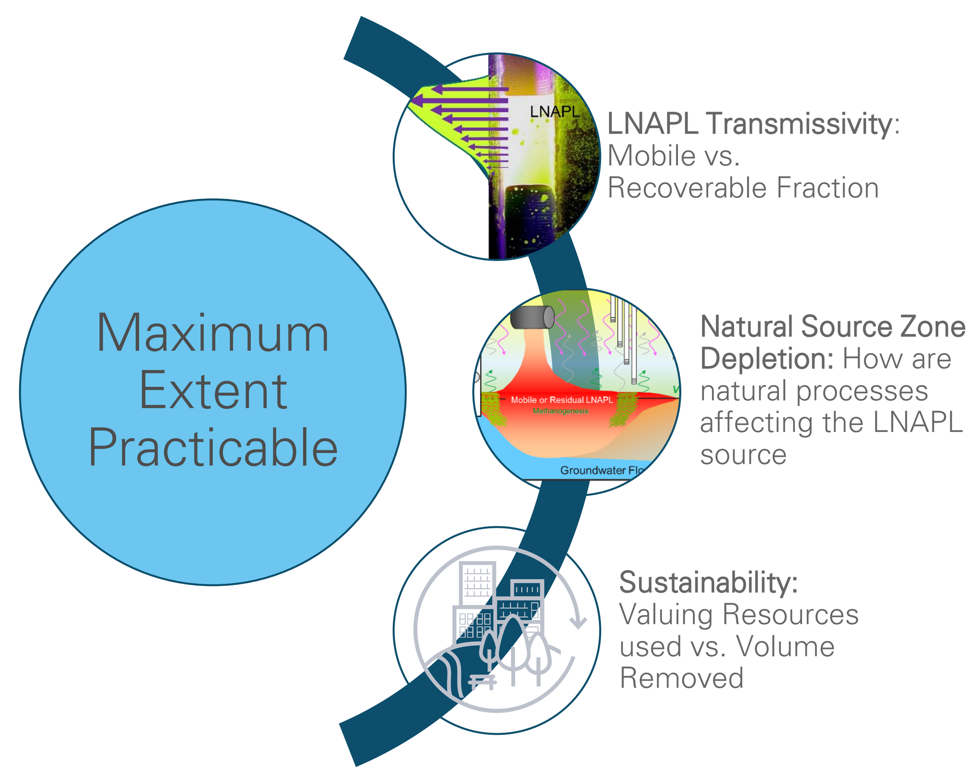
# Investigating Broadly Applicable Transition Points to Support Sustainable Remediation

