Results of Technology Screen

Remediation of Uranium in Groundwater

Focused Feasibility Study for

300-FF-5 Operable Unit

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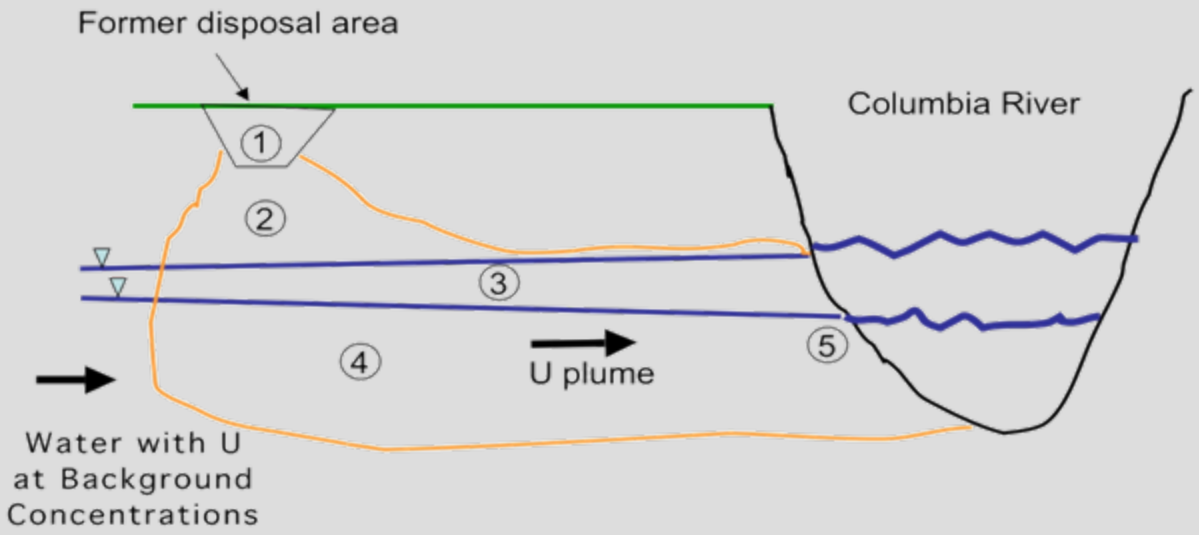
Overview

- Dissolved uranium in groundwater in 300-FF-5 Operable Unit aquifer.
- Focused feasibility study to evaluate remediation alternatives for uranium in groundwater.
- **Remediation objectives:**
  - **Restore—to extent possible— groundwater to its highest beneficial use, which is presumed to be a drinking water supply.**
  - **Reduce risk to human health and the environment.**

Idealized Vertical Profile



1. Former disposal area: *process ponds and trenches*
2. Lower vadose zone sediments *below disposal area*
3. "Smear zone": *Periodically wetted sediment above water table that fluctuates with Columbia River level*
4. Aquifer: *Upper-unconfined aquifer comprised of sediment and groundwater*
5. Groundwater-river interface: *Dynamic zone where groundwater and Columbia River water infiltrate and mix as levels fluctuate at riverbank and channel*

Feasibility Study Process

- Establish remedial action objectives
- Develop general response actions
- Inventory applicable technologies and management strategies
- **Screen appropriate technologies**
- Combine technologies into alternatives
- Conduct preliminary screening of alternatives
- Evaluate selected alternatives with nine criteria
- Compare alternatives
- Prepare feasibility study report
- Prepare proposed plan

Comparison of Perspectives

1993-1995 Feasibility Study	2007-2008 Phase III Feasibility Study
Focus on multiple chemicals of concern impacting groundwater only.	Focus on uranium primarily affecting groundwater.
Assumed effective source control measures applied to vadose zone sediment to minimize contaminant migration to aquifer.	Ongoing release of uranium from vadose zone and fluctuating interface zone requires remedy.
Active technologies focused on groundwater containment or removal.	Active technologies for multiple zones: lower vadose sediments, interface, and aquifer.

