ATTACHMENT 9:
ISCO Coupling Tables

ISCO is often coupled with other remediation technologies as part of the overall treatment approach. Considerations for enhancing the coupling approach and/or cautions to consider in ISCO design and implementation are provided in the following tables.

Table A9-1. Pre-ISCO Mass Reduction Processes that May Be Applied Within the ISCO Target Treatment Zone

Pre-ISCO Technology	Advantages	Disadvantages
Excavation	+ Rapid implementation + Easy to apply oxidant at the infiltrative surface + Soil mixing approaches may be more easily implemented	- Hotspots may remain - Preferential flow may occur through backfill - Contaminated or highly organic backfill may cause excessive oxidant demand - Oxidant treatment of clean backfill represents inefficient oxidant use
Enhanced product recovery / Multiphase extraction	+ Removal of pooled or high NAPL saturation zones improves advective oxidant transport and likelihood of ISCO's success	- Smear zone thicknesses may be increased - Residual NAPL will likely remain
Surfactant enhanced aquifer remediation (SEAR)	+ Surfactants may improve the reactivity of some oxidants + Enhanced solubilization and desorption may occur improving oxidation efficiency in the aqueous phase	- Incompatible surfactants may cause excessive oxidant decomposition - Gas evolution may cause foaming and permeability loss - Some NAPL mass is likely to remain after SEAR - Potential lack of control of mobilized contaminants
Soil vapor extraction / Air sparging	+ Infrastructure may already be in place for in situ ozonation + Contaminated vapors may be captured when using oxidants that evolve significant amounts of gas + May oxidize some reduced minerals, lowering the soil's natural oxidant demand for ISCO	- Desaturated groundwater zones may have lower relative permeability, challenging uniform delivery of aqueous oxidants
Thermal remediation	+ Elevated temperature may effectively activate some oxidants + For some oxidants and resistant contaminants, kinetic rates of degradation may be tremendously improved at elevated temperature	- Elevated temperatures may pose health and safety concerns for some oxidants and contaminants with exothermic reactions - Solidification of silt and clay materials may occur challenging subsequent oxidant delivery - At elevated temperature, excessive oxidant decomposition may challenge effective delivery
Intrinsic or enhanced bioremediation	+ Biological degradation processes (if any) may be anticipated to return to baseline (e.g. unamended natural levels) after ISCO, and may be used as a polishing step	- Elevated biomass and organic substrate concentrations in the treatment zone may cause excessive competition for oxidant and lead to poor treatment efficiencies - Reducing conditions associated with anaerobic conditions may require excessive oxidant dosing

Note: This table duplicates the information included in Screening Process 2 (Table A4-1). This information is presented again to provide users with a second chance to evaluate the value that may be added by a pre-ISCO coupled process even if earlier screening steps do not indicate that a pre-ISCO process is likely required. The green plus symbol (+) denotes positive impacts, and the red minus

symbol (-) denotes negative impacts.

Table A9-2. Considerations for ISCO Applied at Same Time as Other Treatment Processes in Adjacent Zones of Low Contaminant Mass Density

	Treatment Downgradient of or Adjacent to ISCO Treatment in Zones of Low Contaminant Density							
	Enhanced bioremediation				Permeable Reactive Barrier	ISCO	MNA	
	Aerobic		Anaerobic					
Catalyzed Hydrogen Peroxide	+ Partially oxidized dissolved organics mobilized during ISCO process may enhance aerobic bio in down-gradient areas	+ Aerobic bioactivity may be enhanced during peroxide application	- While oxidation process will not sterilize subsurface, oxidation process will create highly oxidized and aerobic conditions that may counteract desirable conditions for anaerobic bio + Partially oxidized dissolved organics (DOC) mobilized during ISCO process may enhance anaerobic bio in down-gradient areas			- If low pH conditions are sustained after treatment, then may be detrimental for persulfate treatment which requires basic conditions for activation + Peroxide does not create problems for subsequent application of permanganate	+ ISCO will generally not affect biological mechanisms for downgradient MNA - Metals liberated by ISCO may cause exceedånce of groundwater cleanup criteria if downgradient geochemical conditions are not suitable for sorption/ precipitation of dissolved metals + Oxidation of reduced metals may improve biological treatment by increasing the electron acceptor pool + ISCO may assist downgradient MNA by liberation of partially oxidized organics (DOC)	- If aquifer buffering capacity is low, then pH change may detrimentally affect downgradient microbiology + Oxygen produced may assist downgradient MNA
Persulfate				+ Sulfate may enhance anaerobic bio in down-gradient areas	- Sulfate released may cause detrimental geochemical conditions and cause fouling of an iron PRB, though only a few examples of this exist and the fouling can be chemically treated	+ Is generally very compatible with peroxide because peroxide can be used to catalyze persulfate - If caustic activator is used and high pH is sustained after treatment, then may be detrimental for CHP process		- If aquifer buffering capacity is low, then pH change as a result of caustic persulfate may detrimentally affect downgradient microbiology + Sulfate may assist downgradient MNA
Permanga-nate					- Permanganate may oxidize surfaces of PRB, reducing reactivity	- Residual manganese dioxide may cause problems for subsequent application of peroxide		
Ozone		+ Aerobic bioactivity may be enhanced during ozone application						+ Oxygen produced may assist downgradient MNA

Notes: The green plus symbol (+) denotes positive impacts, and the red minus symbol (-) denotes negative impacts.

Table A9-3. Considerations for co-located treatment processes applied post-ISCO

Contaminant Mass Density	Post-ISCO Treatment		ISCO Applied Prior to Subsequent Treatment			
			Catalyzed Hydrogen Peroxide	**Persulfate**	**Permanganate**	**Ozone**
High	**Excavation**		+ ISCO may be used to decrease concentrations of TOSCA-regulated compounds, thus decreasing landfill/disposal costs			
High or Low	**Enhanced Bio**	**Aerobic**	+ Residual partially oxidized dissolved organics (DOC) may enhance aerobic bioactivity			
			+ Residual oxygen may enhance aerobic bioactivity			+ Residual oxygen may enhance aerobic bioactivity
		Anaerobic	+ Residual DOC may enhance anaerobic bioactivity - While oxidation process will not sterilize subsurface, oxidation process will create highly oxidized and aerobic conditions that may counteract desirable conditions for anaerobic bioactivity			
				+ Residual sulfate may enhance anaerobic bioactivity	- Manganese dioxide solids may decrease transport and sustain elevated redox potential, though evidence suggests that they do not inhibit reductive dechlorination + Bioactivity can dissolve manganese dioxide, perhaps allowing better transport	
Low	**Iron-reducing Zone or Permeable Reactive Barrier**			- Residual sulfate may be detrimental to iron reaction	- Residual permanganate may passivate iron surfaces	
Low	**Monitored Natural Attenuation**		+ Effects take time to manifest themselves and may vary depending on site-specific conditions such as indigenous microbial community, geochemistry, and hydrology + Reduction in mass flux from the source zone may enhance effectiveness of MNA and cause plume to collapse + Residual DOC may enhance bioactivity			
				+ Residual sulfate may enhance anaerobic bioactivity		

Notes: The green plus symbol (+) denotes positive impacts, and the red minus symbol (-) denotes negative impacts.