

Thermal Management of Wastes from Advanced Fuel Cycles

**Ernest Hardin, Laura Price and Peter Swift
Sandia National Laboratories
Albuquerque, New Mexico**

**International High-Level Radioactive Waste Management
Albuquerque, NM
April 10-14, 2011**

SAND2011-2363C

Objective: Develop a bounding range for thermal output from UNF and HLW from advanced fuel cycles, and assess the associated radiotoxicity and temperatures in a geologic repository (U/TRU cycles)

Outline:

- Used nuclear fuel (UNF) + 3 Cases (heat output, normalized radiotoxicity)
- Reference thermal calculation
- Normalization to electrical energy produced
- Isolation performance for actinides vs. fission products

Fuel Cycle Concepts

(after Wigeland et al. 2010. *Options Study - Phase II*. DOE Fuel Cycle R&D Technical Integration Office)

Nuclear Power Issue	Suitable Nuclear Fuel Cycle Options
Nuclear Waste Management	<ul style="list-style-type: none"> • Actinide recycle (no UNF disposal) * • Externally-driven once-through systems with complete fuel consumption
Proliferation Risk and Security	<ul style="list-style-type: none"> • “Safeguards-friendly” technologies • Lower material attractiveness
Safety	<ul style="list-style-type: none"> • Virtually all fuel cycle options and technologies
Sustainability	<ul style="list-style-type: none"> • Fuel cycles with more efficient breeding * • Actinide recycle and no UNF disposal *
Economics	<ul style="list-style-type: none"> • All fuel cycle options but less complex technologies may have fewer issues with costs

* Reduce decay heat for waste mgmt. and to reduce needed repository space.

