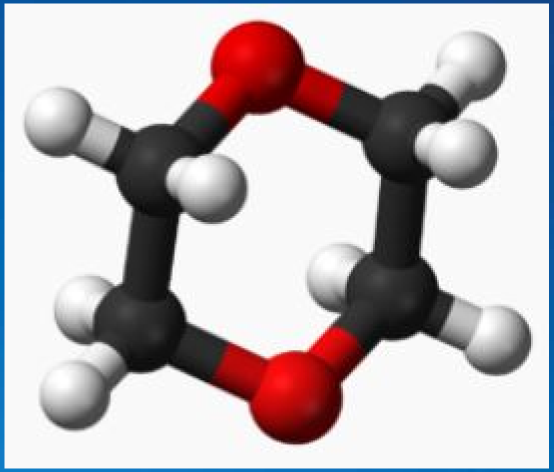
1,4-Dioxane Treatment using Electrical Resistance Heating

February 2014

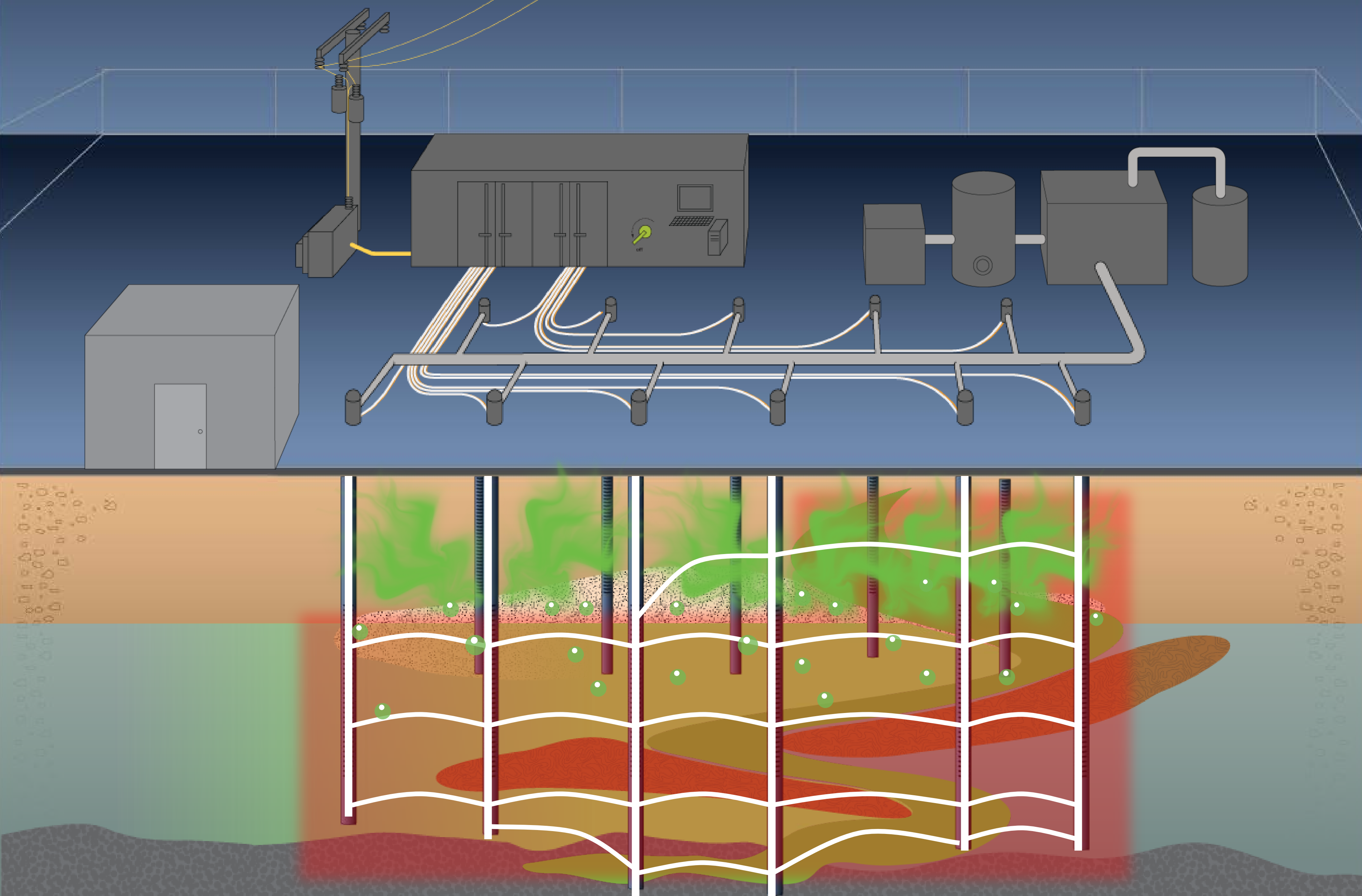


