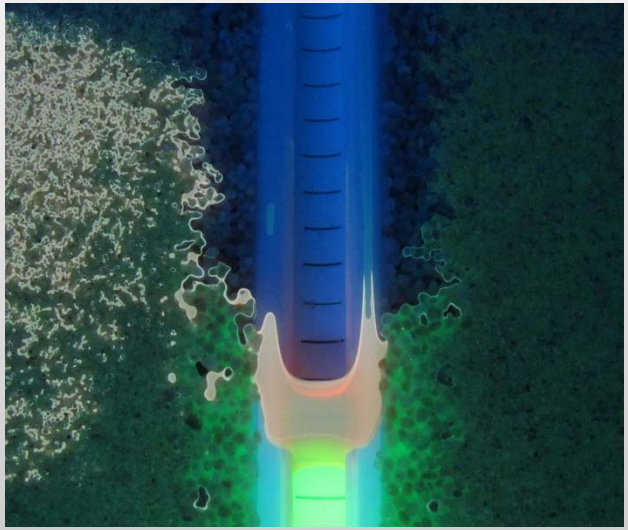
NSZD State-of-the-Practice



Tom Sale / Colorado State University
Presented at

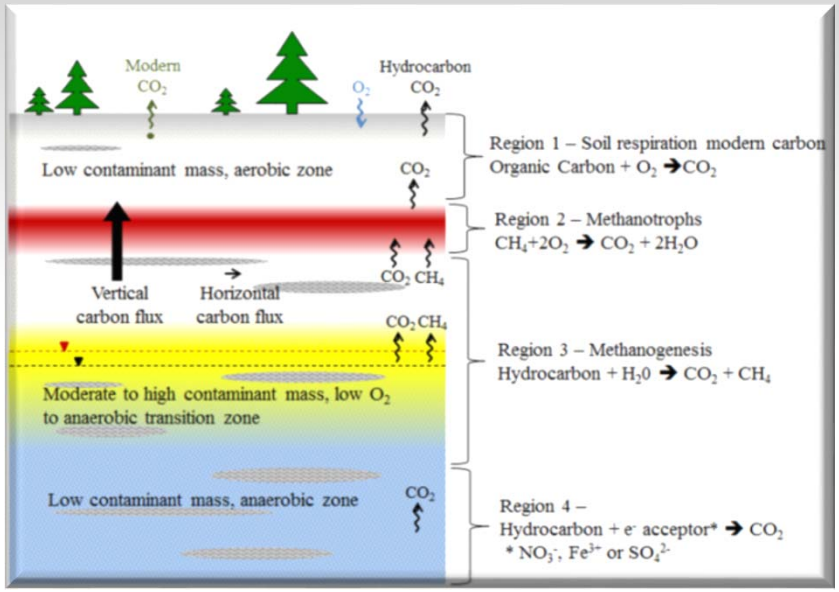
Eleventh International Conference on the Remediation of Chlorinated and Recalcitrant Compounds
April 9, 2018

When I was… 37 years…

2,200 barrels/day

Natural Source Zone Depletion (NSZD)

- What is NSZD and how does it work?
- How does NSZD fit into managing LNAPL sites?
- What are the outstanding issues?



Karimi Askarani et al. 2018

WHAT IS NSZD AND HOW DOES IT WORK?

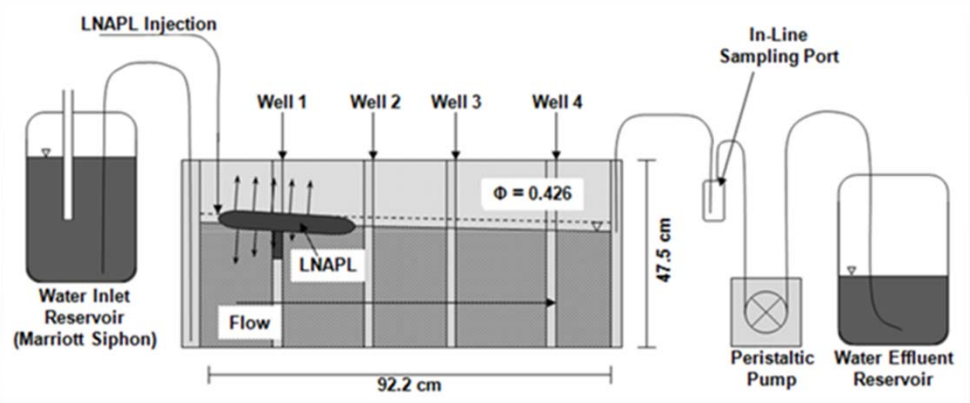
NSZD governs mobility

ground water

A Mass Balance Approach to Resolving LNAPL Stability

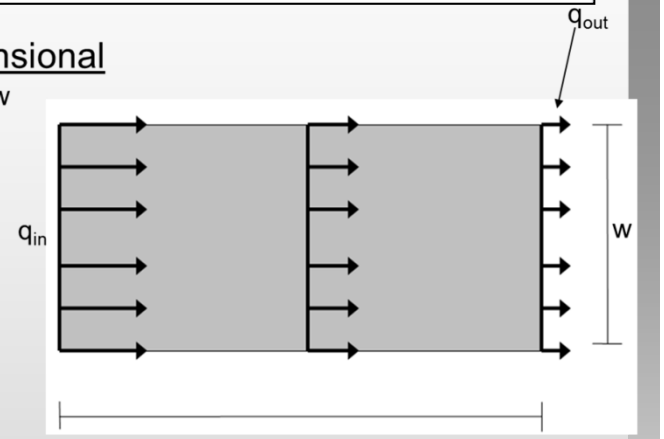
by Nicholas Mahler[1], Tom Sale[2], and Mark Lyverse[3]

