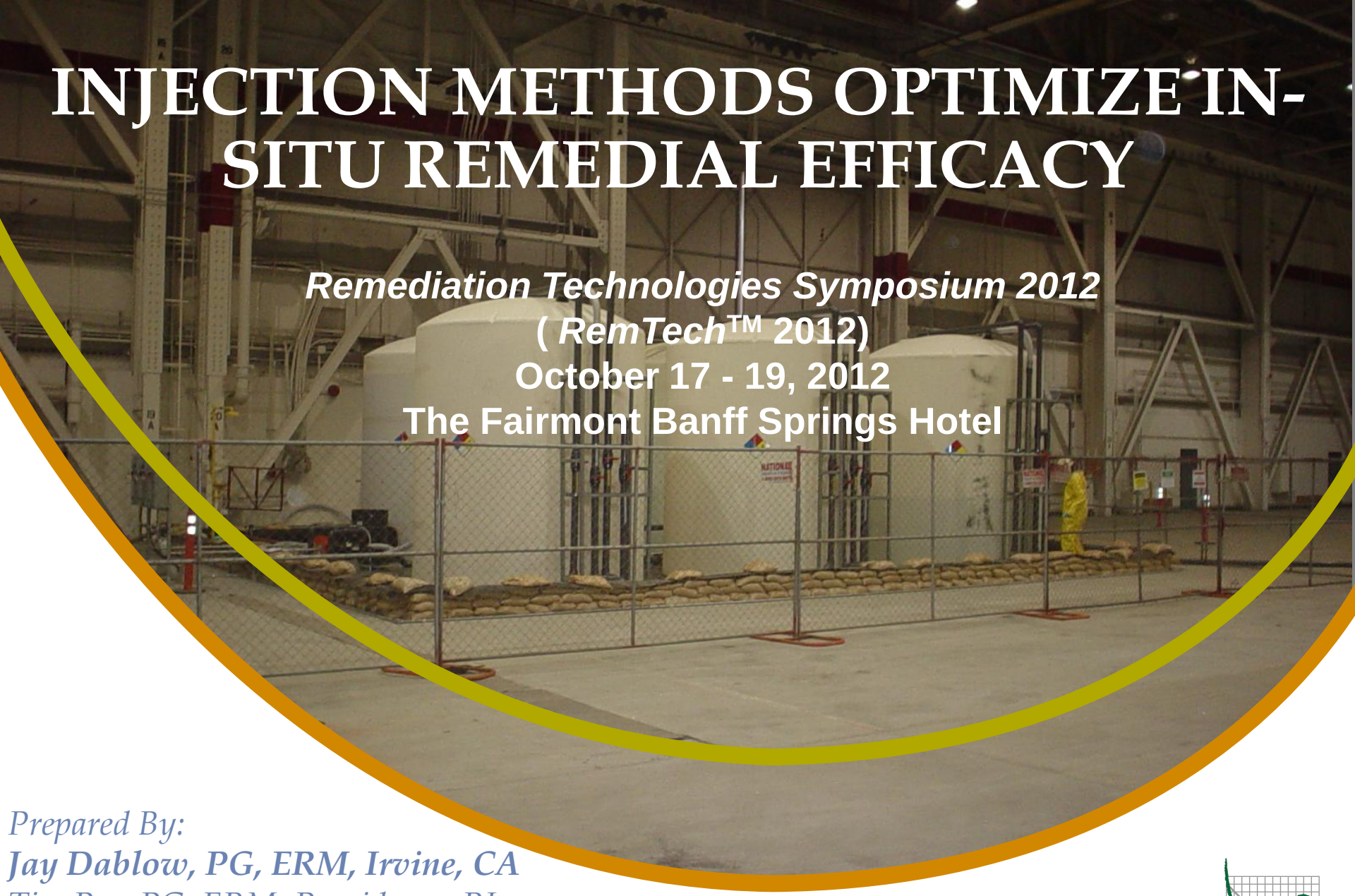
INJECTION METHODS OPTIMIZE IN-SITU REMEDIAL EFFICACY



Remediation Technologies Symposium 2012
(*RemTech*™ 2012)
October 17 - 19, 2012
The Fairmont Banff Springs Hotel