Angus McGrath - Stantec
Angus.McGrath@Stantec.com

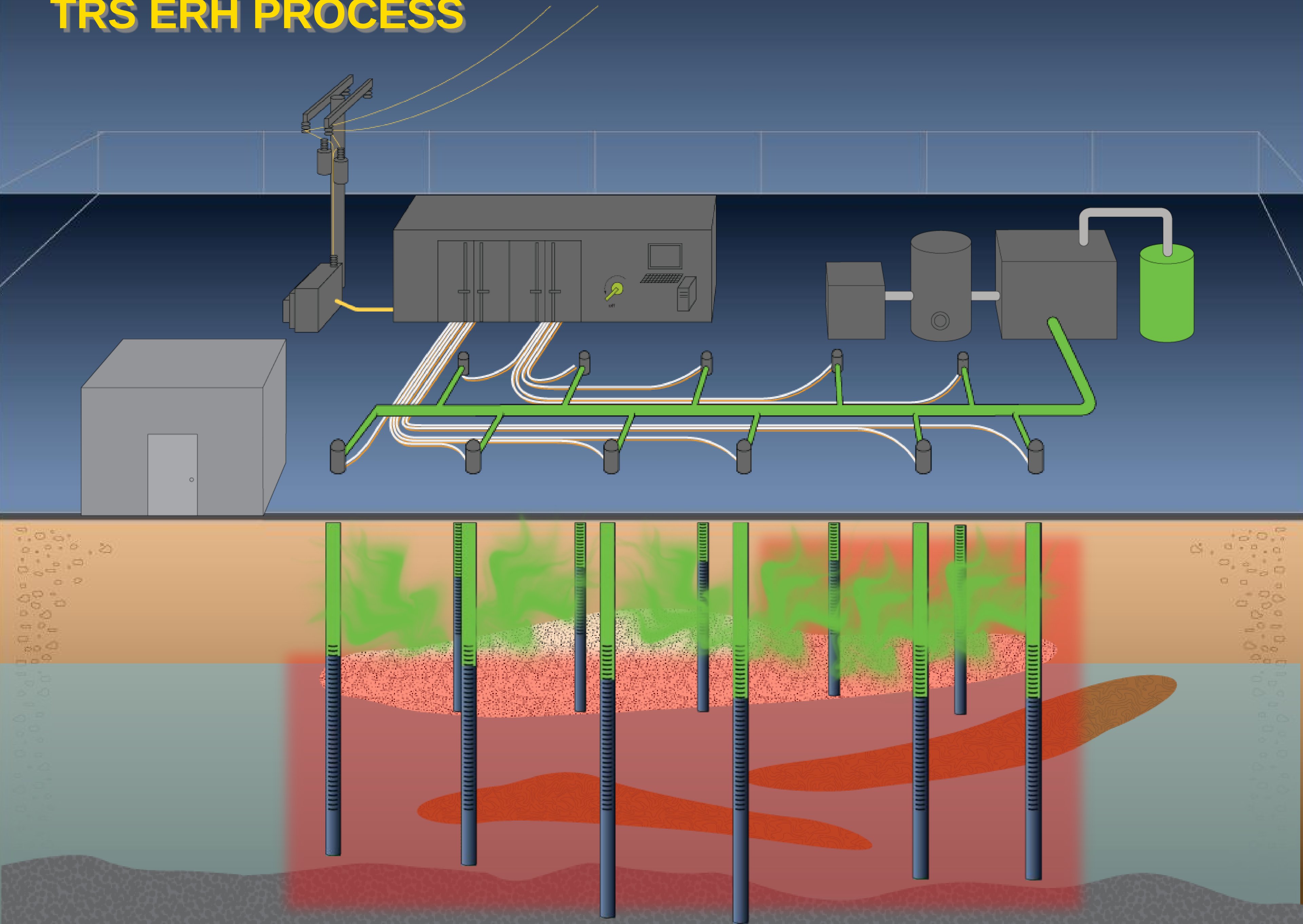
David Schroder - Stantec
David.Schroder@Stantec.com