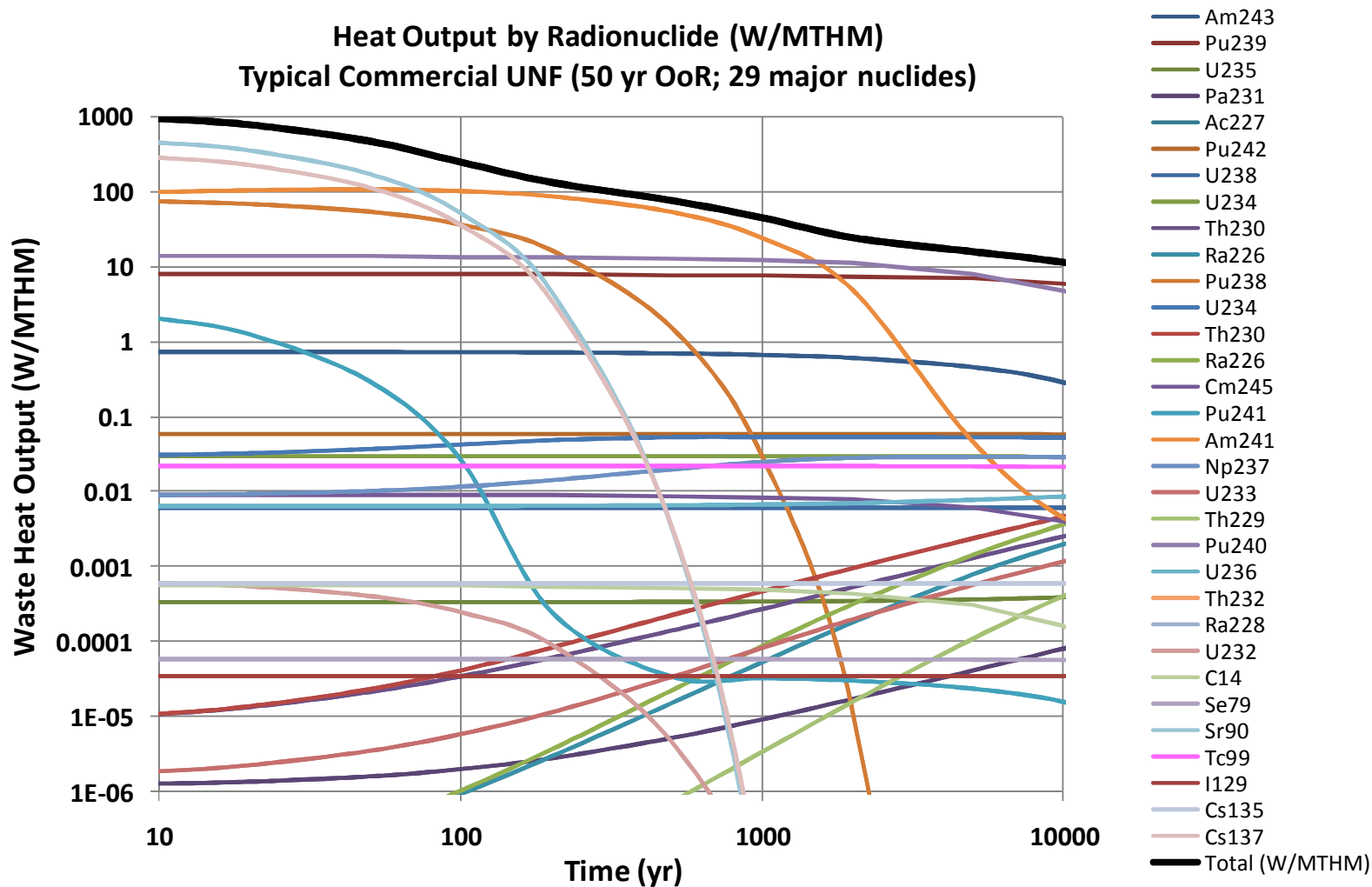
Fuel Cycle Cases Evaluated

	Implementation	Representing	Reference Comparison
Reference	LWR UNF (nominal burnup 40 GWth-d/t)	Direct disposal	Current used fuel inventory
Case 1	LWR UNF with short-lived fission products (SLFPs) removed	SLFP separation, or extended decay storage of used LWR fuel and direct disposal	Idealized case to clarify heat output from actinides
Case 2	LWR UNF content with TRUs separated and fissioned	Reprocessing waste from recycling TRUs, containing FPs and non-TRU ($A \leq 238$) heavy metals	LWR + TRU burner fuel cycle