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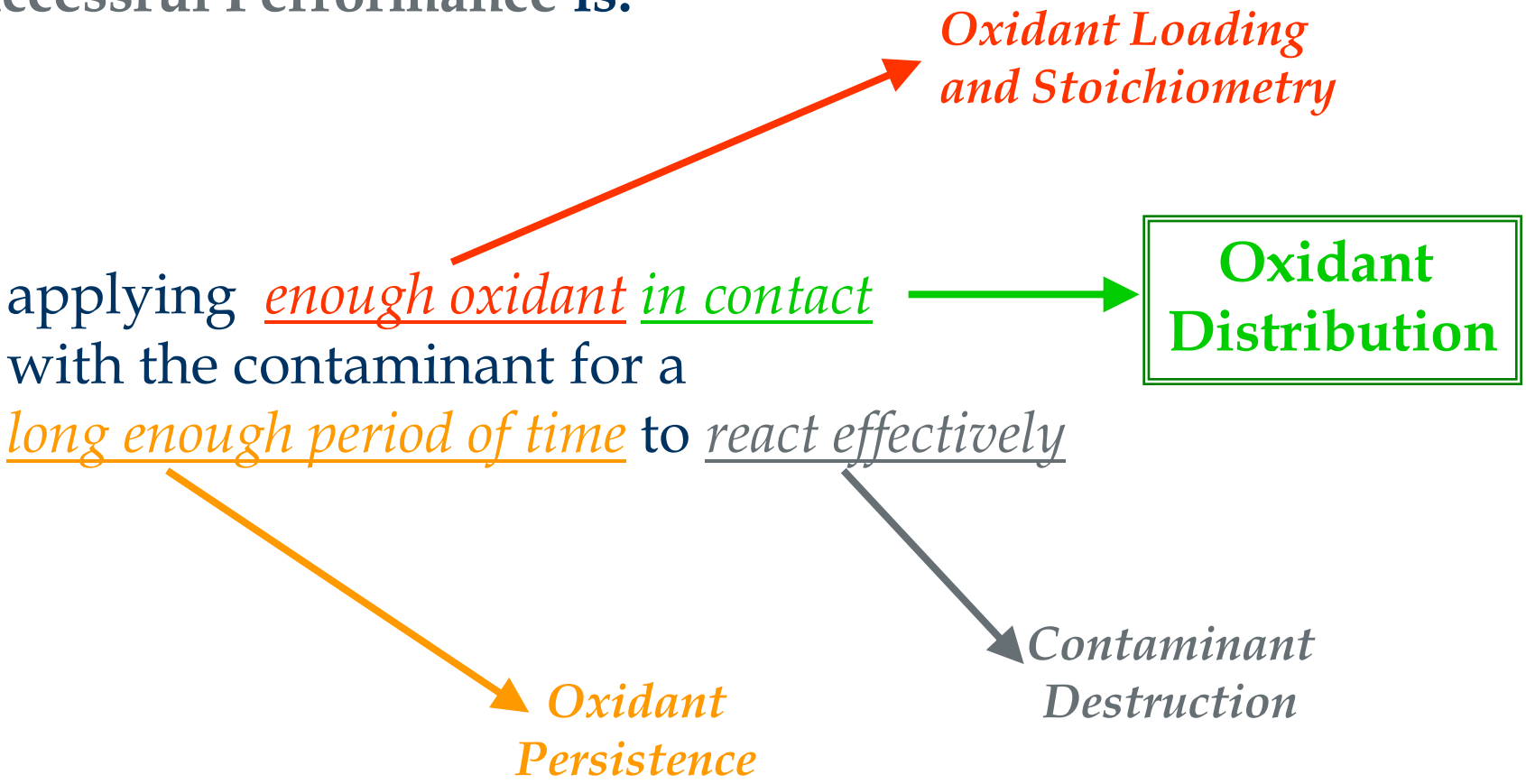
Injection Premise

Successful Performance is:



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Delivery Mechanisms

Presentation will simplify design and focus solely upon delivery, not many of the other important design aspects including:

- Oxidant - choice, applicability, activation, concentration
- Site specific design issues – lithology, groundwater hydraulics, access, sensitive receptors, target mass location
- Optimization strategies – surfactants, coupling, controlled release

While the above factors are important, focus upon "big picture" of delivery

Recognizing…

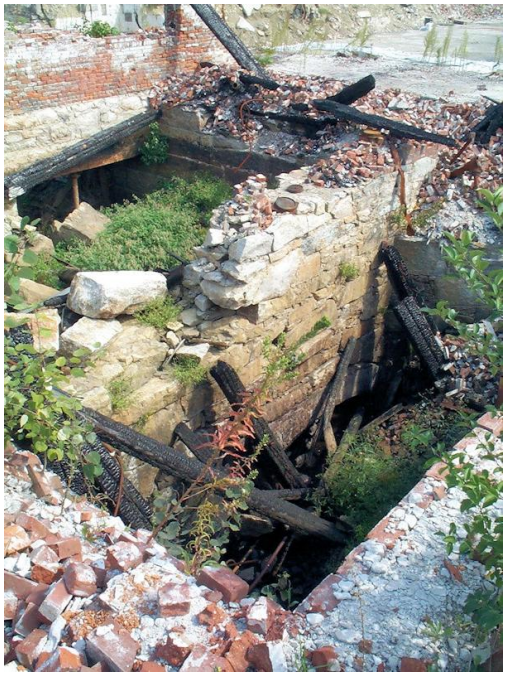
Nature ultimately controls delivery (unless it is destroyed):

- Strata deposited by natural process for millennia
- Strata has natural fabric and directionality (heterogeneity)
- Strata is heterogeneous on multiple scales –
  - *Morphologic – lack of vertical and lateral continuity*
  - *Macroscopic – visual heterogeneity*
  - *Microscopic – non-visual (and often controlling)*