Daniel Oberle – TRS Group
Doberle@Thermalrs.com

TRS ERH PROCESS



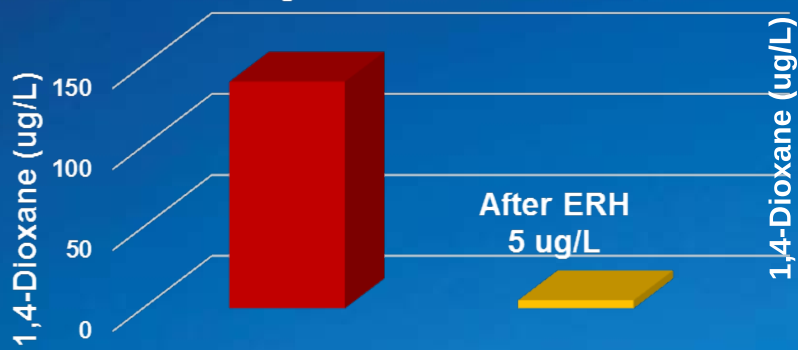
TRS ERH PROCESS



1,4 Dioxane – ERH Projects

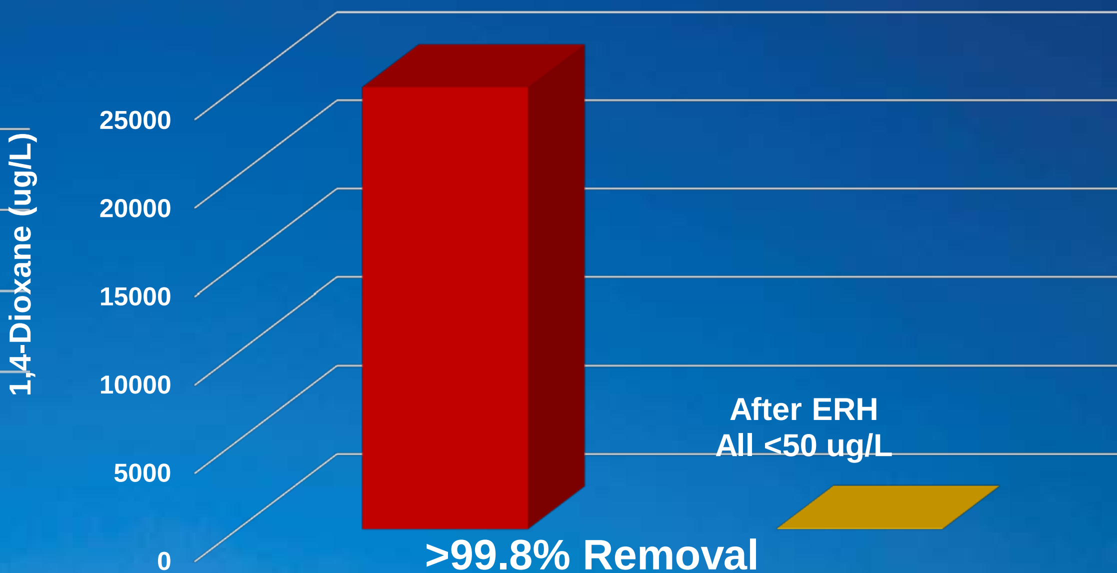
Confidential Client

Los Angeles, CA



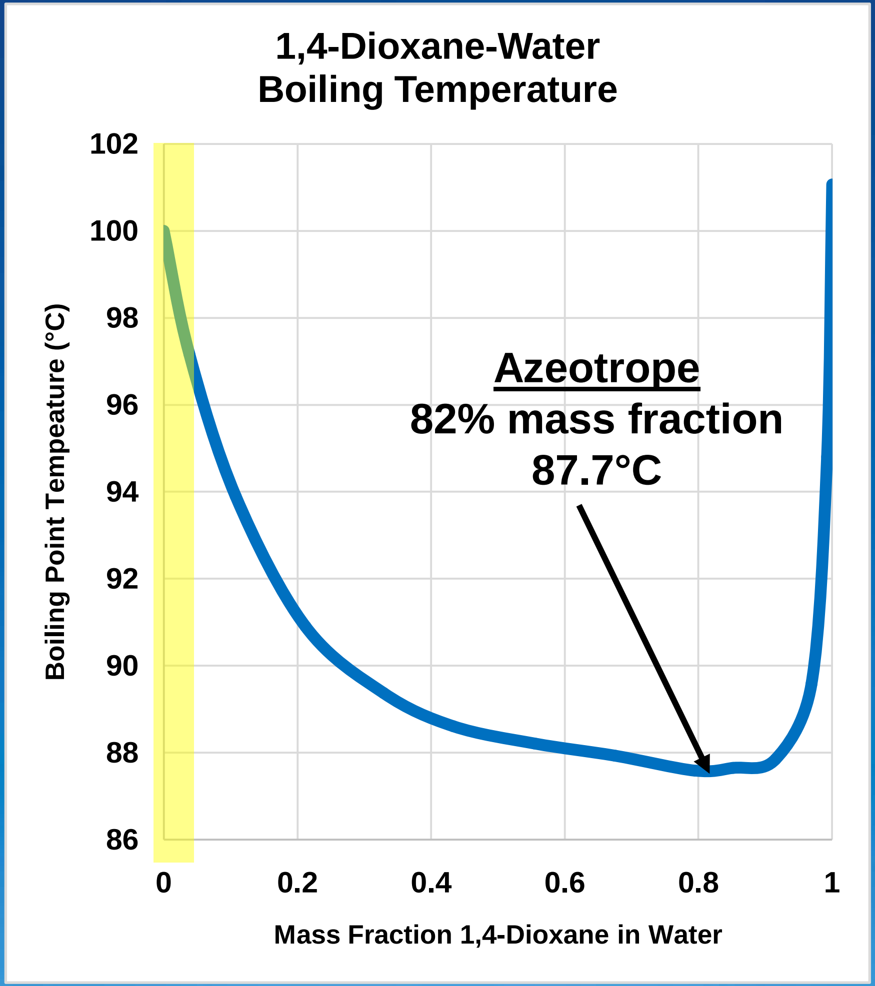