Case 3	LWR UNF + actinide content ($A \geq 232$) continuously recycled	Reprocessing waste from full recycle, containing fission products and heavy metals lighter than ^{232}U or ^{232}Th	LWR + fast U/TRU breeder fuel cycle

Calculation Methods

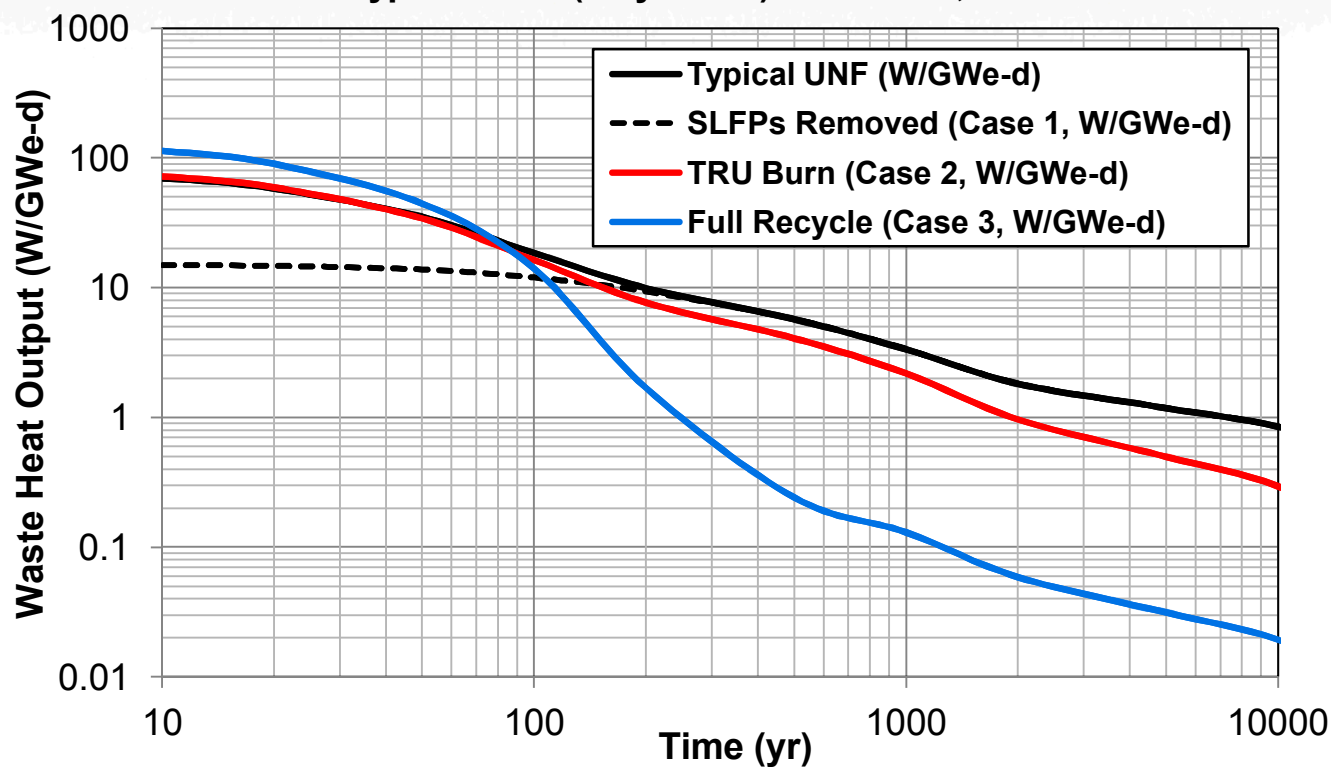
- **Use perfect separation and transmutation yields for bounding cases**
- **Use binding energies and fast-fission yields for energy and fission product (spreadsheet) calculations**
- **Use analytical heat conduction solutions for near-field temperature (at surface of canister)**
 - UNF 50 yr out-of-reactor; 100 yr decay storage
- **Calculate normalized radiotoxicity using biosphere dose conversion factors from Yucca Mtn. performance assessment**