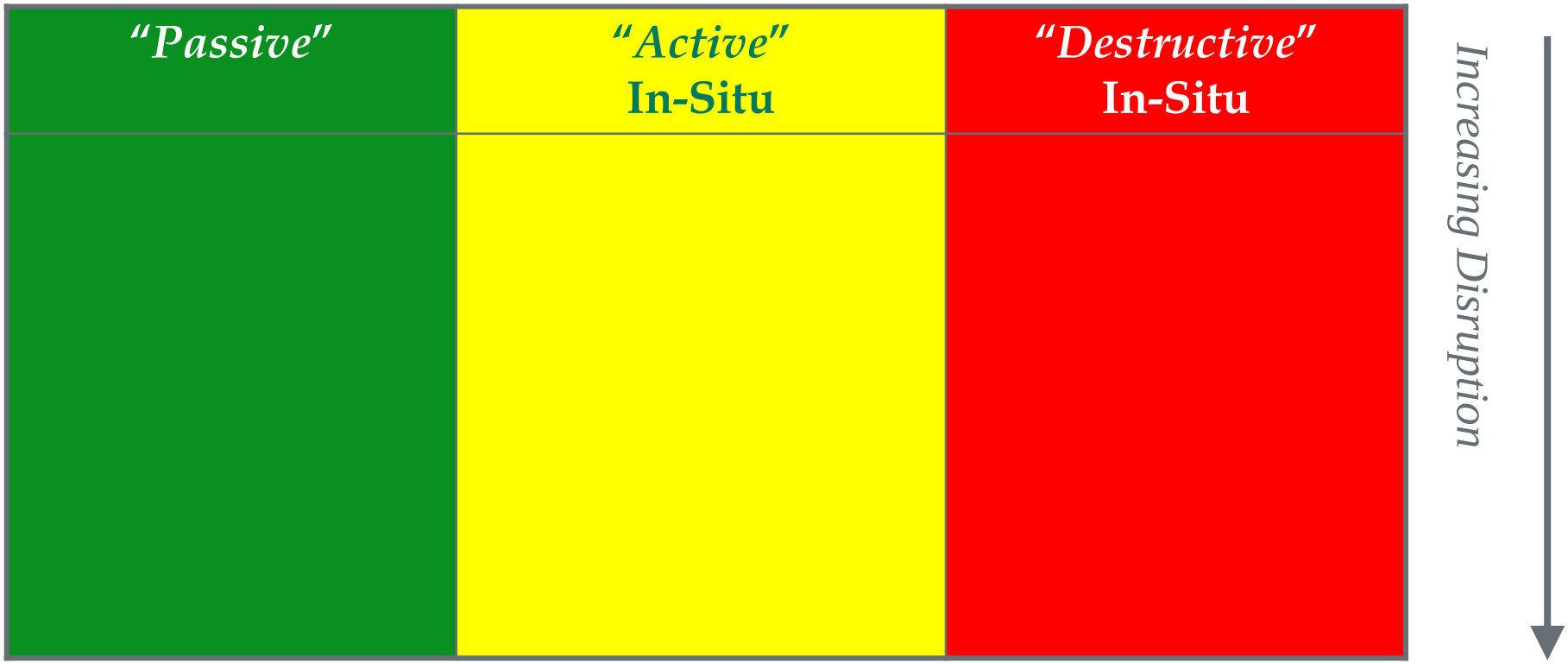
Recognizing…

- Physical (contaminant-specific) properties – density, solubility, diffusion, retardation, degradation, polarity

- Effect of man-made alterations – compaction, excavation/construction, hydraulics



Delivery Methods



Delivery Methods

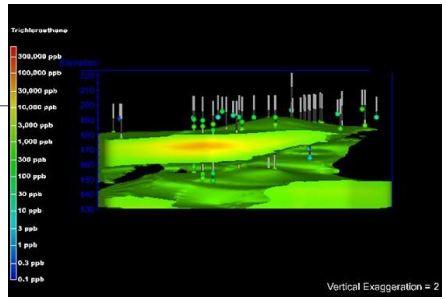
"Passive"	*"Active"* In-Situ	*"Destructive"* In-Situ
Encapsulation	Existing Wells	Excavation / Engineering
	Temporary Wells	
Flow through	Recirculation	
	Pore dilation	Media Fracturing
Constant head		
	Electrokinetics	
	Thermal Methods	
Push-Pull		Soil Mixing

Increasing Disruption

Energy Input and Short-Term Cost

Time Required and Long Term Cost

Selection of Delivery Mechanisms



Variety of approaches exist, each with advantages and limitations – no "silver bullet"

Complex set of inter-related factors, including (partial list):

- Cost – labor, subcontractor, materials, time, footprint
- Amendment – hazard, physical properties (e.g., viscosity, reactivity, corrosivity, stability, activation), concentration, volume, pressure, kinetics
- Site limitations – access, geology, utilities, sensitive receptors (e.g., lakes, streams and/or wetlands), work restrictions (hours, temperature, vibration, stray current)
- Target – mass, phase, dimensions, treatability, availability
- (Un) Certainty – degree of characterization, conceptual model