2012



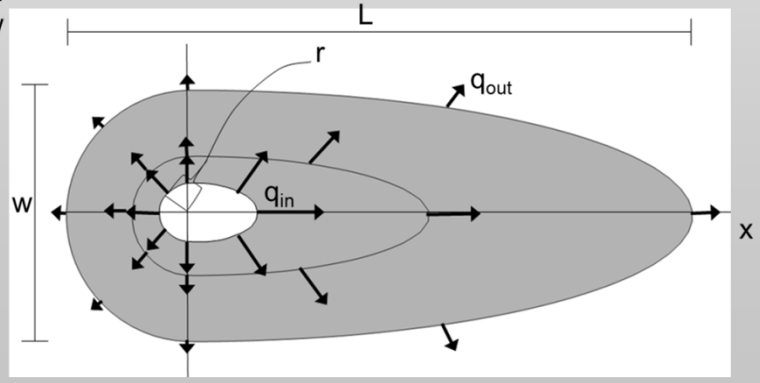
One-dimensional

Plan View



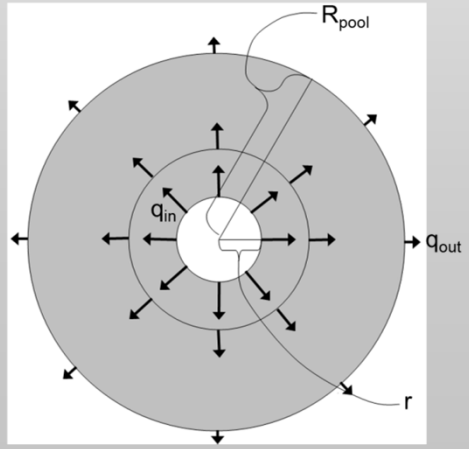
Oblong

Plan View

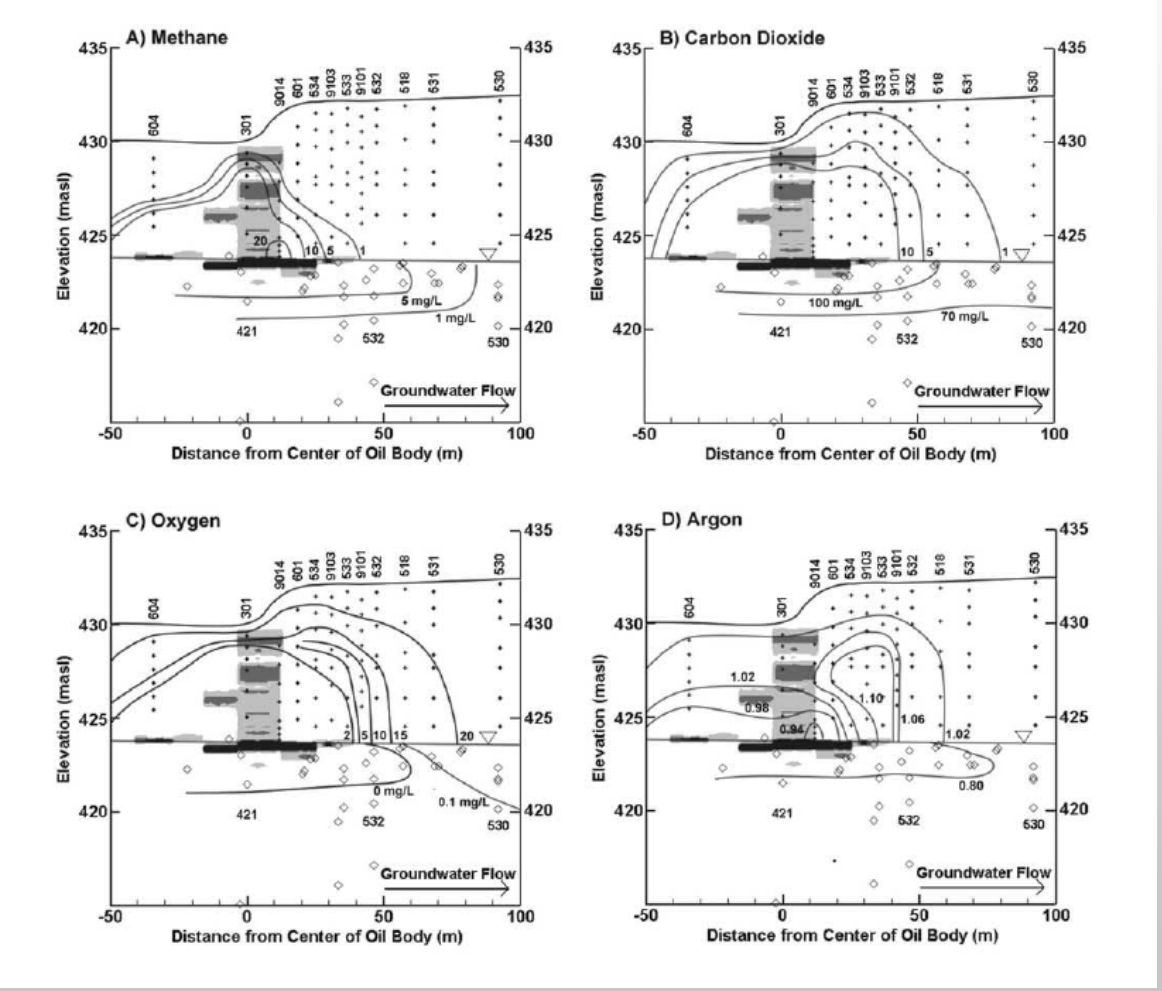


Circular

Plan View



Natural losses



Amos et al. 2005

Milestones

WATER RESOURCES RESEARCH, VOL. 32, NO. 7, PAGES 2231–2249, JULY 1996

Estimation of rates of aerobic hydrocarbon biodegradation by simulation of gas transport in the unsaturated zone