Fuel Cycle Cases – Decay Chains



Fuel Cycle Cases – Heat Output

Total Waste Heat Output, Normalized to Electricity Produced
Typical UNF (50 yr OoR) + Cases 1, 2 & 3

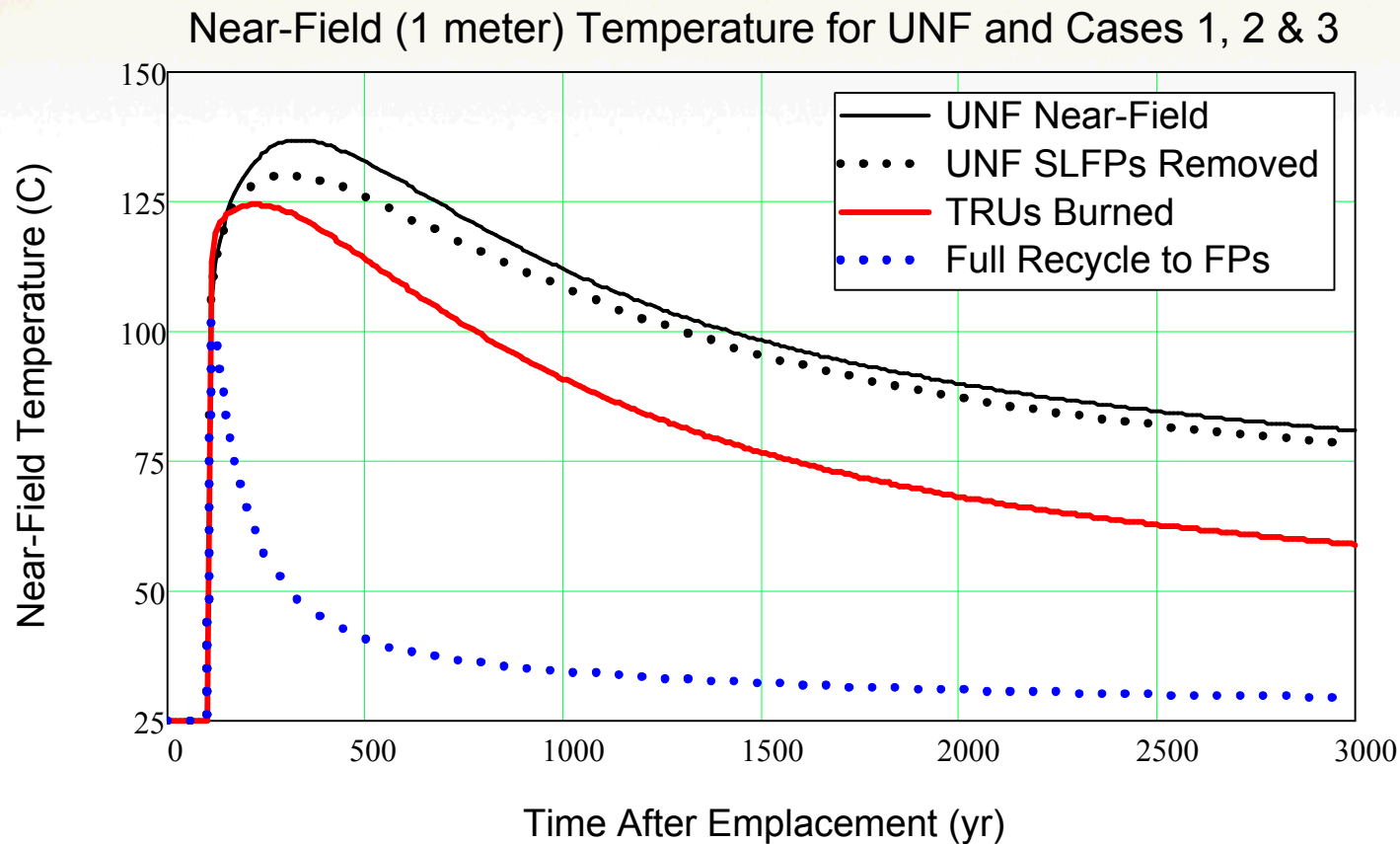


Normalization data:

Case 1: LWR UOX once-through (45 GWth-d/t)	15	GWe-d/t (reference)
Case 2: LWR + TRU burner	18	GWe-d/t
Case 3: LWR + continuous actinide recycle	312	GWe-d/t