96.5% Removal

Before ERH
1,000 to 90,000 μg/L



>99.8% Removal

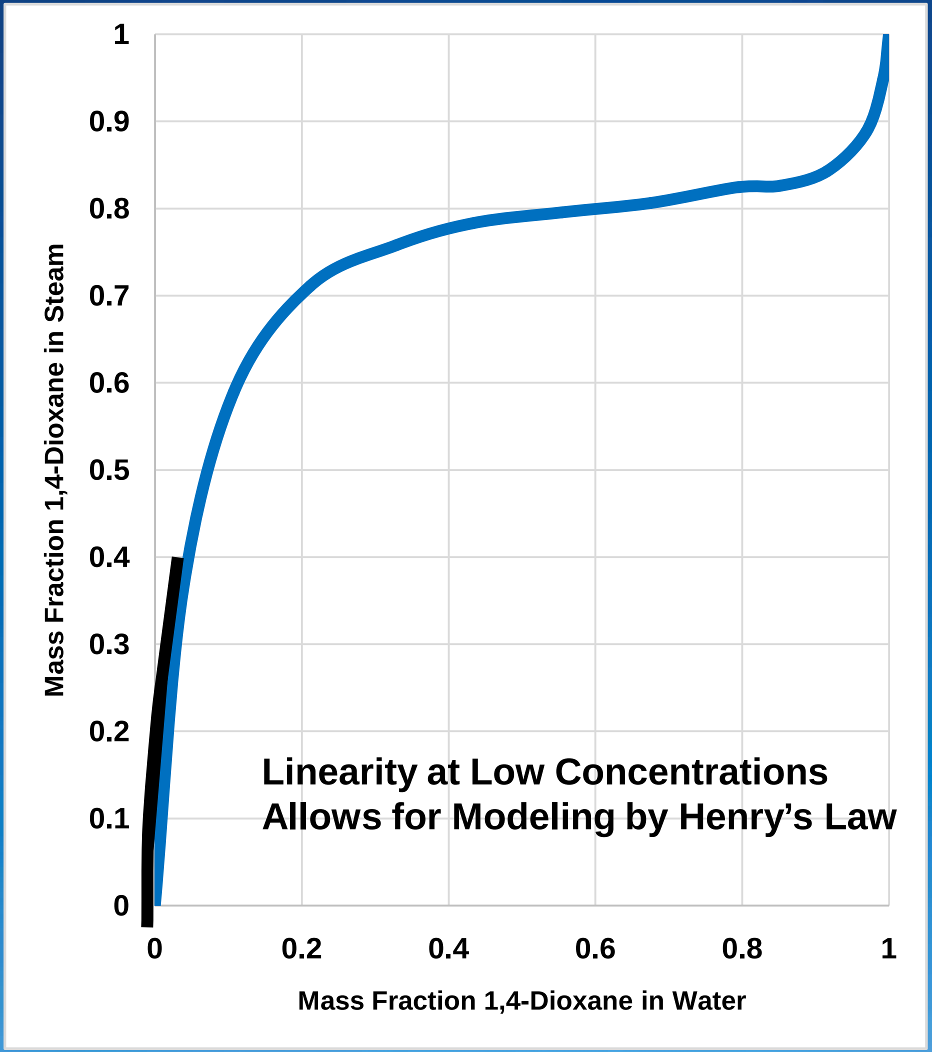
1,4-Dioxane and Water Chemistry



Source: Scheider and Lynch, J. Am. Chem. Soc., 65(6), 1943

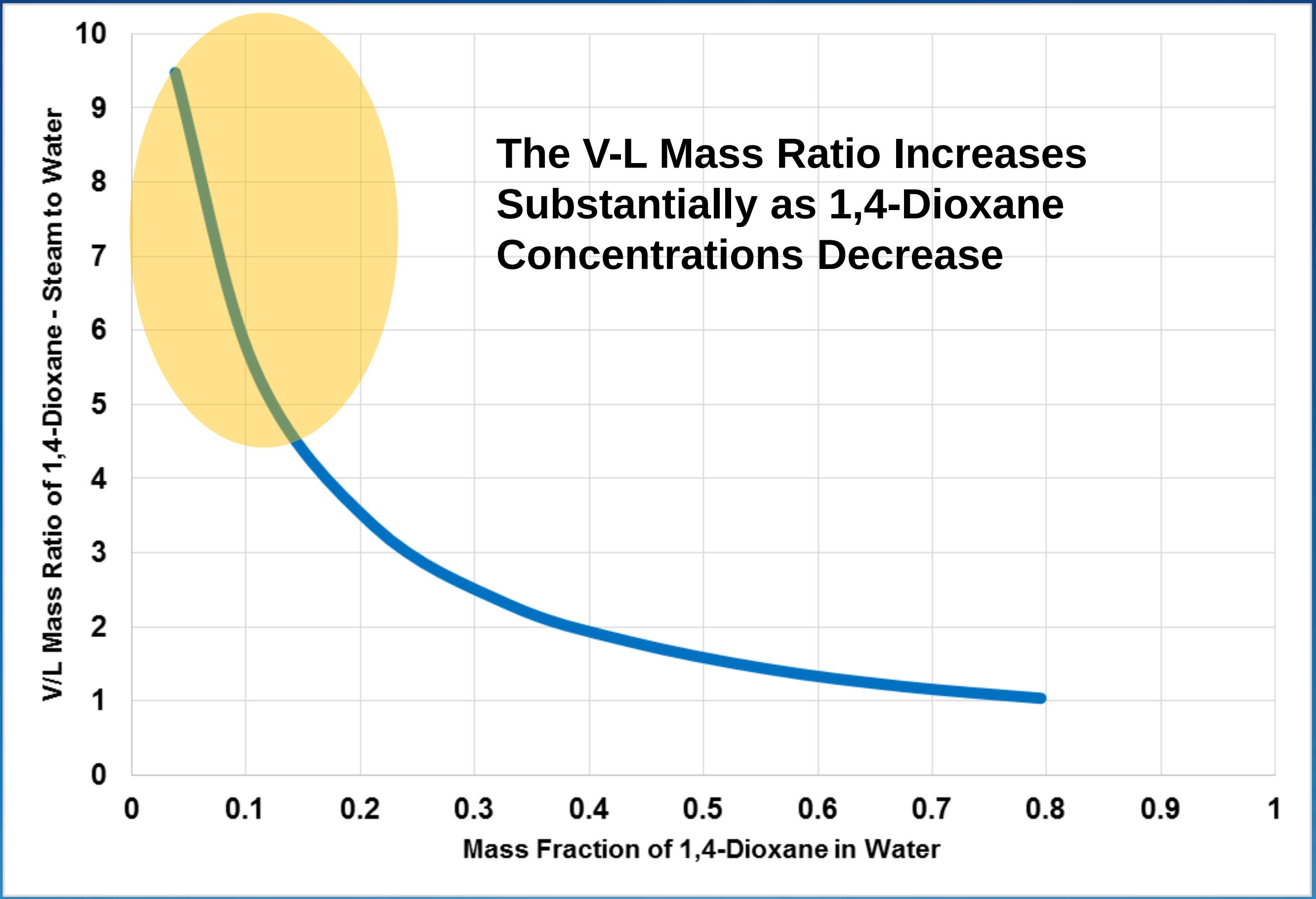
Stantec TRS