Matthew A. Lahvis and Arthur L. Baehr
U.S. Geological Survey, West Trenton, New Jersey

WATER RESOURCES RESEARCH, VOL. 41, W02001, doi:10.1029/2004WR003433, 2005

Use of dissolved and vapor-phase gases to investigate methanogenic degradation of petroleum hydrocarbon contamination in the subsurface

Richard T. Amos,[1] K. Ulrich Mayer,[1] Barbara A. Bekins,[2] Geoffrey N. Delin,[3] and Randi L. Williams[1]

Ground Water Monitoring&Remediation

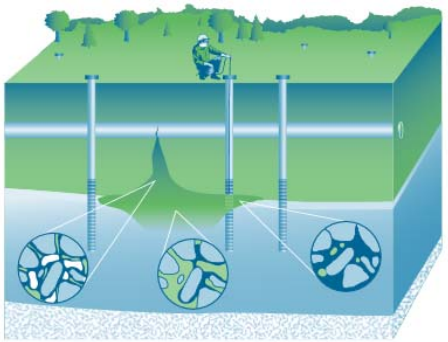
Source Zone Natural Attenuation at Petroleum Hydrocarbon Spill Sites—I: Site-Specific Assessment Approach

by Paul Johnson, Paul Lundegard, and Zhuang Liu

2006

Technology Overview

Evaluating Natural Source Zone Depletion at Sites with LNAPL

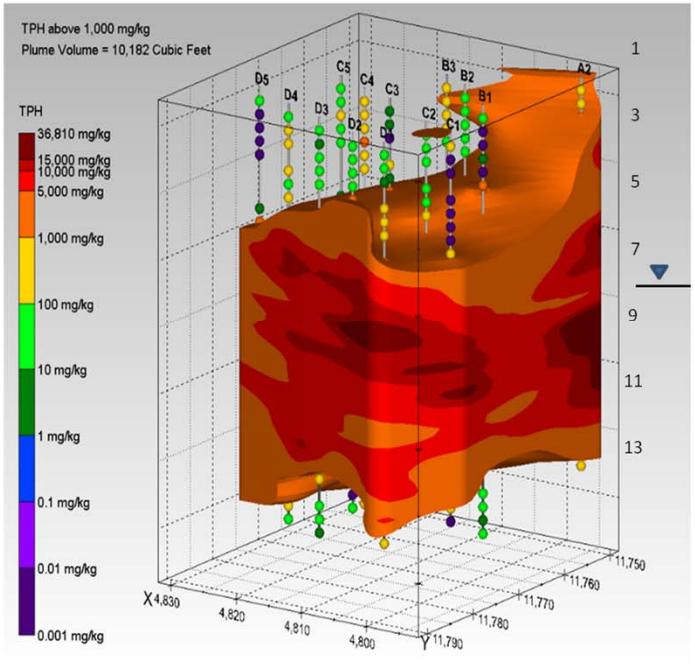


April 2009

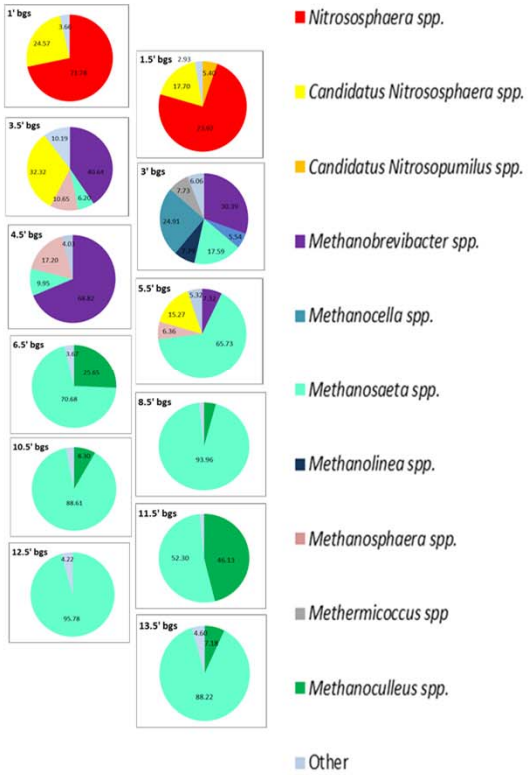
Prepared by
The Interstate Technology & Regulatory Council
LNAPLs Team