Fuel Cycle Cases

Reference Repository Near-Field Temperature

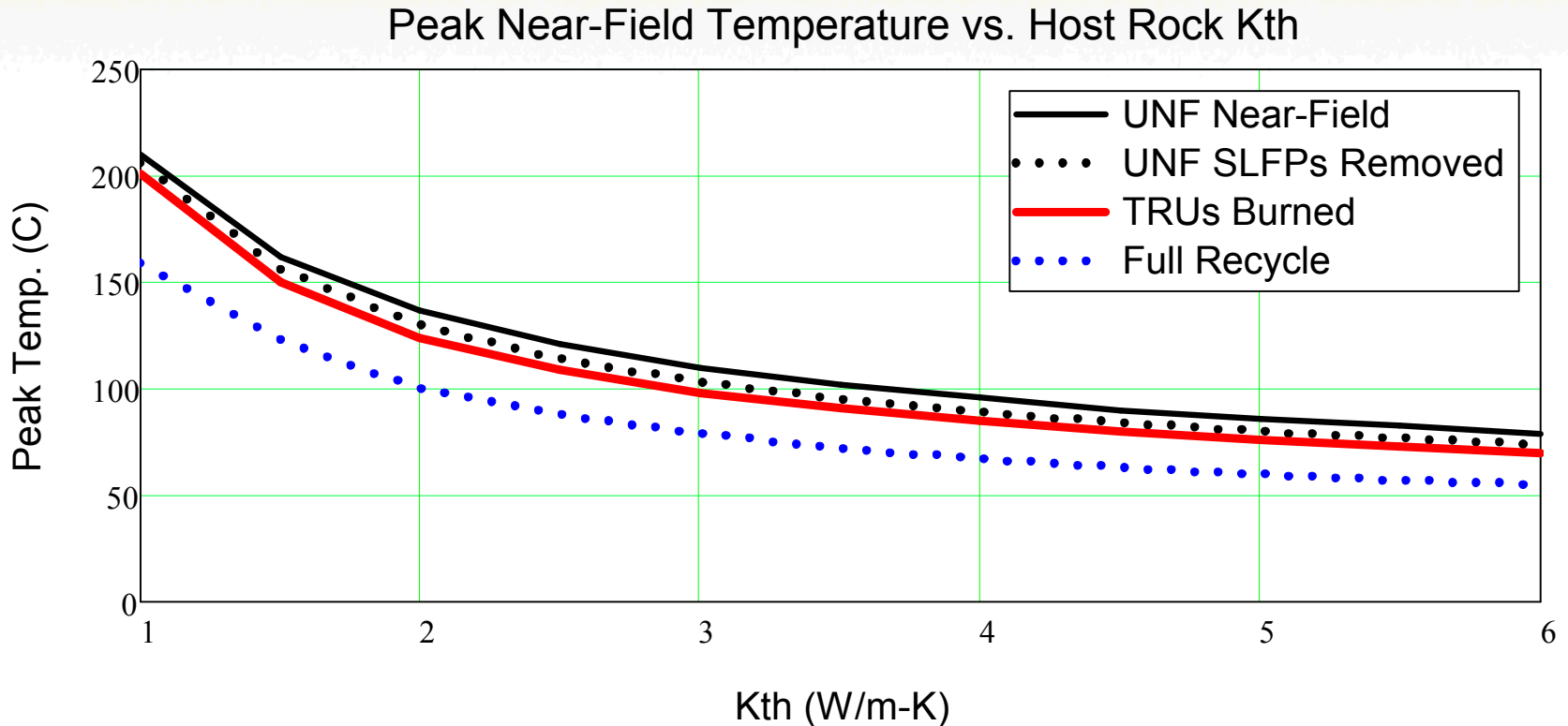


Simulation Conditions: 100-yr decay storage, $K_{th} = 2$ W/m-K, line-source spacing = 100 m

Normalization data: ~130 GWe-d per 