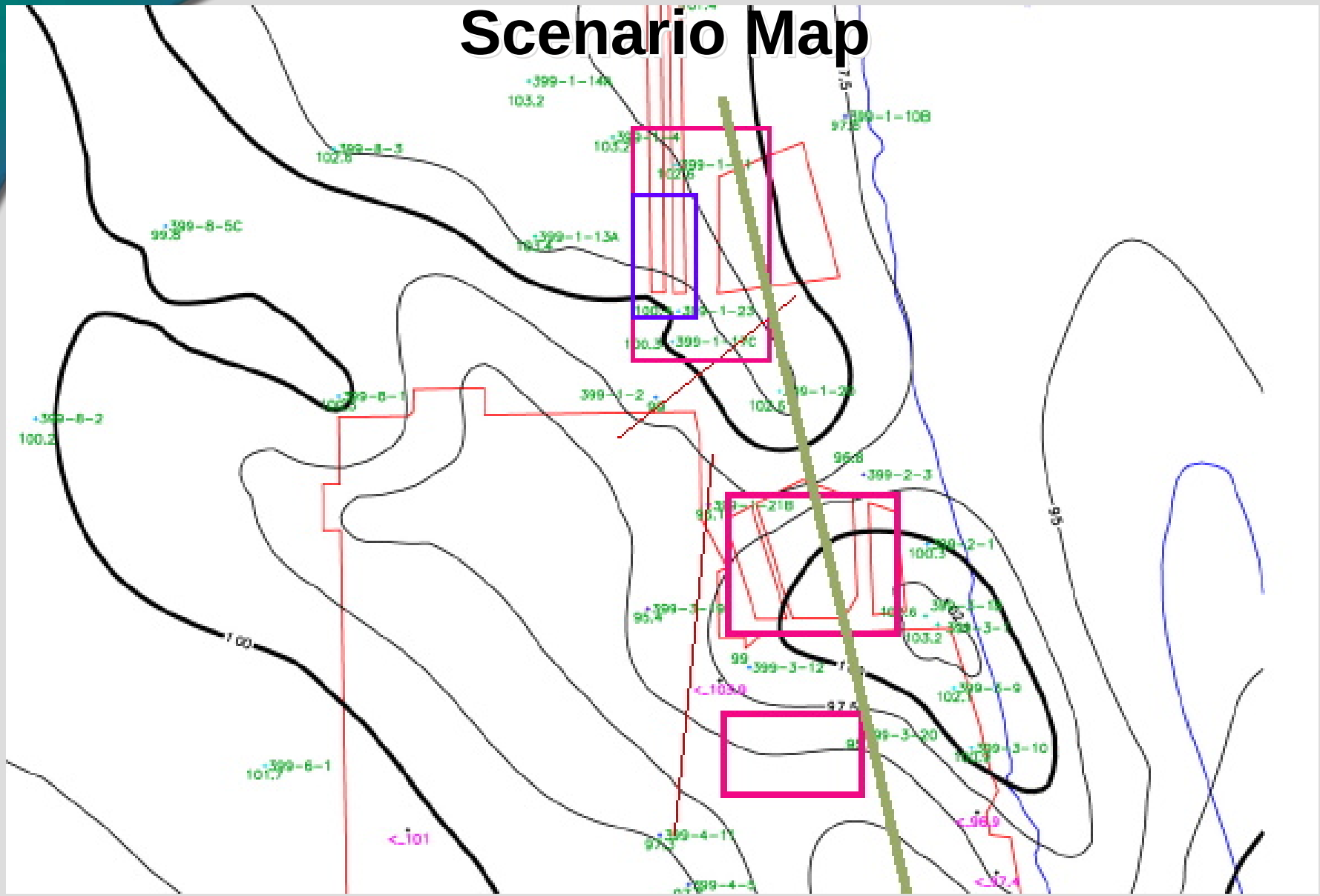
Technology Comparison

1993-1995 Feasibility Study	2007-2008 Phase III Feasibility Study
Physical control with incidental chemical treatment technologies considered.	Physical, chemical, and biological technologies considered. Prior PLUS
Hydraulic containment • Pumping - ex-situ treatment • Slurry wall	In-situ stabilization • Source control • Plume control • Plume interception
Removal • In-situ flushing • Groundwater extraction • Aquifer dredging	Source removal • Sediment excavation

Groundwater Technologies

- Twenty-four active technologies identified that treat uranium in groundwater and reduce or prevent groundwater contamination.
- Basis of screening selection:
  - Effectiveness
  - Implementability
  - Cost.
- Two technologies retained after screening:
  - Injected phosphate with calcium citrate (barrier)
  - Injected polyphosphate (barrier or area).

Scenario Map



Smear Zone Technologies

- Six active technologies identified that treat uranium in pore water and sediment of the groundwater interface zone ("Smear Zone").
- Two technologies retained after screening:
  - Stabilization by application polyphosphate solution.
    - Variety of application geometries.
  - Selective excavation for very focused areas.
    - Appropriate only where incidental construction may coincidentally occur.

Lower Vadose Zone Technologies

- Ten active technologies identified that treat uranium deposits in lower unsaturated sediments.
  - Unremediated sediments beneath waste disposal areas are likely the largest source of uranium contamination.
- Three technologies retained after screening:
  - Stabilization by application polyphosphate solution.
    - Wetting by infiltration from surface application.
  - Vadose wetting with calcium citrate and sodium phosphate.
  - Selective excavation of known source areas.
    - More appropriate where incidental excavation may occur.

