Evaluating the Post-closure Safety of Geological Disposal of Long-lived Radioactive Wastes

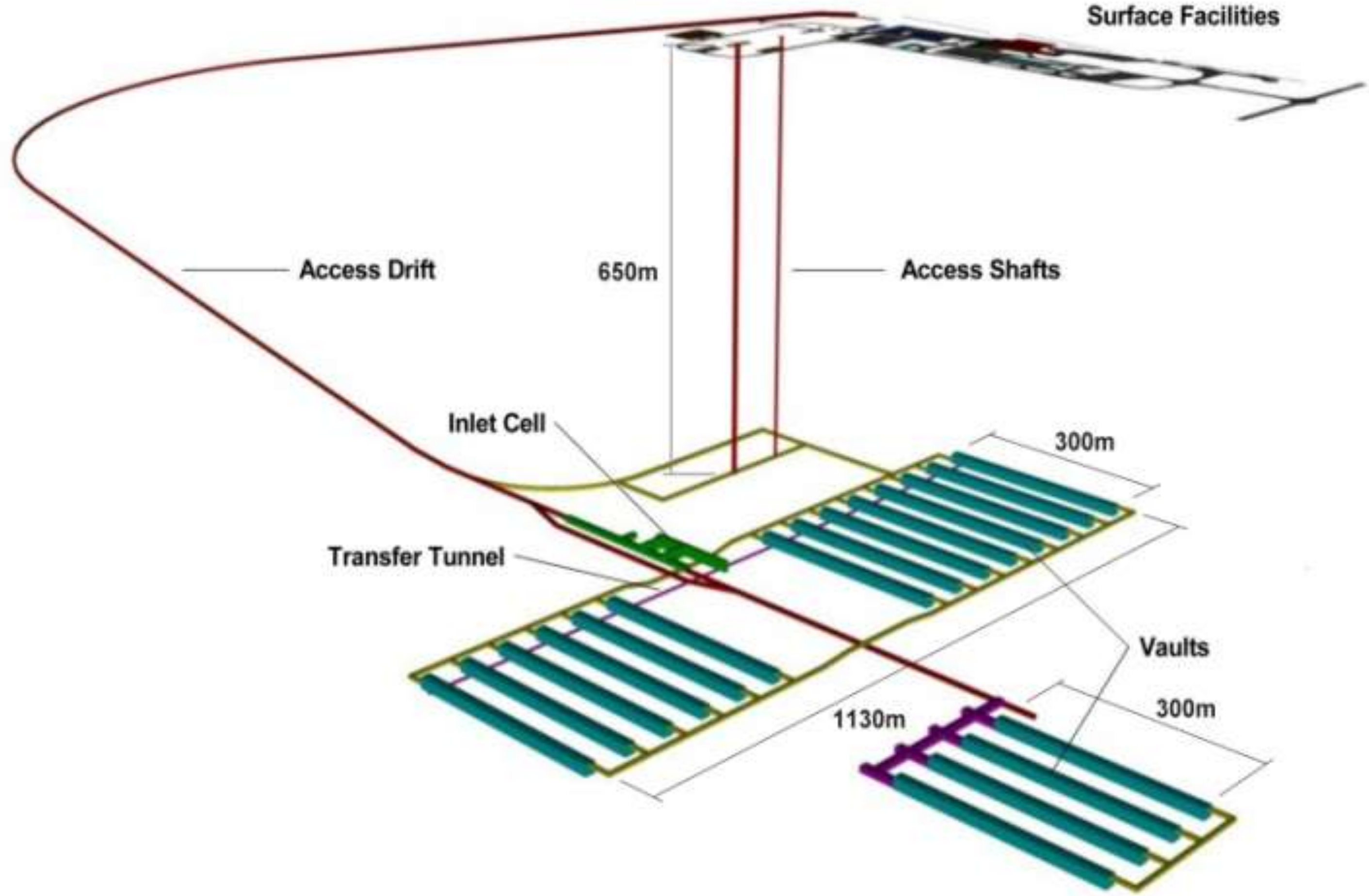
Professor Alan Hooper

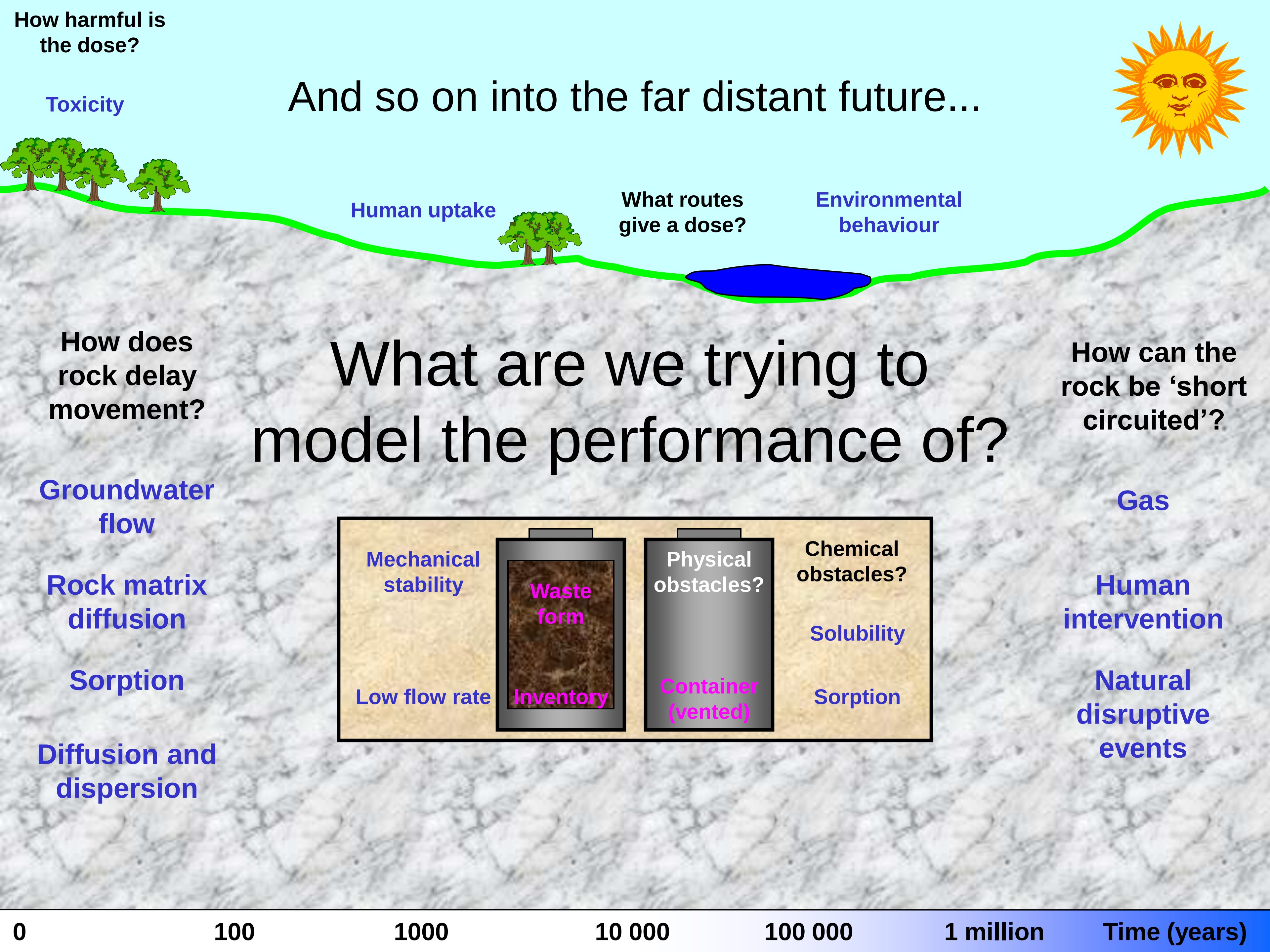
Presentation to IKIMP Workshop

St Anne's College, Oxford

13-14 October 2009

The basic layout of the repository




How harmful is the dose?
Toxicity
And so on into the far distant future...
Human uptake
What routes give a dose?
Environmental behaviour
How does rock delay movement?
What are we trying to model the performance of?
How can the rock be 'short circuited'?
Groundwater flow
Rock matrix diffusion
Sorption
Diffusion and dispersion
Mechanical stability
Low flow rate
Waste form
Inventory
Physical obstacles?
Container (vented)
Chemical obstacles?
Solubility
Sorption
Gas
Human intervention
Natural disruptive events
0
100
1000
10 000
100 000
1 million
Time (years)

Regulatory Risk Guidance Level

- Radiological risk to an individual of one in a million per year (of fatal cancer or serious hereditary effect)
- Term ‘radiological risk’ reflects stochastic response to low-level radiation doses
- Risk calculated for comparison with guidance level reflects both the probability that a given dose will be received and the probability of the relevant effect on health
- Provides a source of much confusion when understandably thought of as ‘risk of failure’