5.5-meter waste package, for all fuel cycle cases.

Fuel Cycle Cases

Peak Near-Field Temp. vs. Rock Thermal Conductivity



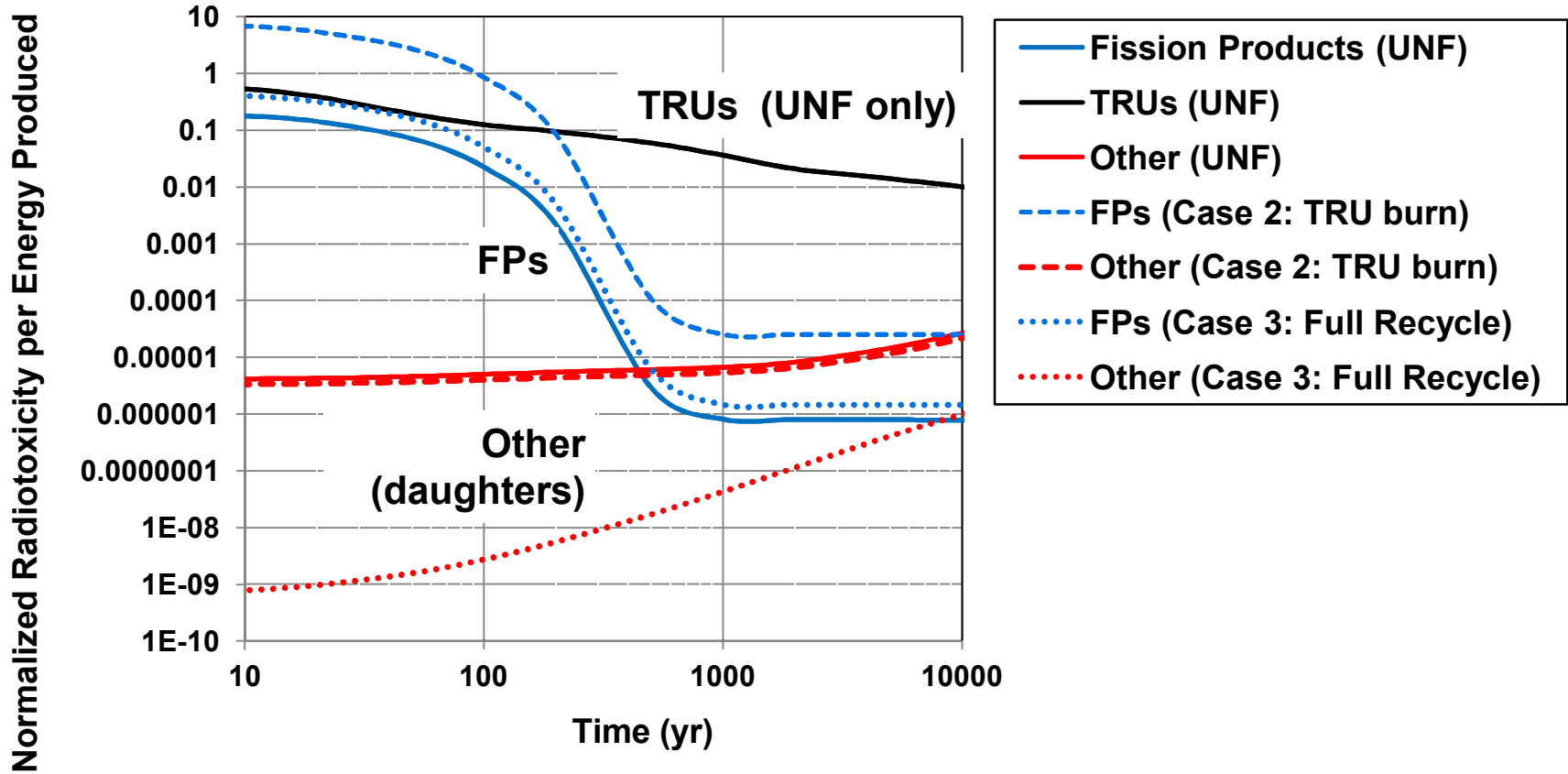
Simulation Conditions: 100-yr decay storage and line-spacing = 100 m