It's a jungle down there

High Resolution Total Petroleum Hydrocarbon



Archaea-Genera



After Irianni-Renno 2016

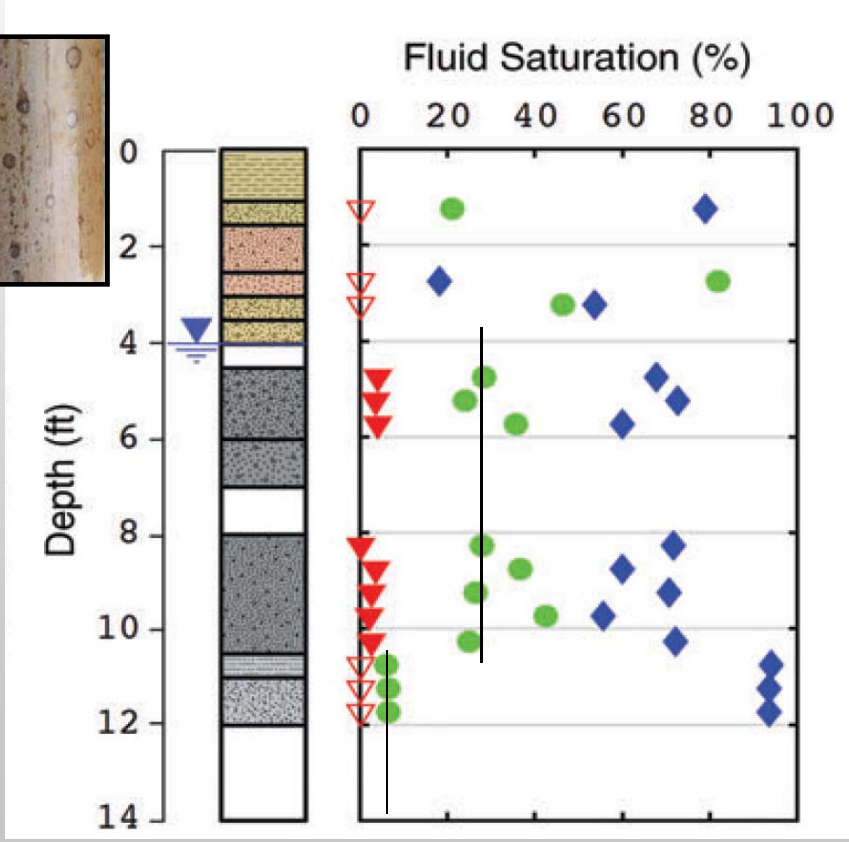
So much going on

- Methanogenesis
- Methane cloud
- Dissolve air flotation
- GW pumping via
  - Ebullition
  - Water level fluctuations
- Mass transfer limited
- <u>Vast majority is GONE</u>

Groundwater Monitoring&Remediation

Overview of Natural Source Zone Depletion: Processes, Controlling Factors, and Composition Change

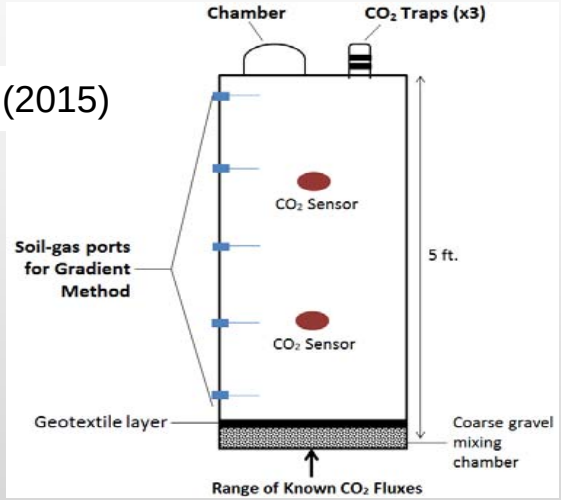
by Sanjay Garg, Charles J. Newell, Poonam R. Kulkarni, David C. King, David T. Adamson, Maria Irianni Renno, and Tom Sale