1,4-Dioxane and Water VLE



Source: Scheider and Lynch, J. Am. Chem. Soc. 65(6), 1943

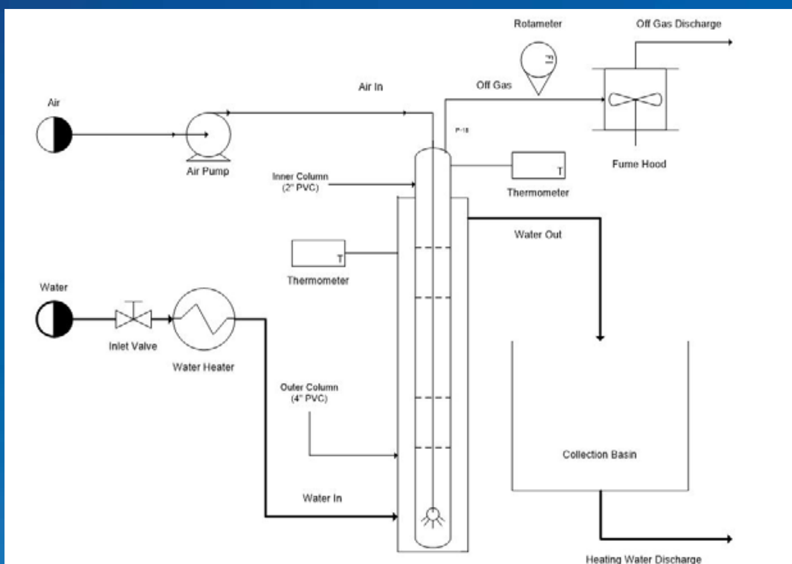
Vapor-Liquid Mass Ratios



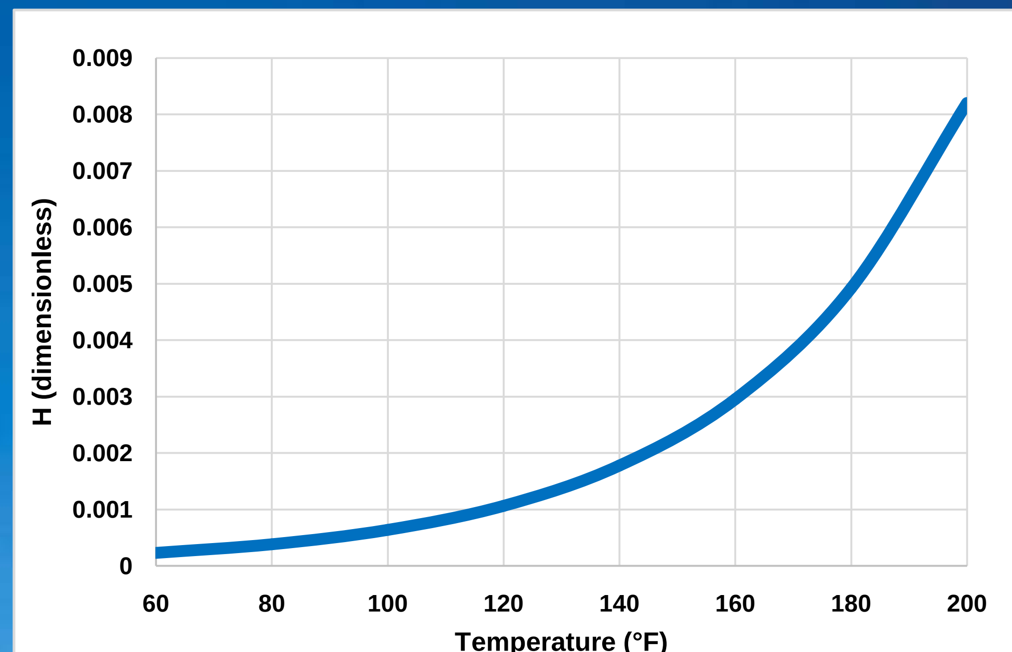
Source: Scheider and Lynch, J. Am. Chem. Soc., 65(6), 1943