Normalization data: ~130 GWe-d per 5.5-meter waste package, for all fuel cycle cases.

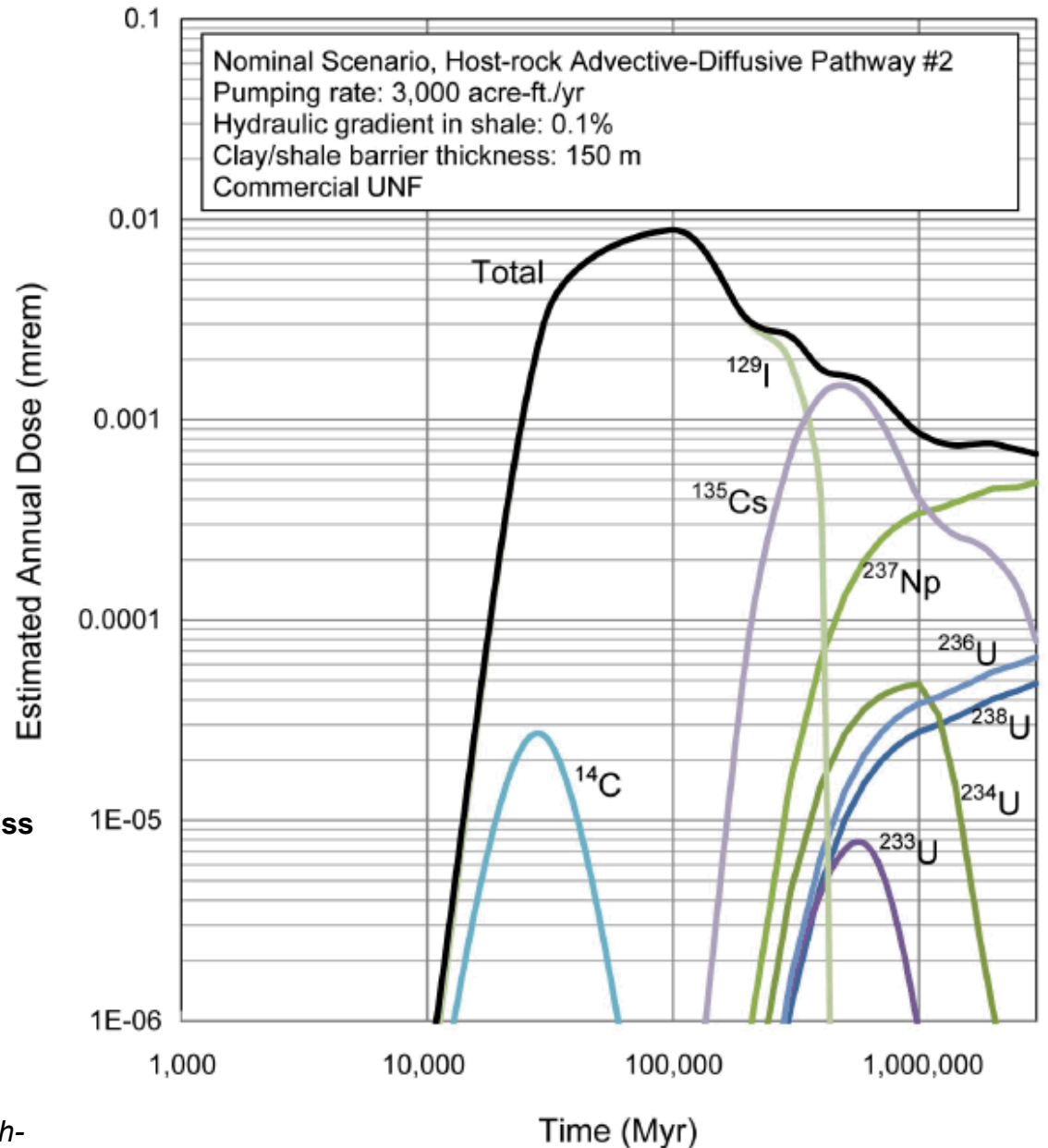
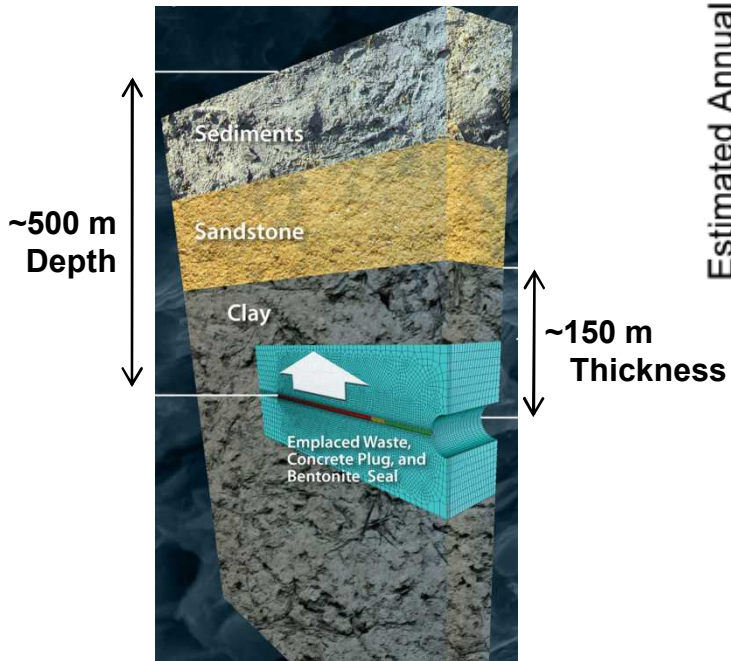
Fuel Cycle Cases

Normalized Radiotoxicity

Normalized Potential Radiotoxicity
 Typical UNF, Case 2 (TRU Burn) & Case 3 (Full Recycle)



Reducing conditions and sorbing mineralogy can greatly retard actinides but not mobile fission products. Example: generic analysis for a repository in clay/shale.



Hansen et al. 2010. *Shale Disposal of U.S. High-Level Radioactive Waste*. SAND2010-2843.

Summary & Conclusions

- **Current + idealized advanced fuel cycles define a range of thermal output (U,TRU)**
- **Repository thermal capacity: normalization to of GWe-yr/acre**
 - Reference case (LWR UNF) ~ 3 GWe-yr/acre
 - Order of magnitude increase possible with continuous recycle and >100 yr decay storage
 - Examine method/cost to emplace HLW at this loading density
- **Transmutation of TRUs increases capacity**
 - Lowers postclosure thermal output (1000's of years)
 - May increase potential dose from fission products