California Environmental Protection Agency

California Department of Toxic Substances Control

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Green Remediation Initiative

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Green Remediation versus Conventional Remediation

Conventional Remediation

- **Focuses on Endpoints**
  - Protect or restore water resources
  - Reduce or eliminate hazardous substance risk
  - Restore property to developable condition
- **Remedies Not Always Sustainable**
  - Natural resources extracted, used in project
  - Recycling, reuse of materials rarely considered.

Conventional Remediation (cont.)

- **Energy Use Not Considered**
  - Transportation to and from site
  - On and off-site operations
- **Greenhouse Gas, Other Substances Emitted**
  - Heavy vehicle traffic
  - On-site construction
  - Long term remedy operations

Green Remediation

- Remains Endpoint Focused
- Examine Impacts Beyond Site Boundaries
- Considers Impacts Not Always Addressed Under RCRA, CERCLA
  - Consumption of energy, raw materials
  - Greenhouse gas and other emissions
  - Impacts over life of remedy

Green Remediation Is Not

- No Action Alternative
- Monitored Natural Attenuation
- Capping or Containment
- Only Using Biodiesel or Solar Panels to Power Systems

DTSC Green Remediation Initiative

- Begun in February 2007 by DTSC's Office of Military Facilities
- Promote Green Technologies in Site Cleanup.
- Evaluate Technologies for Investigation and Cleanup.

Green Remediation Team Goals

- Define Green Remediation
- Develop Evaluation Tool
- Develop Training for Staff
- Invite Technology Presentations
- Incentives to Use Green Technologies
- Publicize Efforts
- Propose Legislation

Regulatory Challenges

- "Green" Must Not Justify No Action
- Cost/Benefit Analysis to Avoid Cleanup
- Reconcile "Green" Evaluation With
  - CERCLA Nine Criteria analysis
  - Environmental impact analysis (CEQA)
- Will "GREEN" provide "VALUE ADDED"?
- Need Tools, Guidance Documents

Early Efforts

- Review of the Literature
  - Lots on sustainable development, little on remediation
  - Research papers of limited use to general practitioner.
- Interim Definition of Green Remediation
  - Applies to entire life of remedy
  - Considers all inputs and outputs of remedy
  - Minimize resource consumption, waste, and emissions
- Develop Rating Matrix

Early Matrix Factors

- Energy Consumption
- Liquid and Solid Waste Production
- Air Quality
  - Regulated pollutants
  - Non-regulated pollutants, greenhouse gases
- Product Utilization, Including Recycling

Early Matrix Factors (cont.)

- Community Benefits
- Duration Required
- Treatment Effectiveness
- Life-Cycle Cost
- Worker Safety