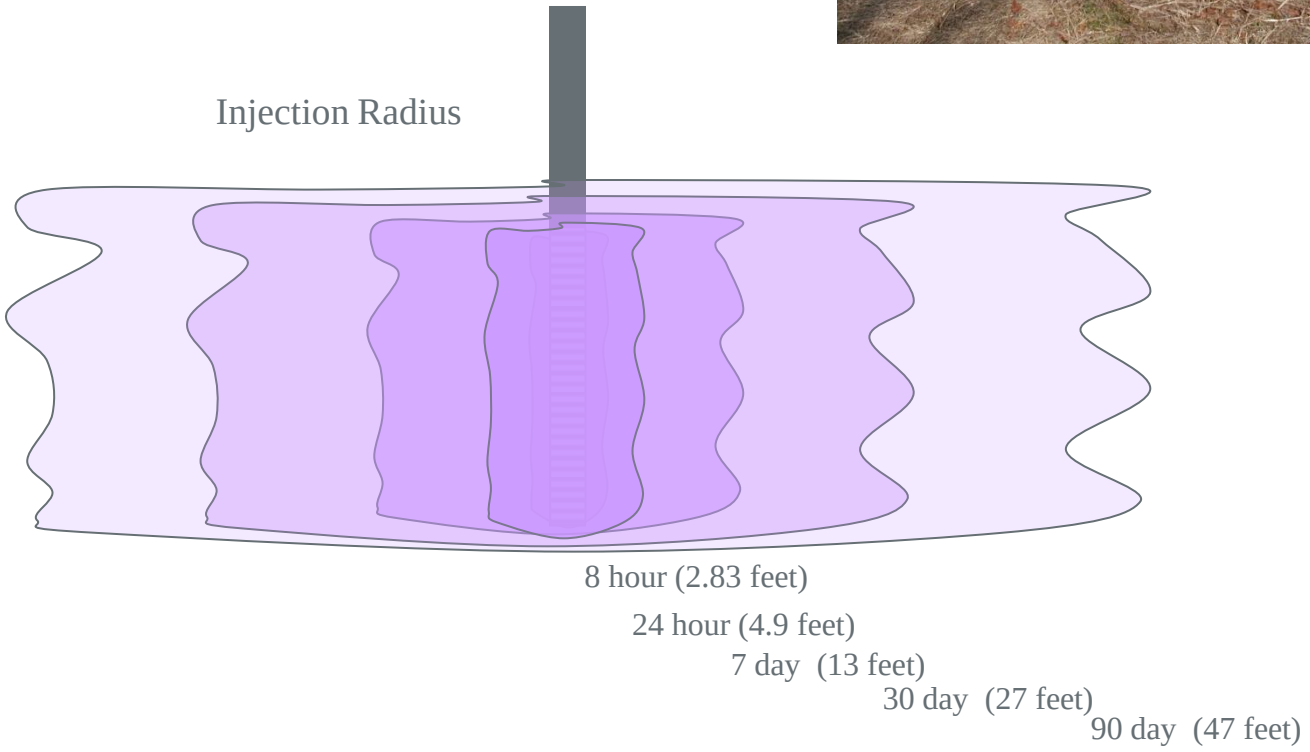
Selection of Delivery Mechanisms

So How Do We Select Mechanism?

- Experience – previous experience in similar conditions
- Risk Aversion – certainty and variability
- Efficacy – anticipated short-term/long-term cost, timeline and perceived effectiveness
- Site limitations – structures, hours, ownership, Site conditions, location, aesthetics, Client-specific requirements
- Contract – performance guarantee, treatment goal, closure goal
- Health and Safety

“Passive” Delivery Methods

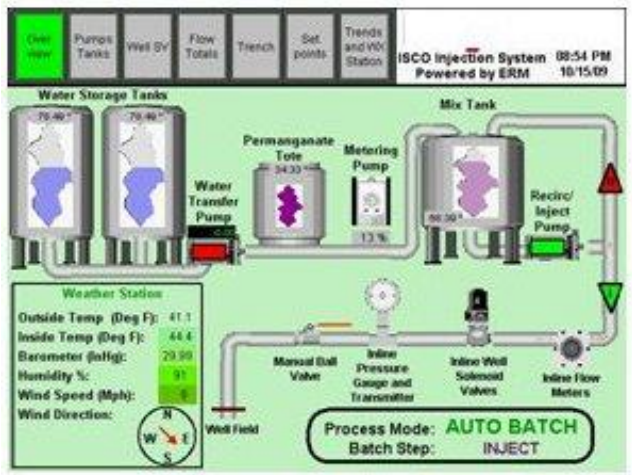
Allow unimpeded natural processes

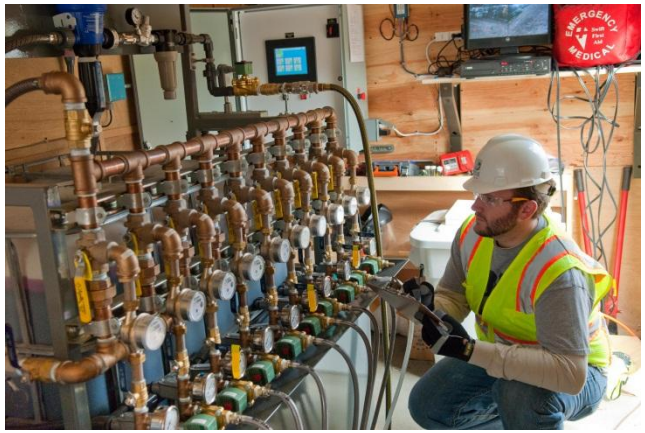


“Passive” Delivery Methods

Allow unimpeded natural processes

- ❑ Constant head
- ❑ Gravity feed, low pressure
- ❑ Automated
- ❑ Solar powered





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"Active" In-Situ Delivery Methods

Maximize Site Conditions

Single well/point

Pore Dilation
"Pressure Pulse"