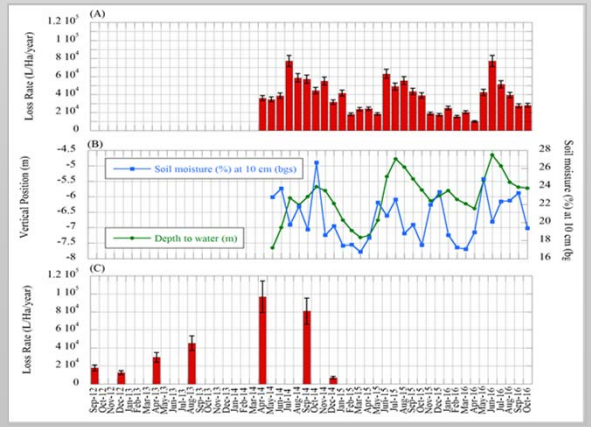


Field methods to resolve loss rates

- Gradient
- Dynamic Chamber
- CO_2 Traps
- Thermal

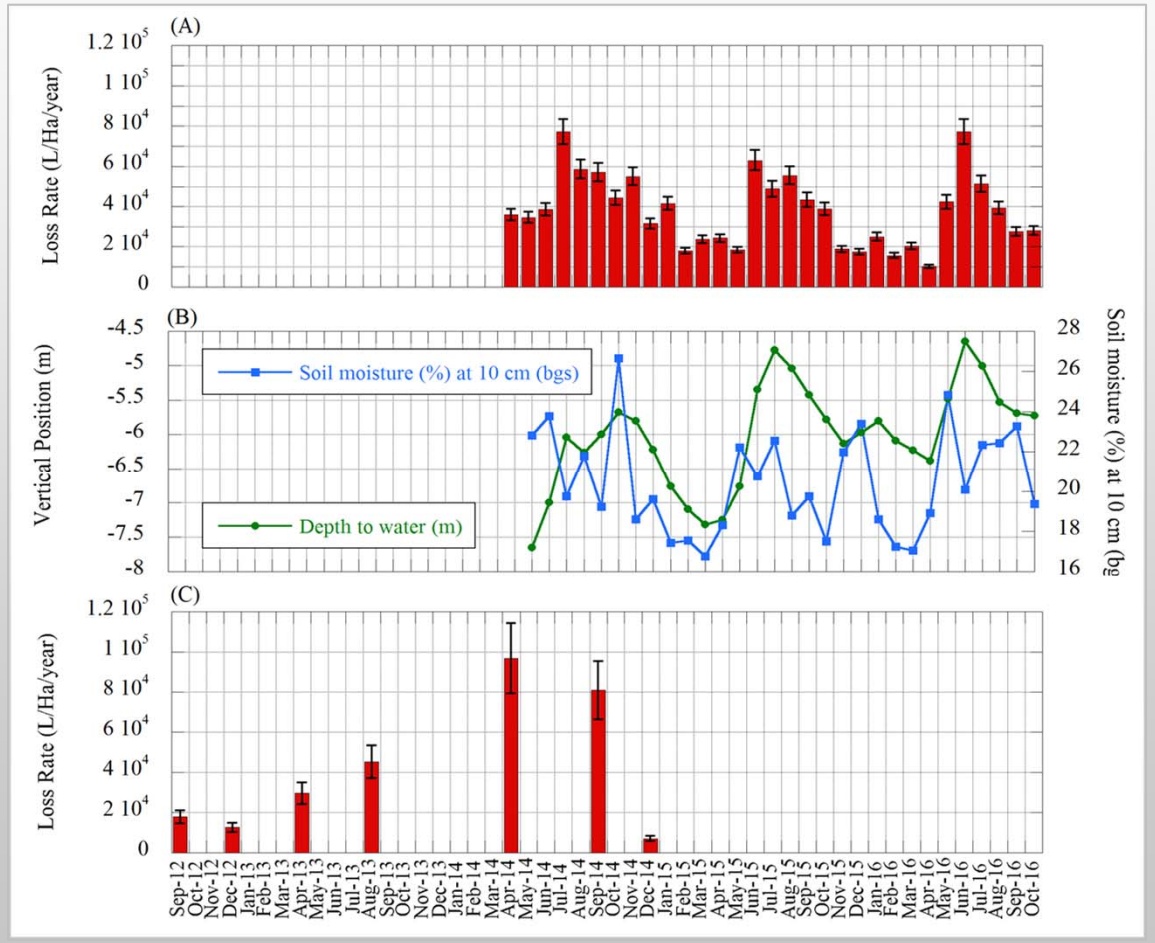
Tracy (2015)





