mixture attacks plant			4			
Corrosive mixture attacks geology			4			
Sorption and desorption			4			
Mineral dissolution			4	4		
Heavy metal release			4	4		
4. Mechanical						
Soil and rock deformation around boreholes	4	4		4		
Propagation of fractures beyond the target zone	4	4	4	5		
Fluid exceeds fault sealing pressures	4	4		5		
Fault valving	4	4		4		
Micro-cracking in the casing cements		4		4		

Table S4. The key parameters and their variations for the ‘regional fracturing fluid flow and stray gas migration’ scenario.

Parameters	Variation	Literature
Overburden thickness, m	1100 – 2100	(EIA 2011; 2011)
Fault width, m	5 – 20	(Gassiat et al. 2013; Kissinger et al. 2013b; Reagan et al. 2015; Pfunt et al. 2016)
Overburden permeability, m^2	1×10^{-18} – 1×10^{-15}	(Gassiat et al. 2013)
Overburden anisotropy ratio	1 – 1000	(Freeze and Cherry 1979; Neuzil 1994)
Deep aquifer permeability, m^2	5×10^{-16} – 5×10^{-12}	(Nordbotten et al. 2005; Wigand et al. 2008; Birkholzer et al. 2009; Michael et al. 2010; Vilarrasa et al. 2013)
Deep aquifer porosity	0.05 – 0.35	(Nordbotten et al. 2005; Wigand et al. 2008; Birkholzer et al. 2009; Michael et al. 2010; Vilarrasa et al. 2013)
Fault permeability, m^2	2×10^{-11} – 1×10^{-10}	(Gassiat et al. 2013; Kissinger et al. 2013b; Birdsell et al. 2015; Pfunt et al. 2016)
Fault porosity	0.08 – 0.12	(Myers 2012; Saiers and Barth 2012; Pfunt et al. 2016)
Salinity, kg/m^3	150 – 350	(King 2012)

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