"Active" In-Situ Delivery Methods

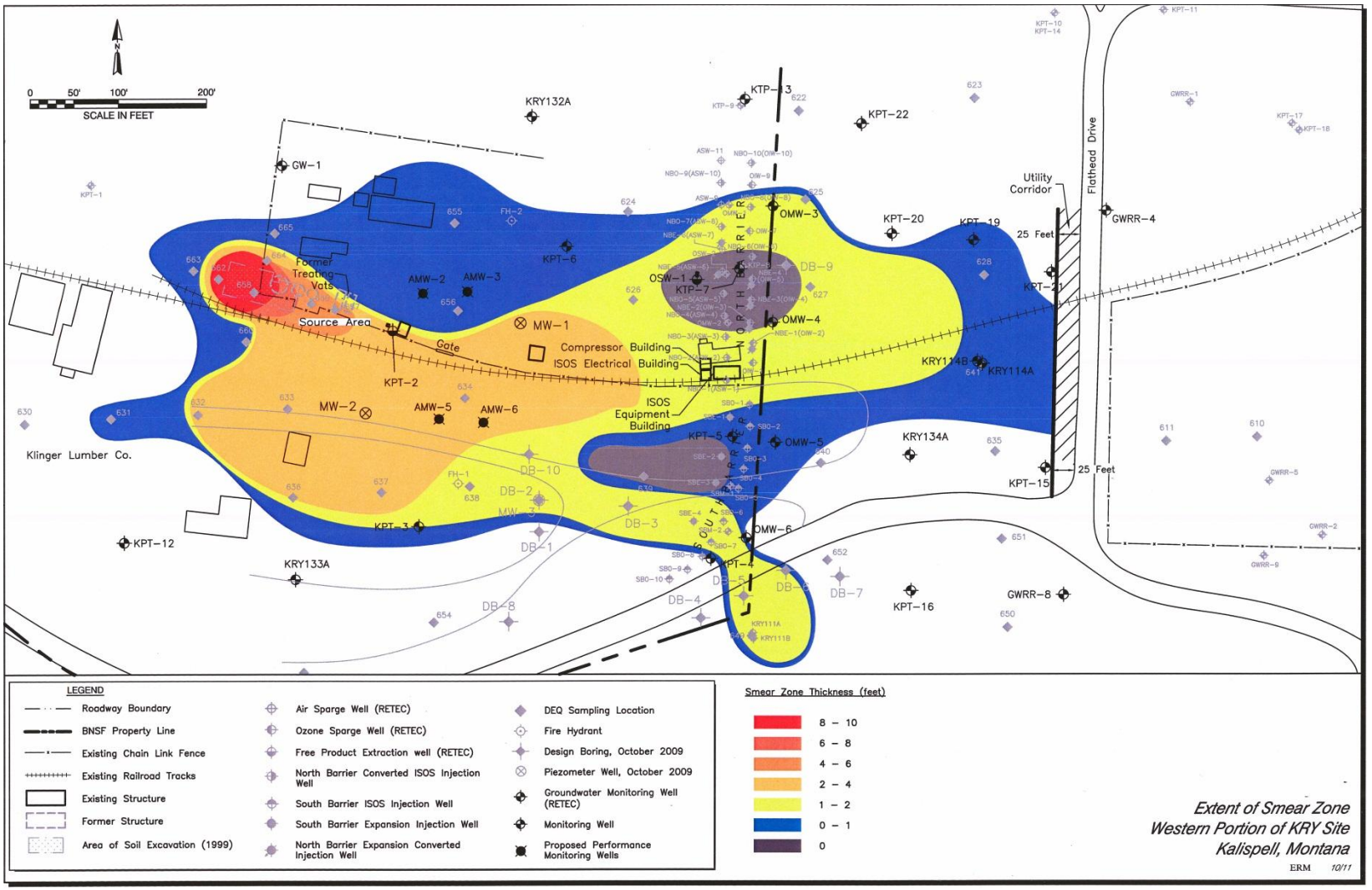
Maximize Site conditions

- Multiple locations
- Increased pressure
- Variable Concentrations
- Bottom/up or Top/down
- Injections of 30,00 gallons per day