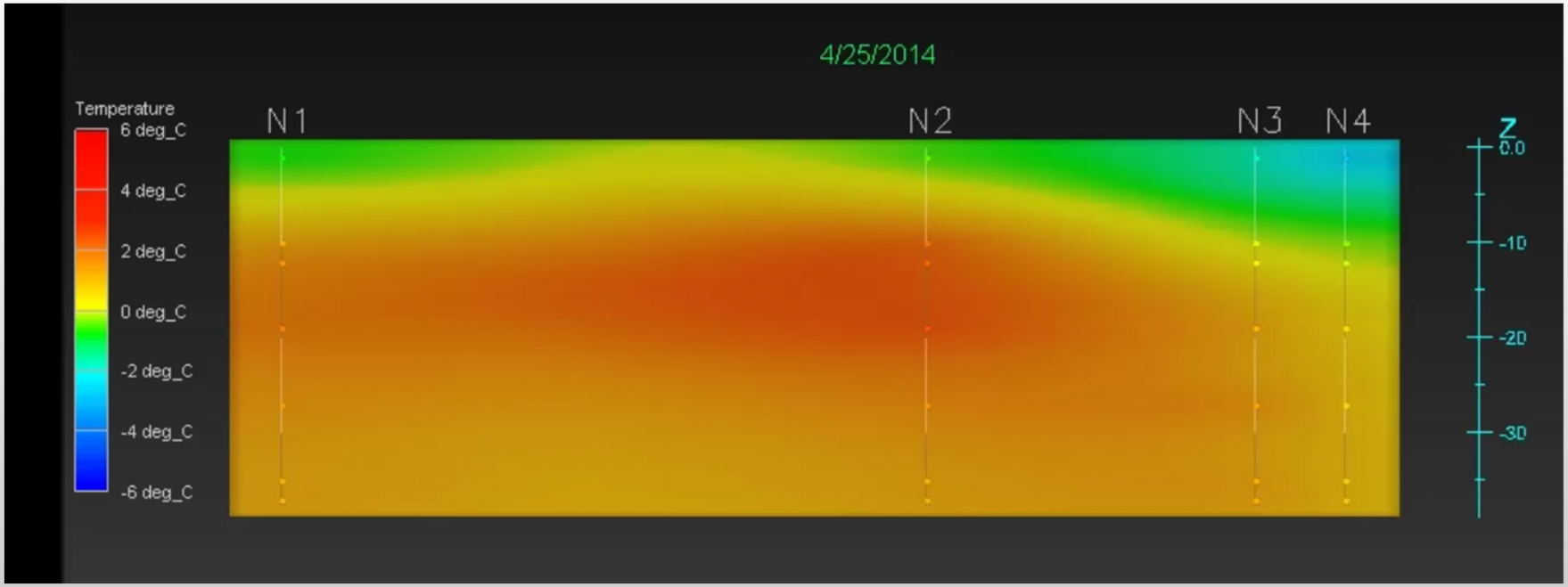
Apparent vs. actual NSZD rates

1 W/m^2 = ~1000 gal/acre /yr



Karimi Askarani et al. 2018

Dynamic processes in the vadose zone



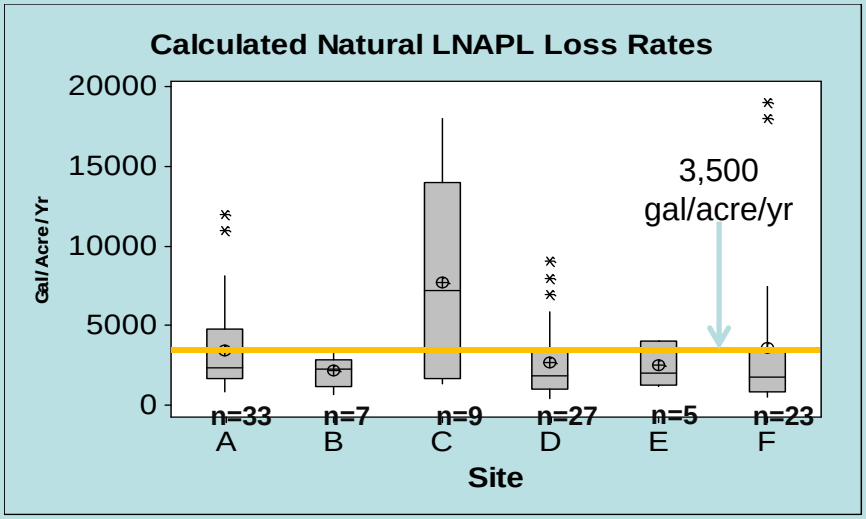
Stockwell (2015)

HOW DOES NSZD FIT INTO MANAGING LNAPL SITES?

LNAPL Loss Rates

Middle 50% of sites
700-2800 gal/acre/yr

Garg et al. 2017



McCoy, et al. (2015).

See Also - American Petroleum Institute (API). 2017. *Qualification of vapor phase-related natural source zone depletion processes*. American Petroleum Institute.

LNAPL Loss Rates

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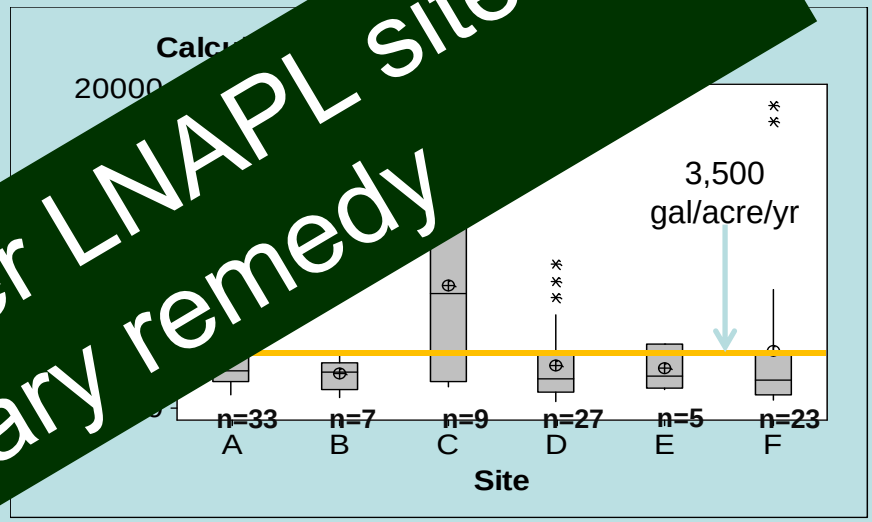
Garg et al. 2017



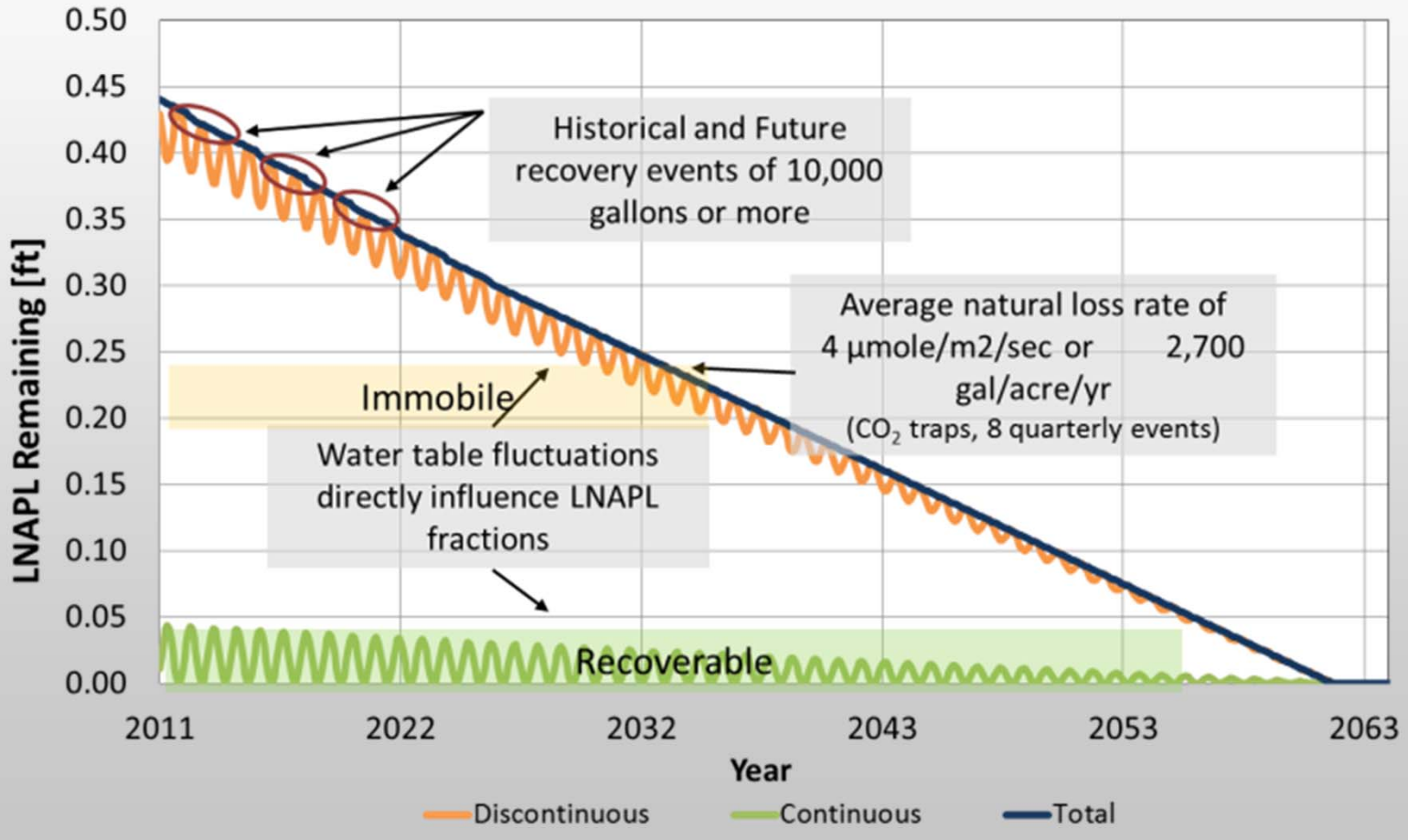
McCoy, et al. (2015).