Candidate Technologies for Saturated Zone (Groundwater) 1 of 2

Technology Type	Technology	Effective?	Technically Implementable?	Cost Effective?
Passive	No Action		Yes	YES
	Institutional Controls	Yes	Yes	YES
	Monitored Natural Attenuation	Yes	Yes	YES
Physical	Slurry Wall Containment	?	No	
	Grout Walls - Grout Injection	?	?	
	Grout Walls - Deep Soil Mixing	?	No	
	Selective Hydraulic Containment with Pumping	Yes	Yes	NO
	Groundwater Extraction-Wells	?	Yes	NO
	Groundwater Extraction-Interceptor Trench	?	No	
	Treated Water Disposal to Surface Water (Columbia River)	Yes	Yes	NO
	Treated Water Disposal to Groundwater (Reinjection)	Yes	Yes	NO
Chemical	Ex-situ Ion Exchange	Yes	Yes	NO
	Ex-situ Reverse Osmosis	Yes	Yes	NO

Cost evaluation was conducted only on technologies that were previously evaluated as effective and implementable.

Candidate Technologies for Saturated Zone (Groundwater) 2 of 2

Technology Type	Technology	Effective?	Technically Implementable?	Cost Effective?
Chemical	Ex-Situ Precipitation	Yes	Yes	NO
	In-Situ Flushing	Yes	No	
	Pemeable Reactive Barrier-Zero Valent Iron	No	No	
	Pemeable Reactive Barrier-Amorphus Ferric Oxyhydroxide	No	No	
	Pemeable Reactive Barrier-Hydroxyapatite	No	No	
	Pemeable Reactive Barrier-Zeolite	No	No	
	In-Situ Reactive Barrier-Injected polyphosphate	?	Yes	YES
	DART Implacement of ZVI and Apatite Pellets in Wells	No	Yes	
	In-Situ Reactive Barrier-Nanoparticle Injection	No	Yes	
	Colloidal ZVI Injection	No	Yes	
	In-Situ Reactive Barrier-Calcium Citrate & Sodium Phosphate Injection	?	Yes	YES
	In-Situ Redox Manipulation by Dithionite Injection	No	Yes	
Biological	Microbial Dissimilatory Reduction of U(VI)	No	No	
	Anaerobic In-situ Reactive Zone	No	No	

Cost evaluation was conducted only on technologies that were previously evaluated as effective and implementable.

Candidate Technologies for Smear Zone

Technology Type	Technology	Effective?	Technically Implementable?	Cost Effective?
Passive	No Action		Yes	YES
Physical	Selective Excavation to Water Table	Yes	Yes	YES
	Pressure Grout Injection at Water Table with Dense Push Rod Well Pattern	Yes	No	
Chemical	Injection of Reactive Substace to Form Water Barrier at Water Table	Yes	No	
	Stabilization by Application of Polyphosphate Solution	Yes	Yes	YES
Biological	Temporary Bio-Flushing to Anaerobicly Stablize Uranium	?	No	
	Anaerobic In-Situ Reactive Zone	Yes	No	

Cost evaluation was conducted only on technologies that were previously evaluated as effective and implementable.

Candidate Technologies for Vadose Zone

Technology Type	Technology	Effective?	Technically Implementable?	Cost Effective?
Passive	No Action		Yes	YES
Physical	More Extensive Excavation to Water Table	Yes	Yes	YES
	Impermeable Surface Cap	Yes, Partially	No	
Chemical	Vadose Wetting with Mobilizing Agent and Hydraulic Extraction of Solution	Yes	Yes	NO
	Vadose Wetting with Immobilizing Agent-Hydroxyapatite Reaction	Yes	No	
	Vadose Wetting with Immobilizing Agent-Polyphosphate	Yes	Yes	YES
	Vadose Wetting with Colloidal ZVI	?	No	
	Vadose Wetting with Dithionite Solution	?	No	
	Vadose Wetting with Calcium Polysulfide	No	Yes	
	Vadose Wetting with Calcium Citrate & Sodium Phosphate	?	Yes	YES
Biological	Temporary Bio-Flushing to Anaerobicly Stablize Uranium	No	No	

Cost evaluation was conducted only on technologies that were previously evaluated as effective and implementable.

Formulate Remedial Alternatives

- Based upon identification of the apparent source of uranium to the groundwater, we have started to formulate remedial strategies.
- The conceptual model is presently being updated.
  - Are the sources at the water-table interface zone directly related to the original discharge ponds and trenches?
- The alternatives we formulate are incorporating the conceptual model, the hydrologic models, and the results of the treatability and pilot studies.

Summary

- Technologies were identified according to the location of action…three zones.
- Technologies were screened according to effectiveness and implementability.
- Remaining technologies were evaluated according to relative cost.
- Implementation of remedial action(s) will be an iterative process with performance feed-back.

Questions?