Henry's Law Constant -
Experimental Determination

Methodology



Henry's Law – 1,4 Dioxane



Source: Stantec - Internal R&D Testing Report

Henry's Law Constant - Field Data

1,000 scfm steam
1,500 scfm air

Air Out
1,500 scfm air
1,600 ppb 1,4-Dioxane
= 0.12 lb/day

95% of the 1,4-dioxane mass was conveyed into the vapor phase where it was effectively removed onto vapor phase granular activated carbon.

Condensed Steam

5 gpm condensate
94 ug/L 1,4-Dioxane
= 0.006 lb/day

ERH Treatment

Only 5% of the 1,4-dioxane mass remained in the condensed steam.

Stantec TRS

Henry's Law Data –
Experimental vs. ERH Field Data

Henry's Law

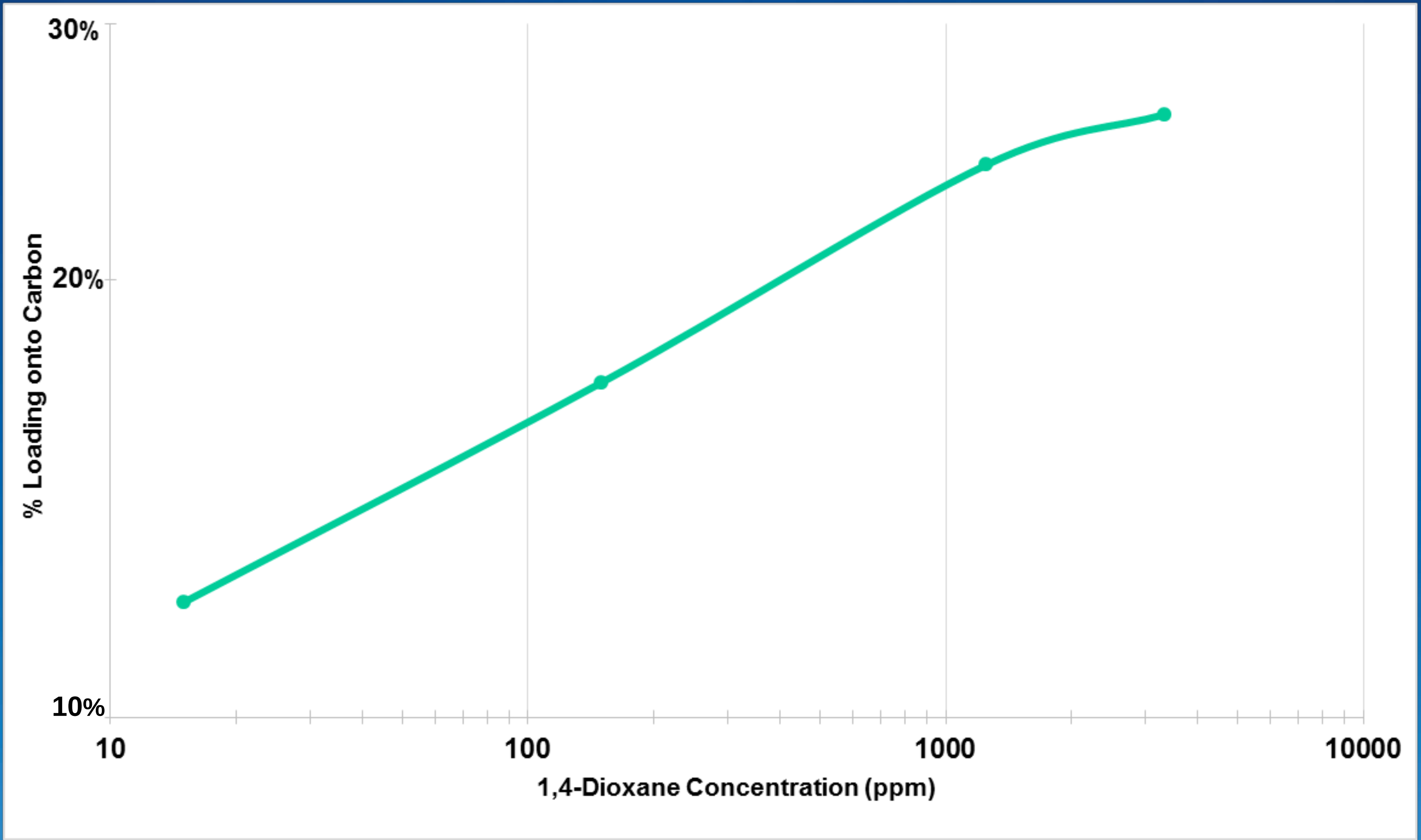
$$\frac{5gpm \times 3.785\frac{l}{gal}}{5gpm \times 3.785\frac{l}{gal} + 0.009 \times 1500scfm \times 28.32\frac{l}{ft^3}} \times 100\% = 4.7\%$$