Today, at most older LNAPL site NSZD is the primary remedy

can Petroleum Institute (API). 2017. *Qualification of va related natural source zone depletion processes*. American Pet m Institute.

So when are we going to run out?

Glide Path



Anna Skinner (2012) and Eric Emerson (2014)

Pillars of NSZD Remedies?

- Low cost monitoring (because it will take time)
- Verification of progress
- Enhanced NSZD for portions of sites with the greatest longevity

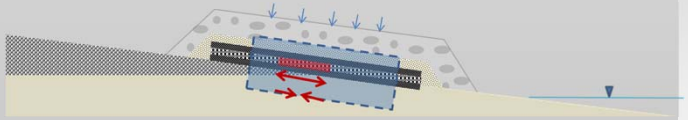
WHAT ARE THE OUTSTANDING ISSUES?

What controls LNAPL longevity?

- Releases
  - Specific LNAPL volume
  - Active versus inactive
- Temperature
- Release of reaction by products
- Oxygen and other electron acceptors
  - Passive
  - Active

And…

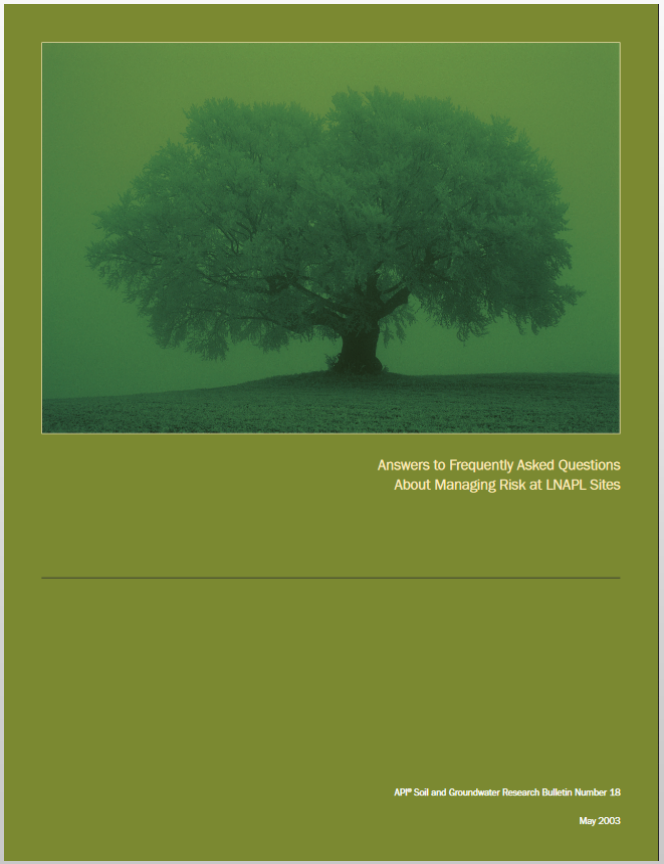
- What controls the longevity of risk drivers…BENZENE and …?
- How and where should we enhance NSZD?
- What risk are posed by reaction intermediates?
- Non-standard NSZD sites