Types of uncertainty

- In a repository system there are a number of different areas in which uncertainty may influence a performance assessment;
  - uncertainty over future states of the system
  - data uncertainty
  - model uncertainty
  - uncertainty about human behaviour

Approach to Scenarios

- Base scenario
  - may include major time-dependent effects such as expected climate change
  - deals with the release of radionuclides in groundwater or in gaseous form
- Variant scenarios
  - are defined by an initiating event, e.g. an earthquake, hence a deviation from the base scenario
  - includes human intrusion and nuclear criticality

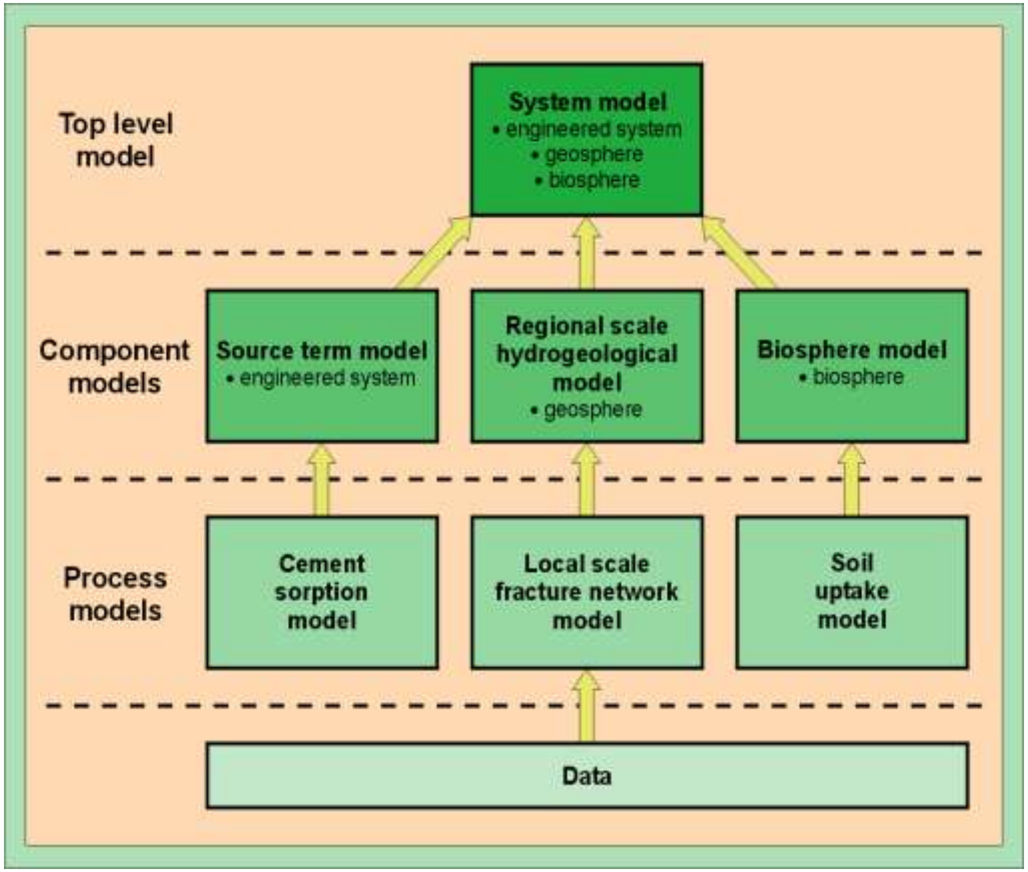
Treatment of uncertainty within a scenario

- FEP analysis and the systematic development of scenarios can deal with some uncertainties connected with the future
- For a defined scenario, there are other uncertainties:
  - data uncertainty
    - including uncertainty resulting from spatial variability and time-dependence
  - conceptual and mathematical model uncertainty