Multiple wells/points

Chemical Mixing Facilities

Smear Zone Extent – Former Wood Treating Site



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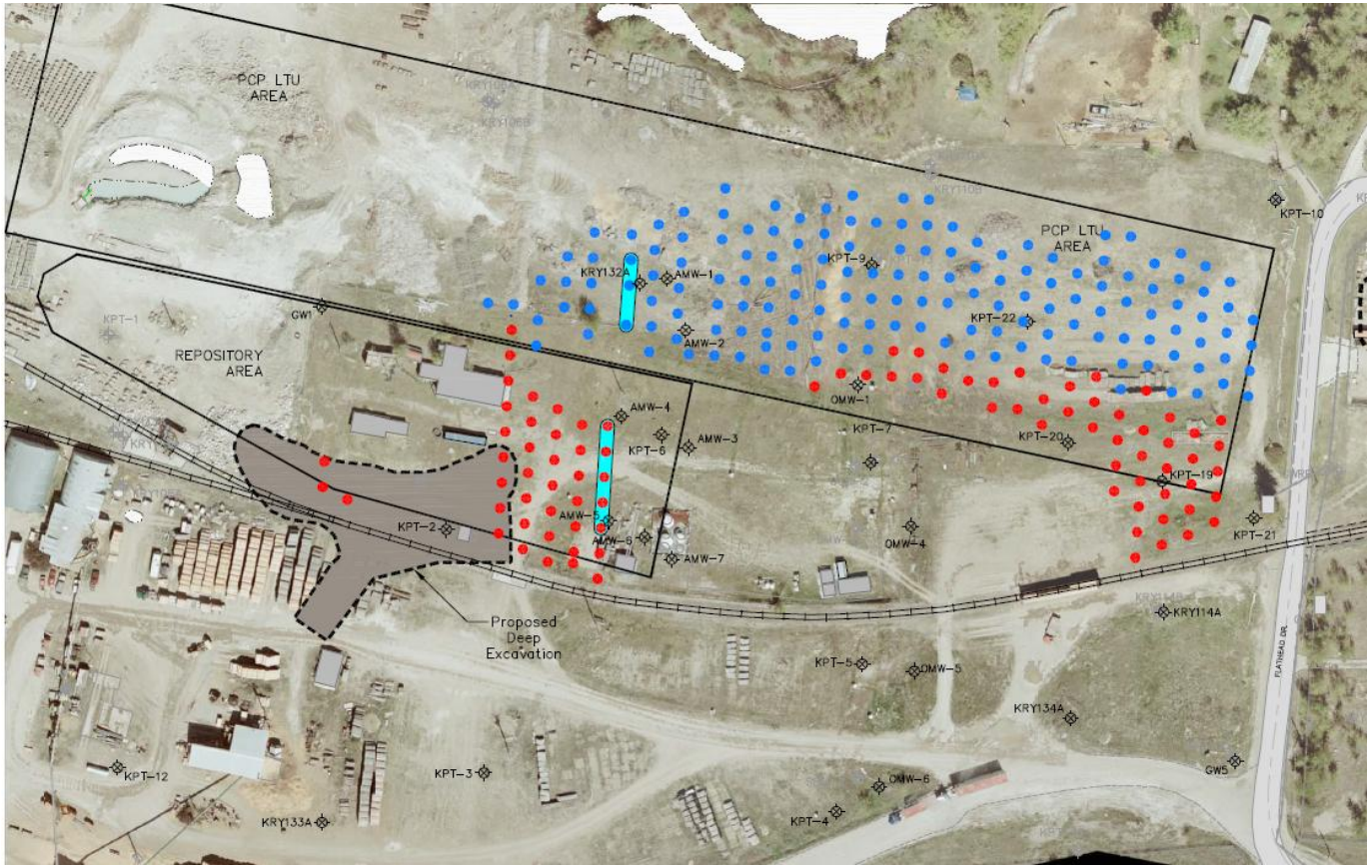
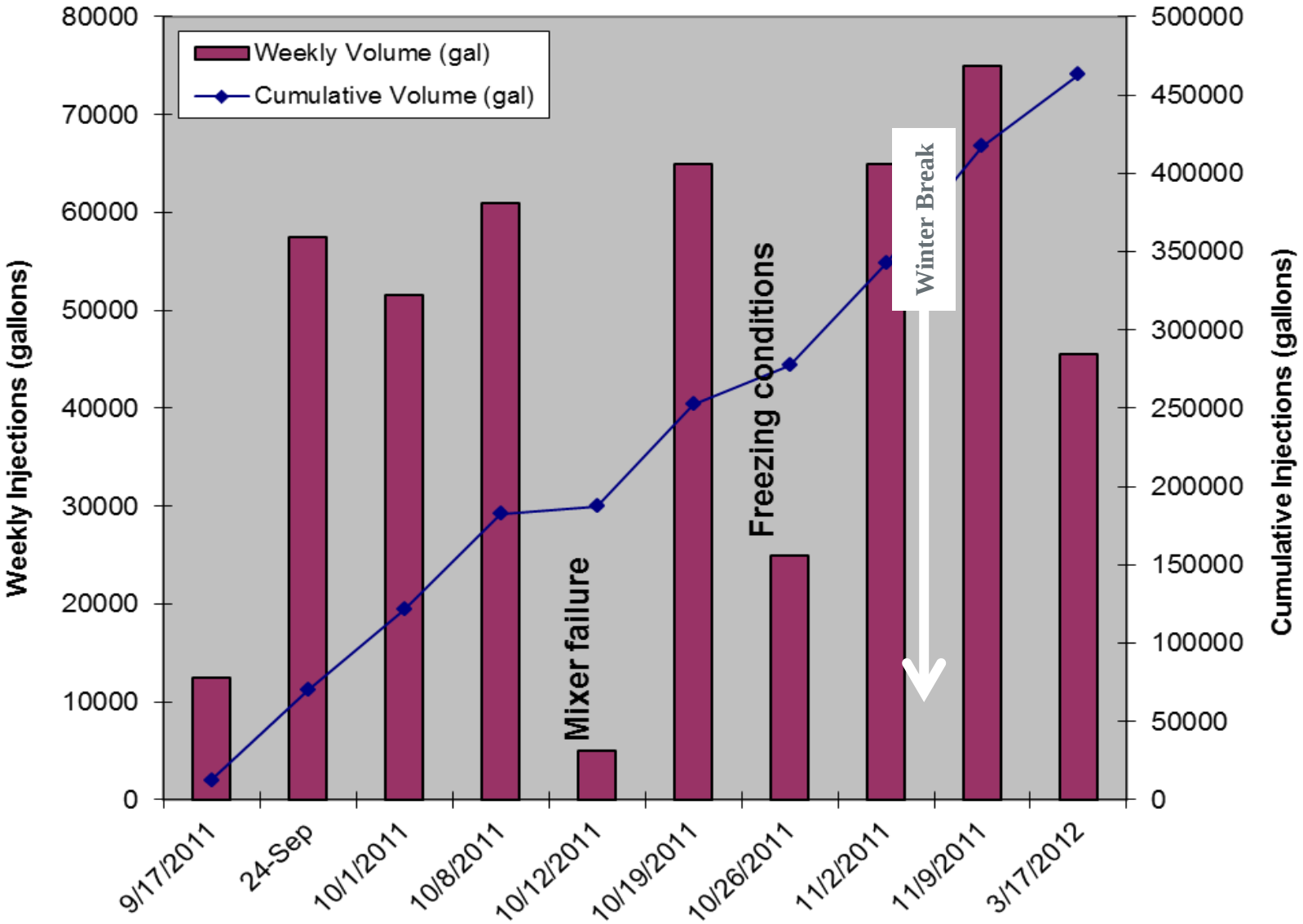
Phase 1 Injections - September to November 2011