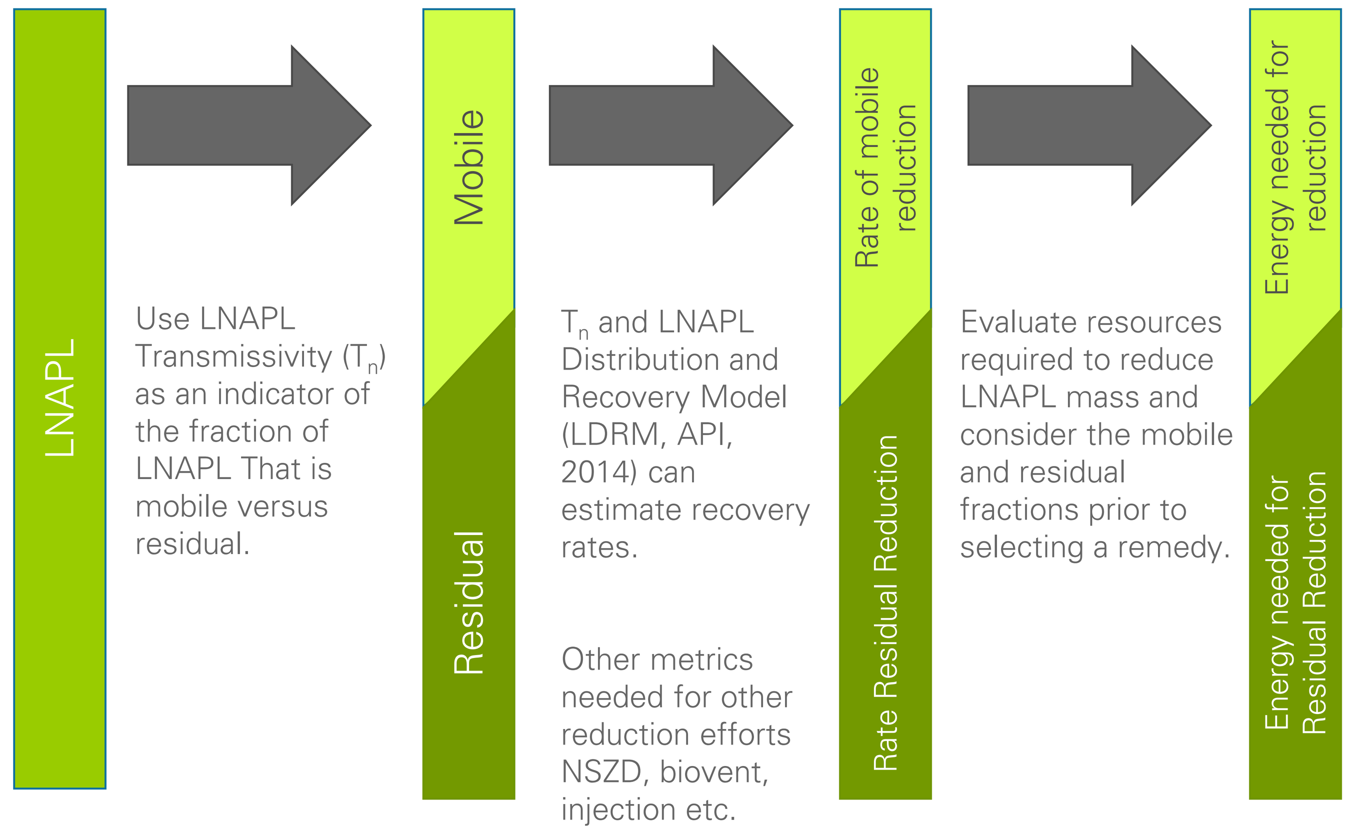
Andrew Kirkman (BP, Naperville, IL), Steven Gaito (AECOM, Providence, RI), Brad Koons (AECOM, Minneapolis, MN), Jonathon Smith (AECOM, Southfield, MI)

## Using 2022 Knowledge to define Maximum Extent Practicable

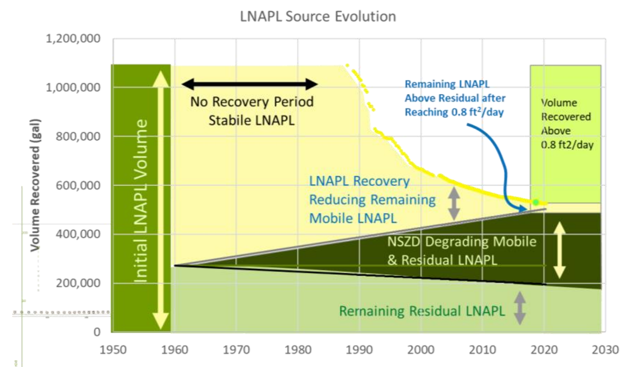



Federal and state regulations state to recover LNAPL to the maximum extent practicable (MEP), with the primary objective of limiting LNAPL migration. Hydraulic recovery is an effective remedial technology to reduce the LNAPL saturation and reduce potential for migration. Hydraulic recovery will have limited benefit to composition concerns, dissolved- or vapor-phase plumes.

LNAPL is present in monitoring wells at your site, and you are required to recover LNAPL to the maximum extent practicable. Where do you start? Hydraulic recovery? Where are you in the LNAPL lifecycle? Hydraulic recovery is an effective tool early in the LNAPL lifecycle when the majority of LNAPL is mobile and recoverable. As LNAPL sites age, natural processes deplete the LNAPL mass resulting in a larger fraction of the LNAPL mass in a residual state and reducing the effectiveness of hydraulic recovery. LNAPL transmissivity ($T_n$) can identify when the majority of LNAPL is mobile.