95.3% mass transfers to vapor phase
4.7% mass remains in condensate

To increase mass transfer to vapor phase…..
increase the extracted air flow

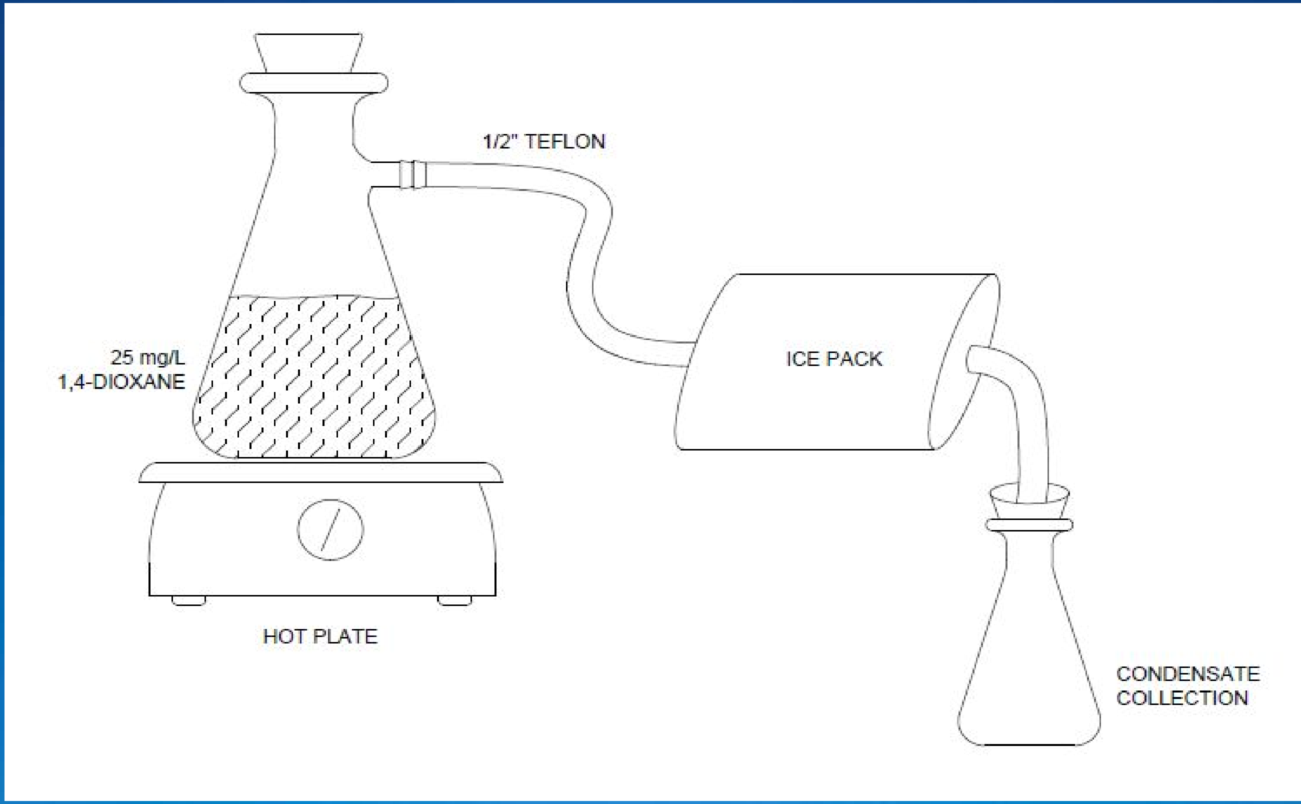
Stantec TRS

1,4-Dioxane Adsorption



Source: Stantec - Internal R&D Testing Report

1,4-Dioxane VLE Lab Study - Water



- Start with 1,000 mL of 26 mg/L 1,4-dioxane solution
- Boil solution down while collecting L and V samples
- Analyze samples using EPA Method 8260B (3 ug/L Detection Limit)

VLE Lab Study Results - Water

Sample	1,4-dioxane (mg/L)	% Water Boiled	% Concentration Reduction
Starting Concentration	26	0%	0%
Liquid Sample 1	8.0	13.2%	69.23%
Liquid Sample 2	0.285	39.5%	98.9%
Liquid Sample 3	0.016	65.8%	99.94%
Liquid Sample 4	0.0063	98.7%	99.98%
Condensate 1	230	13.2%	N/A
Condensate 2	36	39.5%	N/A
Condensate 3	3.4	65.8%	N/A
Condensate 4	0.585	98.7%	N/A