- Two intervals applied to dissolved phase (blue)
- Three intervals applied to smear zone (red)
- 243 injections completed (6.4 points, 12,400 gal./day)

Cumulative Volume of ASP Injected in 2011



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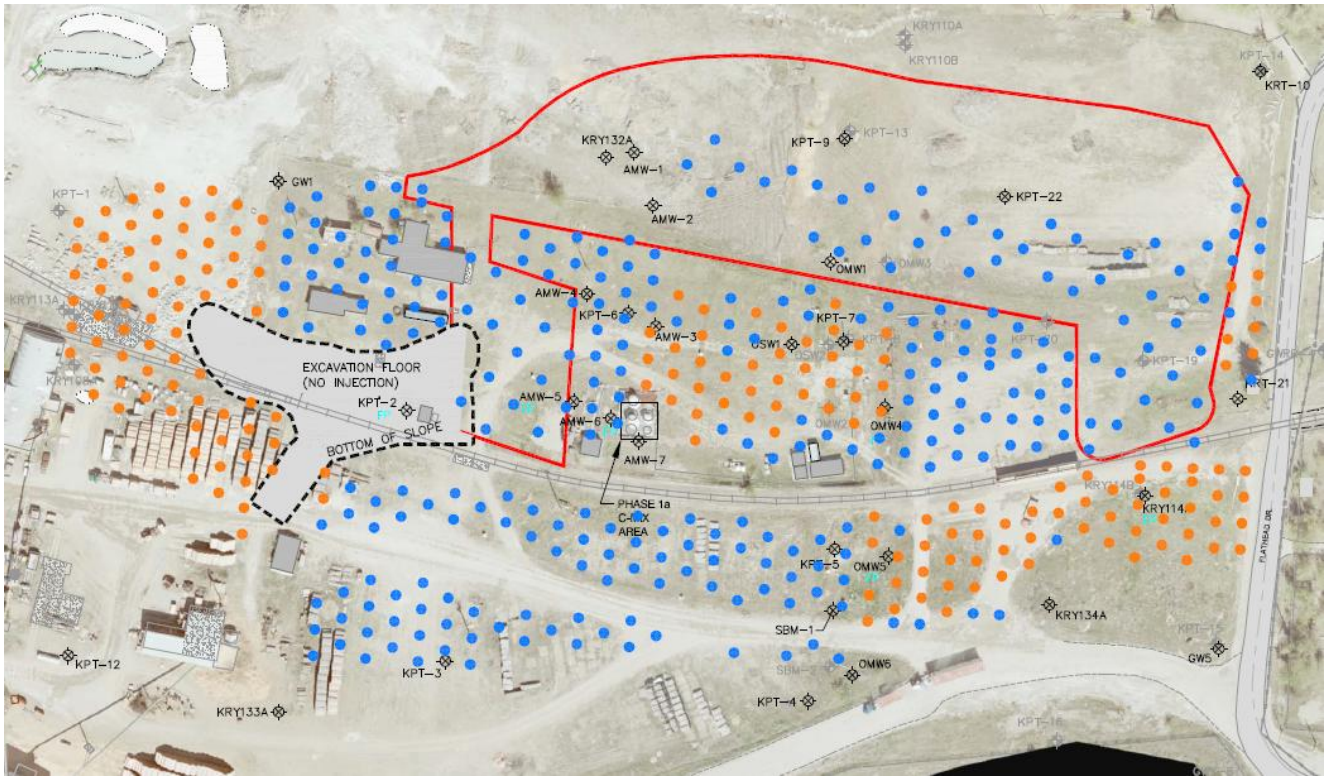
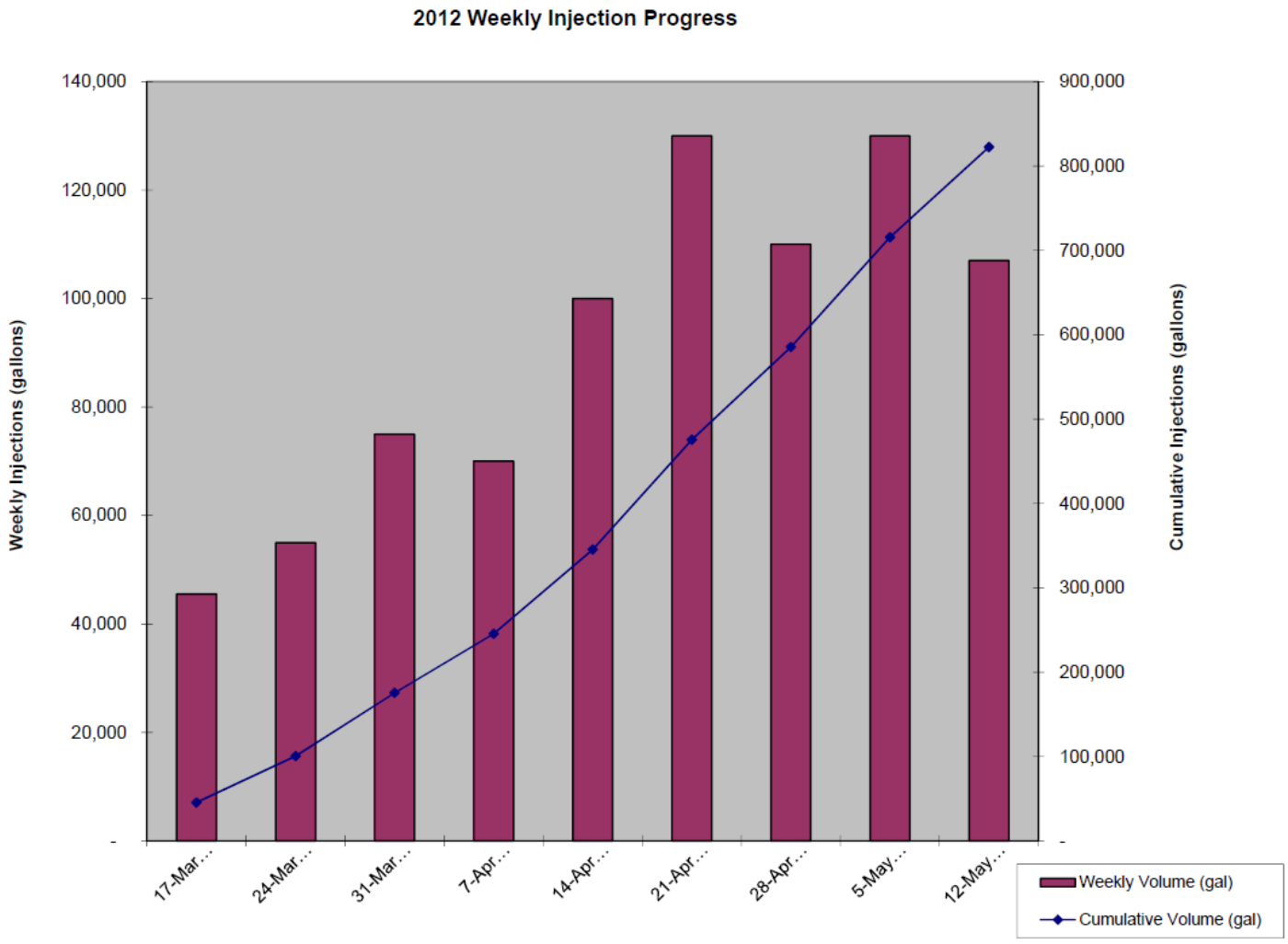
Phase 1a Injections March to May 2012