First Matrix Attempt

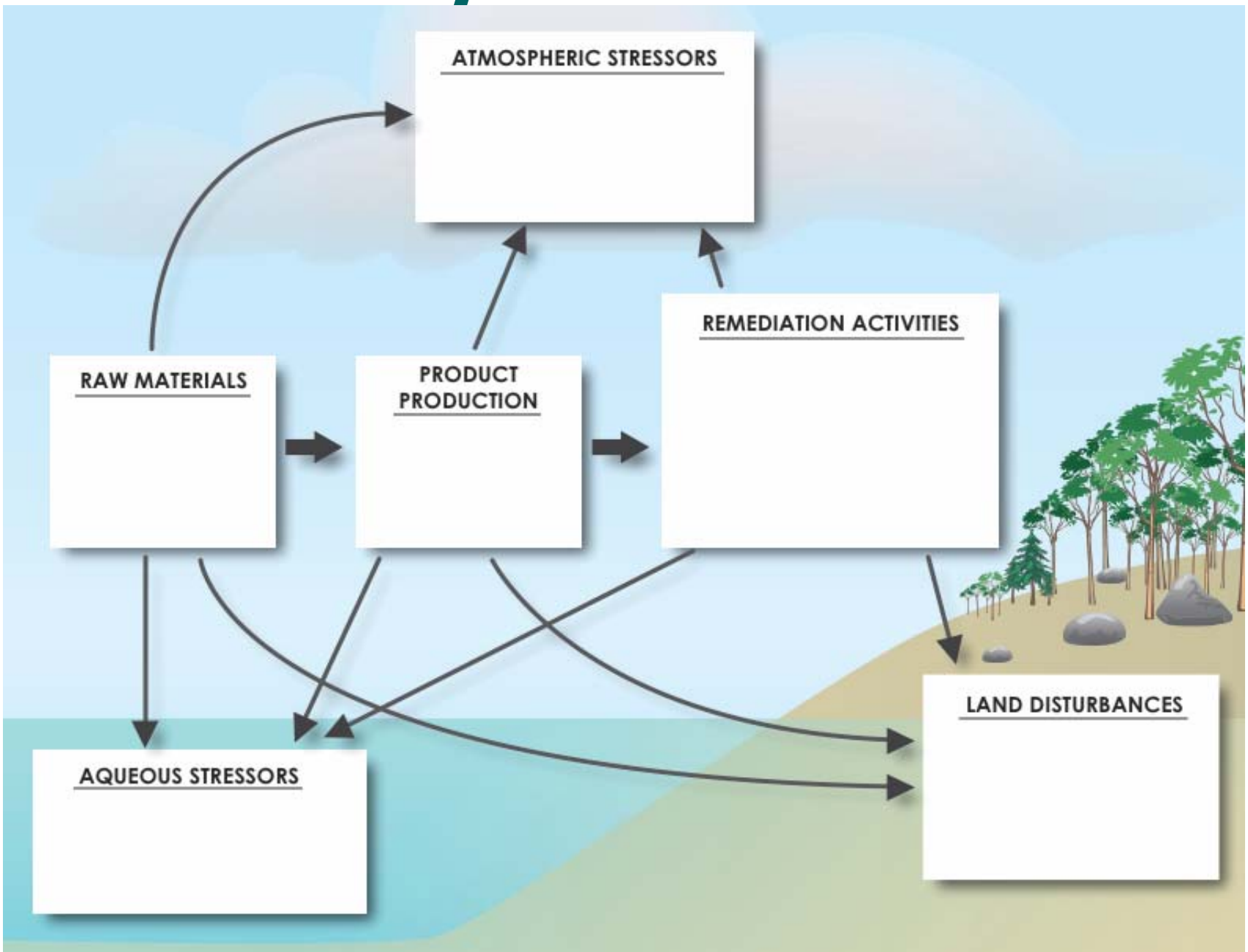
	Treatment Alternatives--Soil					Treatment Alternatives--Groundwater			
	Containment	Excavation & Disposal	Bioventing	Containment (Capping)	Bioventing and Excavation	GW Extraction & Ex-Situ Treatment (Pump & treat)	Chemical Oxidation	Enhanced Bioremediation Barrier	Ferox Process
Raw Materials Extraction									
Energy Consumption									
Liquid Waste Production									
Solid Waste Production									
Air Quality Impacts									
Greenhouse Gas Production									
Other Contaminants									
Virgin Materials/Ore Extraction									
Quantity Extracted									
Utilizability fraction									
Renewable resource fraction									
Worker Safety									
Community Benefits									
Cost									
Manufacturing									
Energy Consumption									
Liquid Waste Production									
Solid Waste Production									
Air Quality Impacts									
Greenhouse Gas Production									
Other Contaminants									
Raw Materials Utilization									
Consumption									
Recycling/reuse Potential									
Worker Safety									
Community Benefits									
Cost									
Point of Use									
Energy Consumption									
Liquid Waste Production									
Solid Waste Production									
Air Quality Impacts									
Greenhouse Gas Production									
Other Contaminants									
Product Utilization									
Recycling/reuse Potential									
Worker Safety									
Community Benefits									
Duration Required									
Effectiveness in Reaching Treatment Objective									
Life-Cycle Cost									

First Attempts

- Too detailed, no system boundaries
- Caught up in the details
  - What about the manufacture of the excavator?
  - What about the manufacture of the PVC pipe?
- Tried other approaches then decided…
- Need better approach

  –> Life Cycle Framework

Life-Cycle Framework



Life-Cycle Framework

- **Life Cycle Assessment**
  - Detailed, quantitative evaluation of remedy
- **Life Cycle Management**
  - Simpler, qualitative approach
- **Major Reference:**

M.L. Diamond, C.A. Page, et al. Department of Geography, University of Toronto, Toronto, Ontario, Canada. *Life-Cycle Framework for Assessment of Site Remediation Options: Method and Generic Survey*, Environmental Toxicology and Chemistry, 18:4, p. 788-800, 1999.

Life-Cycle Assessment

- Identify system boundaries
  - System, temporal, geographic
  - Includes soil, groundwater, air
- Detailed process evaluation
  - Process flows
  - Process outcomes
- Assess
  - Stressors impacts
  - Long term and short term impacts

Life-Cycle Management

- Inputs include raw materials, energy, water
- Outputs include emissions, solid waste, site quality, land use degradation, stagnation
- Evaluate Stressors
  - Physical, chemical, or biological impacts on humans and environment
  - Impacts include pollution, resource depletion, and disturbances

Table 2. Potential impacts checklist for remediation options[a]