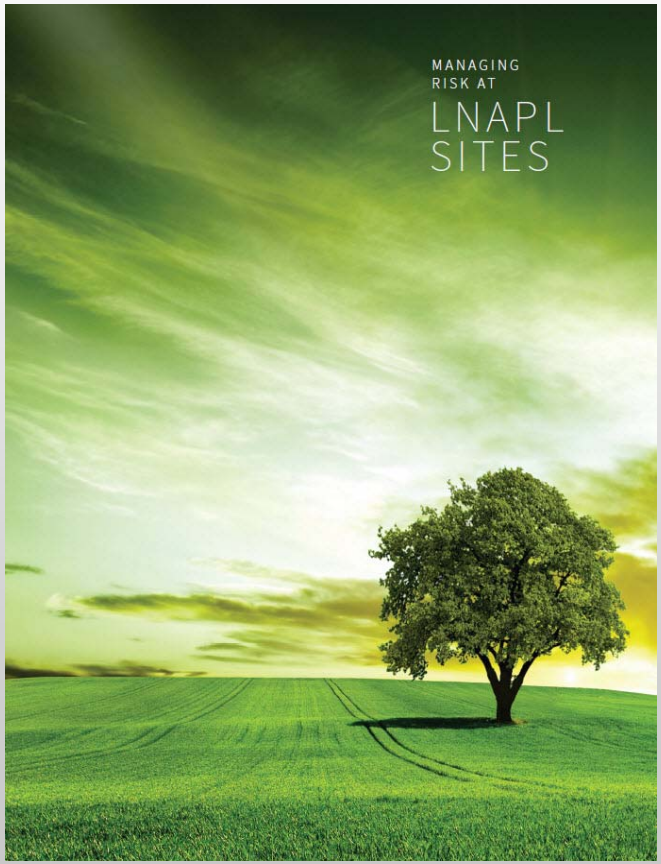
- <u>How does NSZD fit into remedy decisions</u>

CLOSING

A journey



2003



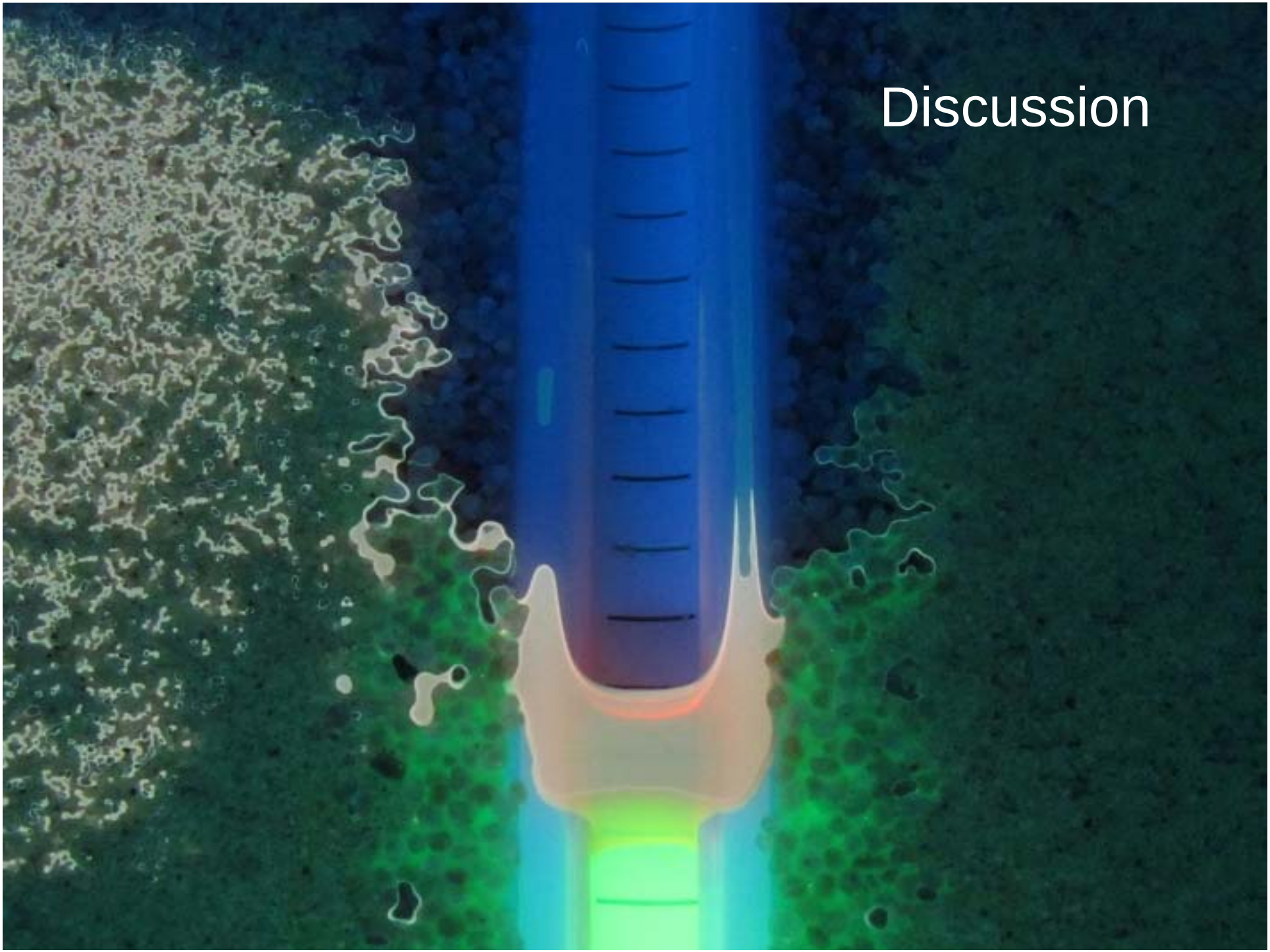
2018

80% of the References are New

Acknowledgements

- Chevron
- ExxonMobil
- Suncor
- Shell
- BP
- and others

Research peers/ collaborators


Discussion