- **Reapplied base-activated persulfate to smear zone (hotspot injections – 60 points).**
- **Targeted smear zone in vicinity of D/F repository, soil staging area, retention ponds, rock washing area and contractor area – 399 points.**
- **Increased application of sodium-hydroxide activator (blue is 3:1 and orange is 5:1 molar ratio).**

Cumulative Volume of ASP Injected in 2012



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5/15/2012

"Destructive" In-Situ Delivery Methods

In Situ Lang Tool Mixing

- *Improves contact in heterogeneous soils*
- *Improves vadose zone application of liquid oxidants*
- *Applicable to depths of 18 feet*

“Destructive” In-Situ Delivery Methods

Large Auger In Situ Mixing

Evaluation of Delivery Mechanisms

During Injection – Indirect Measurement Tools

Groundwater

- Indicator parameters – pressure, head, physical parameters (pH, conductivity, ORP, temp. turbidity), color, concentration

Soil

- Surficial breakout – surface, low or wet areas
- Tilt meters

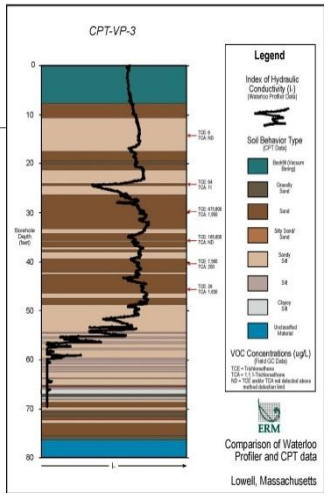
Other

- Utilities – sewer, building foundations and man-made preferential flow zones (preferential backfill)

If you are not looking for them, indirect measures provide no value

Evaluation of Delivery Mechanisms

After Injection – Direct Measurement



Groundwater

- Contaminant Concentrations
- Indicator parameters - physical/chemical/biological, color

Soil / Rock

- Direct inspection – soil sampling, test pitting, coring
- Indirect inspection - geophysical logging

Vapor

- Operational Monitoring – SVE / sub slab, GoreSorber™

Avoid "over interpretation" of potentially suspect data

Questions?