Stressor categories	Potential impact categories	Levels of concern for remediation options: No action	Encapsulation	Dig & haul	In situ bioremediation	Soil washing	Vapor extraction
	Pollution						
• Acid emissions[b]	Acid rain	□	□	■	□	⊠	□
• Greenhouse gases[c]	Global warming	□	⊠	■	⊠	⊠	□
• Ozone-depleting substances[d]	Ozone-depletion	□	□	□	□	⊠	□
• Air pollutants and photochemical smog[e]	Air pollution	□	□	■	□	⊠	□
• Nutrients discharged	Eutrophication	□	□	□	⊠	□	□
• Process water quality stressors	Stress on aquatic species	□	⊠	⊠	□	⊠	⊠
• Toxic contaminants and particulates to air	Airborne transport to other media[f]	■	□	■	⊠	■	⊠
	Human health impairment[g]	■	□	⊠	□	⊠	⊠
◊ Toxic contaminants in surface and ground water[h]	Ecotoxicity impacts	■	■	□	⊠	□	⊠
	Human health impairment[g]	■	⊠	□	⊠	□	⊠
◊ Toxic contaminants in soil[h]	Ecotoxicity impacts	■	■	□	⊠	□	⊠
	Human health impairment[g]	■	⊠	□	⊠	□	⊠
◊ Chemical soil quality stressors[ij]	Soil quality disturbances	□	□	⊠	■	■	□
	Disturbance						
• Heat discharge	Heat damage/dispersion of heat	□	□	□	⊠	□	⊠
• Off-site construction, excavation, or land fragmentation	Habitat alteration or destruction	□	□	■	□	⊠	□
◊ Nonremediation of land	Land stagnation	■	■	□	□	□	□
◊ Compaction, paving, or application of an impervious soil coverage	Effects on soil moisture, aquifer recharge, ecosystem regeneration	□	■	□	□	□	□
◊ Aquifer quality stressors	Interrupted drainage, changes in aquifer level, change in stream base flow	□	■	⊠	⊠	⊠	□
◊ Nonchemical soil quality stressors[ik]	Soil quality disturbances	□	□	⊠	□	■	□
• Human social stressors[l]	Human social disturbances	⊠	□	⊠	□	⊠	□
	Depletion						
• Fossil fuel use/energy consumption	Primary energy source depletion	□	⊠	■	□	⊠	⊠
• Solid waste	Land or space consumption	□	□	■	□	⊠	□
• Water use	Water consumption	□	□	⊠	□	⊠	□
• Mineral use	Mineral consumption	□	□	□	□	□	□

[a] • and ◊ denote process- and site-related stressors, respectively. Levels of concern are no or low (□), moderate (⊠), and high (■).
[b] SO_x, HCl, NO_x, particulates.
[c] CO_2, chlorofluorocarbons (CFCs), methane, methyl chloride.
[d] CFCs, CO, methyl furan, methyl chloride.
[e] Volatile organic compounds (VOCs), semivolatile compounds, PAHs, NO_x, SO_x, particulates.
[f] Ecotoxicity.
[g] Human toxicity.
[h] Migrating or remaining in surface water, groundwater, or soil.
[i] Affecting or changing the original (i.e., preremediation) soil quality.
[j] Nutrient levels, organic content, microbial population, pH.
[k] Porosity, soil particle size.
[l] Noise, dust, odor, vibration, aesthetic value, psychosocial effects.

Impacts and Stressors

- Rank according to amounts emitted
- Factor Local or Regional Concerns
- Pollution Stressors
  - Air pollution
  - Global warming
  - Human Health and Eco-toxicity
  - Soil Quality

Impacts and Stressors (Cont.)

- **Disturbance Stressors**
  - Land Stagnation
  - Drainage, aquifer recharge, stream flow disturbances
  - Heat
  - Habitat Alteration
  - Human Social disturbances
- **Depletion Impacts**
  - Fossil fuel use/energy source depletion
  - Solid waste/land or space consumption
  - Water use/water consumption
  - Mineral consumption

Current Matrix

Stressor	Affected Media	Mechanism/ Effect	Score
Substance release/production			
Airborne NOx & SOx	Air	Acid rain & Photochemical smog	
Chloro-fluorocarbon vapors	Air	Ozone Depletion	
Greenhouse gas emissions	Air	Atmospheric warming	
Airborne particulates/Toxic vapors/gases/Water vapor	Air	Gen Air Pollution/Toxic air/Humidity increase	
Liquid waste production	Water	water toxicity/sediment toxicity/sediment	
Solid waste production	Land	Land use/toxicity	
Thermal releases			
Warm water	Water	Habitat warming	
Warm vapor	Air	Atmospheric humidity	
Physical disturbances/disruptions			
Soil structure disruption	Land	Habitat destruction/ Soil Infertility	
Noise/Odor/Vibration	Gen Env	Nuisance & Safety	
Traffic	Land; Gen Env	Nuisance & Safety	
Land Stagnation	Land; Gen Env	Remediation time; Cleanup efficiency;re-development	
Resource Depletion/Gain (Recycling)			
Petroleum (energy)	Subsurface	Consumption	
Mineral	Subsurface	Consumption	
Construction material Soil/concrete/plastic	Land	Consumption/reuse	
Land & space	Land	Impoundment/reuse	
Surface water & groundwater	Water, Land (subsidence)	Impoundment/ Sequester/reuse	
Biology Resources (Plants/trees/animals/microorganisms)	Air, Water, Land, Subsurface	Species Disappearance Diversity Reduction Regenerative Ability Reduction	

Next Steps

- Finalize Matrix
  - Design for use throughout remedy process
  - Internal and External Peer Review
  - Possible Pilot Test
  - Publish as DTSC Guidance
- Staff Training
- Potential Legislation
  - Regulation
  - Incentives