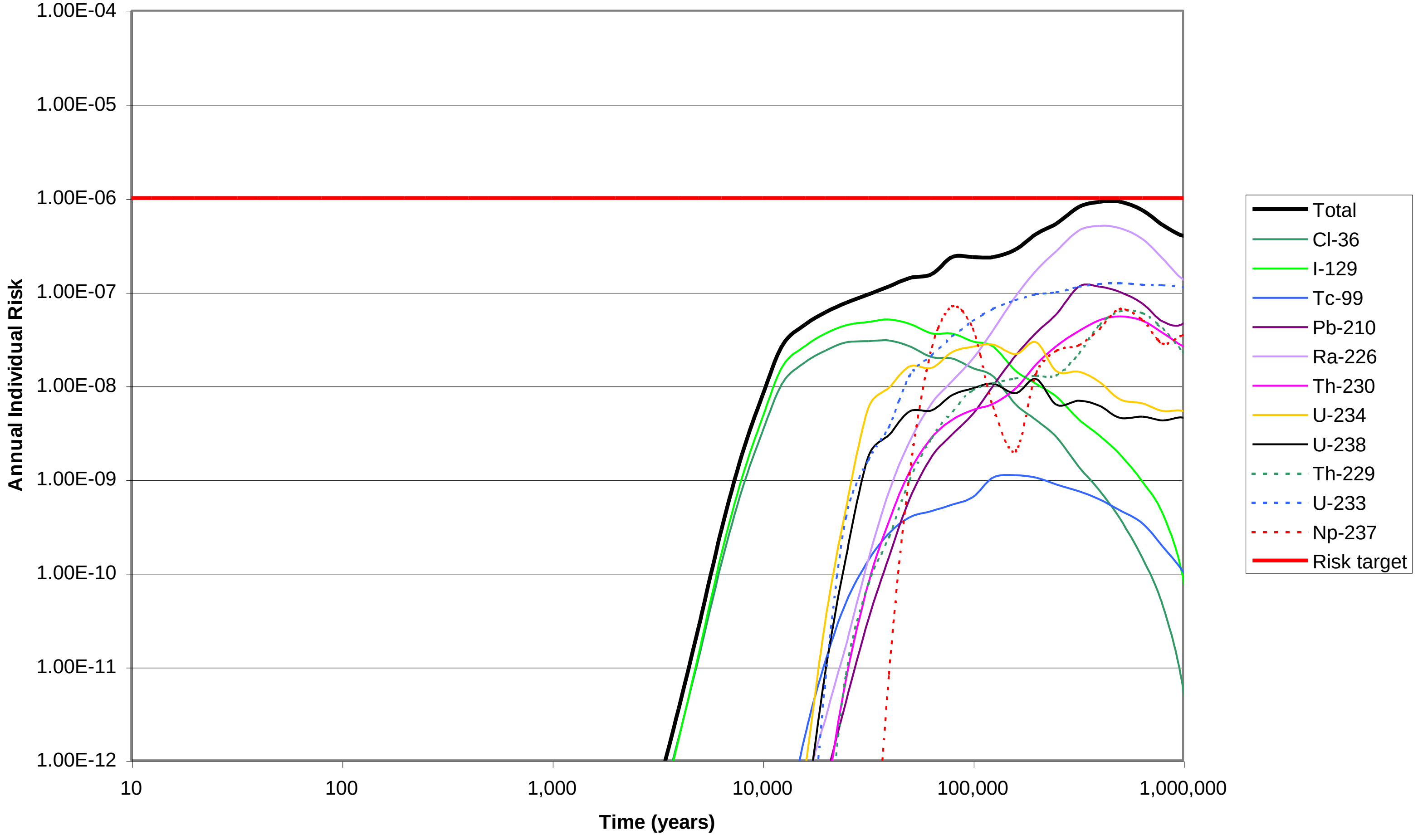
Strategies for handling uncertainty

1. Demonstrating that the uncertainty is irrelevant
   - e.g. safety controlled by other processes
2. Addressing the uncertainty explicitly
   - representing by PDFs in a probabilistic calculation
   - scoping effect of range of uncertainty by deterministic sensitivity calculations
3. Bounding the uncertainty
   - making conservative assumptions
4. Ruling out the uncertainty on the basis of low probability
5. Explicitly ignoring uncertainty or agreeing a stylised approach for handling an irreducible uncertainty

Hierarchy of models to calculate overall performance measure (e.g. risk)



Reference Case radiological risk against time (GPA03 Update)



Groundwater Pathway
What does risk depend on?

$$R_{\text{peak}} \propto \frac{I\,N\,G\;0.06B}{\sqrt{\sigma_s^2 + \sigma_g^2}}$$