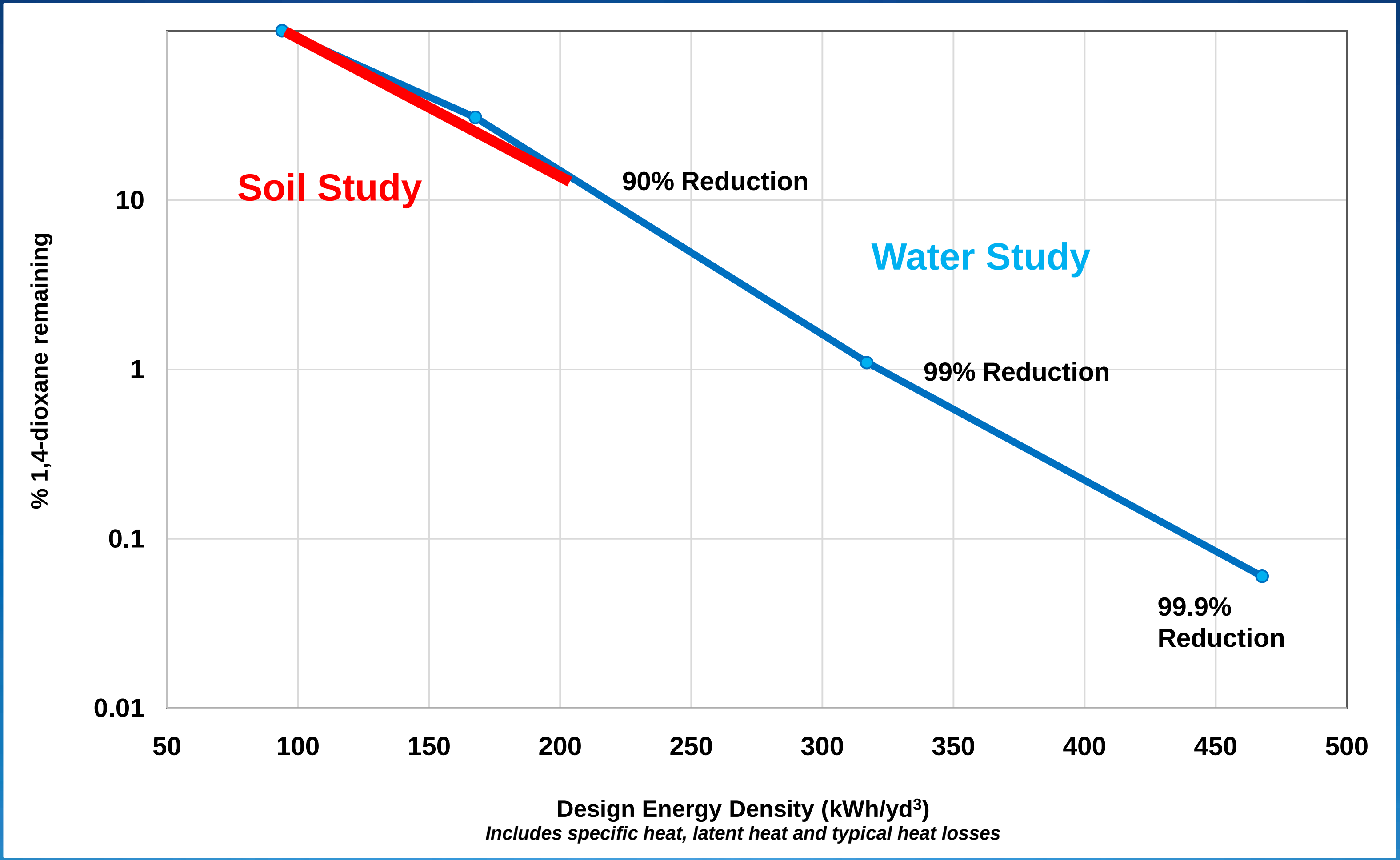
1,4-Dioxane ERH Lab Study – Soil*

Sample	Steaming Energy Density (kWh/yd3)	Results 1,4-dioxane (mg/Kg)	Percent Reduction
Starting Concentration	0	5.4	0%
20% moisture boiled	75	0.67	87.6%
45% moisture boiled	169	<0.58	>89.3%
80% moisture boiled	300	<0.51	>90.6%

Soil samples provided by NAVFAC SW

Stantec TRS

Design Energy Density Values



Assumes 60 kWh/yd3 specific heat and 35% heat loss to surroundings during ERH. Cost for treatment likely to fall into the range of $150 to $300 per cubic yard.

Stantec TRS

Advantages over Pump and Treat

- 90% reduction achieved in 0.5 pore volume removal for ERH vs 20+ pore volume removals for P&T
- Condensate does not contain Fe, Mn or carbonates and it has lower 1,4-dioxane concentrations
- Most of the 1,4-dioxane is conveyed into vapor phase
- Cleanup occurs in several months vs several years
- ERH works great in low permeability soils

Stantec TRS

Conclusions

- 1,4-Dioxane can be remediated using ERH
- Design Targets:
  - ~ 220 kWh/yd^3 for 90%
  - ~ 330 kWh/yd^3 for 99%
  - ~ 440 kWh/yd^3 for 99.9%
- Majority remains in vapor-phase
- Condensate residuals treated by POTW or easily treated with advanced oxidation processes
- Advantages over pump-and-treat include:
  - Significantly less water to treat
  - Lower aqueous concentrations of 1,4-dioxane
  - Less inorganic and organic interference for water treatment
  - Cleanup occurs in months rather than years

Stantec TRS