R_{peak} = peak risk

I = inventory

N = fraction released from repository

G = fraction released from geosphere

B = biosphere factor

σ_s = source term spreading time

σ_g = geosphere spreading time

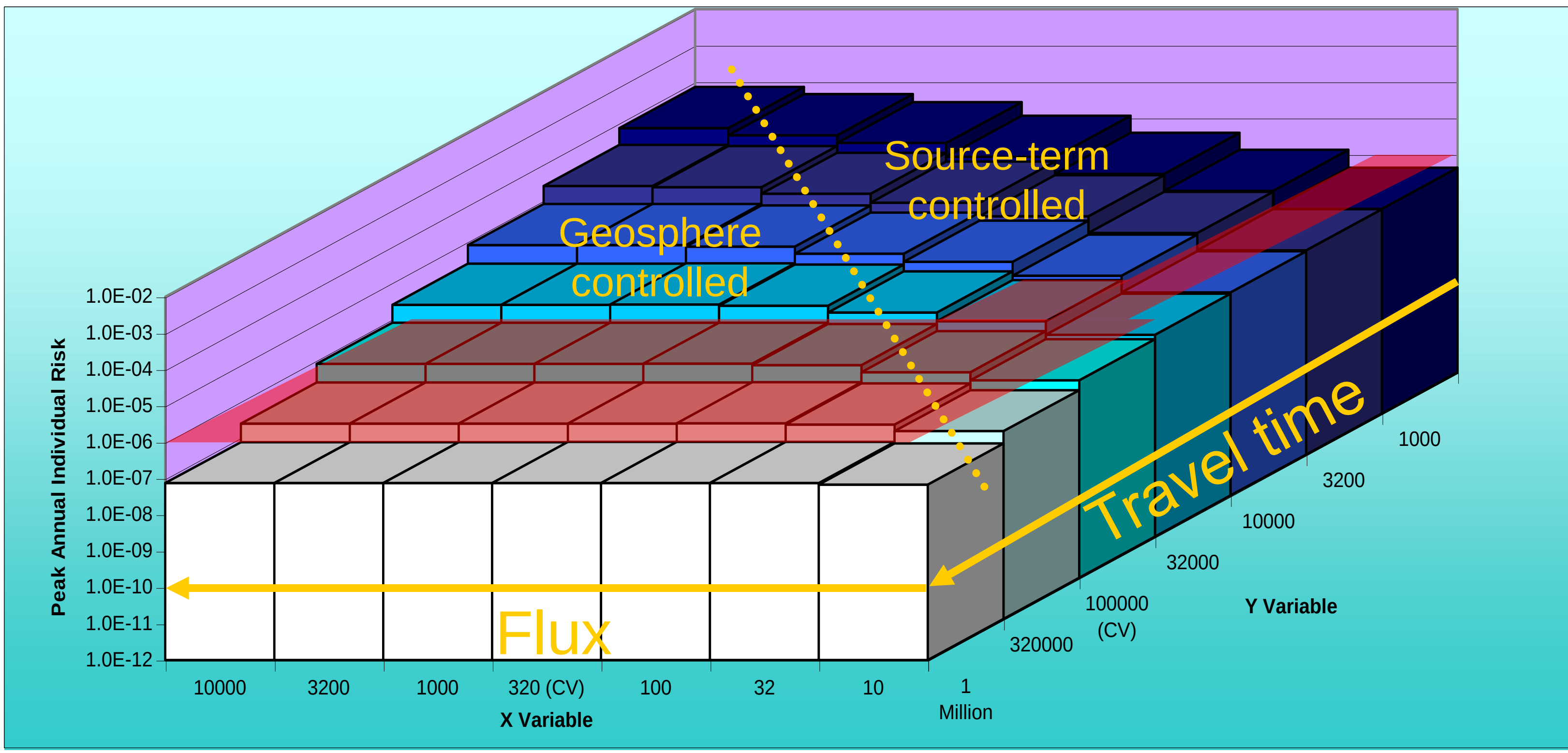
0.06 = dose to risk factor

Iodine-129

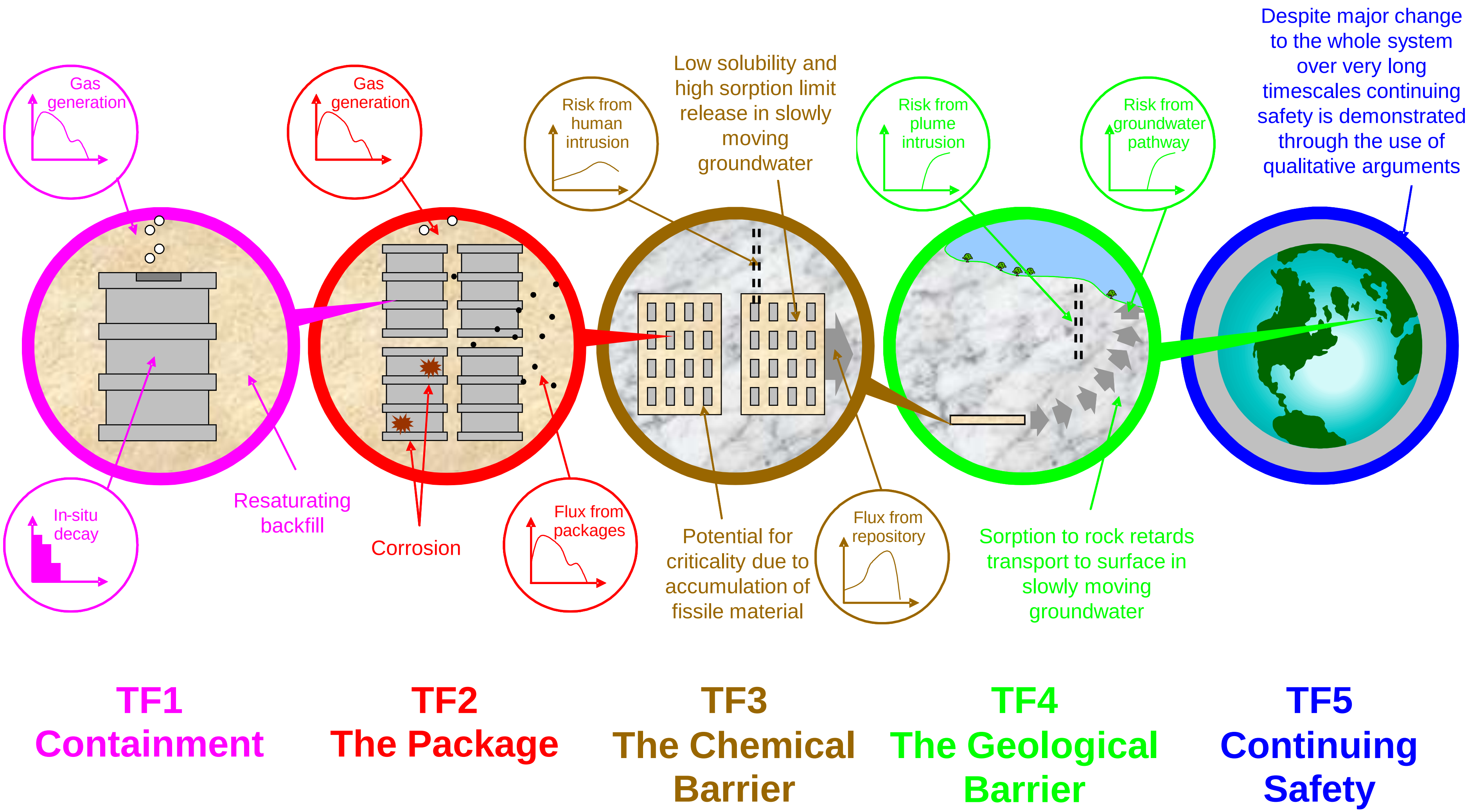
- Iodine-129 has a half life of 15.7 million years
- Inventory of iodine-129 is 1.5 TBq
- Iodine is very soluble and mobile
- Source term spreading time, σ_s, depends on flux through repository, Q
- Geosphere spreading time, σ_g, depends on travel time, T

Iodine-129 Travel time v Flux

Worksheet:		Data			
Radionuclide:	(0-39)	14	OK	Radionuclide is:	I-129
Near-field solubility:	(1-7,X,Y)	3	OK	Near-field solubility:	Central values
Near-field sorption:	(1-7,X,Y)	3	OK	Near-field sorption:	Central values
Far-field sorption:	(1-7,X,Y)	3	OK	Far-field sorption:	Central values
Flux (Q):	(1-7,X,Y)	X	OK	Flux (Q):	Plotted on the X axis
Travel time (T):	(1-7,X,Y)	Y	OK	Travel time (T):	Plotted on the Y axis



Assessment Timeframes



Concluding Remarks

- Radioactive waste management programmes have developed a wealth of modelling and assessment techniques and experience in presenting post-closure safety cases.
- Despite “nuclear dread” geological repositories are variously operating, fully licensed or well advanced through licensing, in a number of countries with strong, independent regulation.
- Information on the intrinsic safety of multi-barrier containment systems has proved a powerful complement to numerical modelling.