## Case Study




LNAPL transmissivity indicates when hydraulic recovery of LNAPL is effective, i.e., Tn below 0.8 ft2/day indicated the majority of LNAPL is at residual saturation and additional hydraulic recovery will provide negligible benefit.

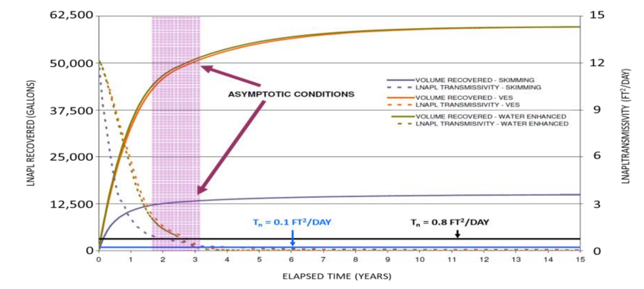
The LNAPL lifecycle concept can be incorporated to understand where the site exists in the spectrum of recoverable vs. residual LNAPL. The example to the right shows how LNAPL recovery progressed the site to the point where Tn is at or below 0.8 ft2/day and the majority of LNAPL is at residual saturation. If additional remediation is necessary, a different technology should be selected.

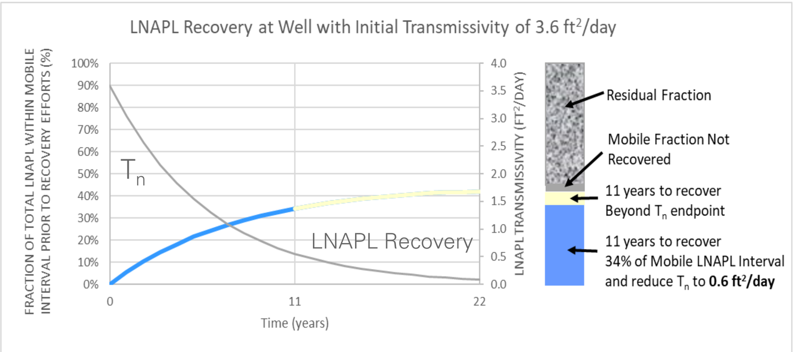
ITRC, 2018

## LNAPL Transmissivity Indicates Mobile vs. Residual

### Asymptotic Recovery

- The plot to the left shows modeled LNAPL recovery for three different LNAPL recovery methods, skimming, vacuum enhanced skimming (VES), and water enhanced LNAPL recovery.
- The LNAPL transmissivity was indicative of asymptotic recovery regardless of the LNAPL recovery method



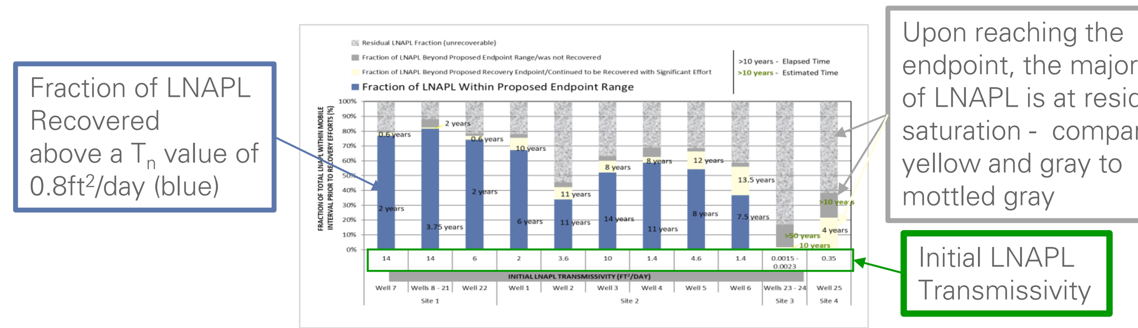




### Fraction of LNAPL Recovered

- The residual LNAPL fraction was estimated from soil core analyses from the mobile LNAPL interval and/or model calibration to field data
- The fraction of LNAPL recovered was plotted and compared to the fraction not recovered and the residual fraction
- LNAPL transmissivity calculated from recovery tracking data.

### LNAPL Recovery

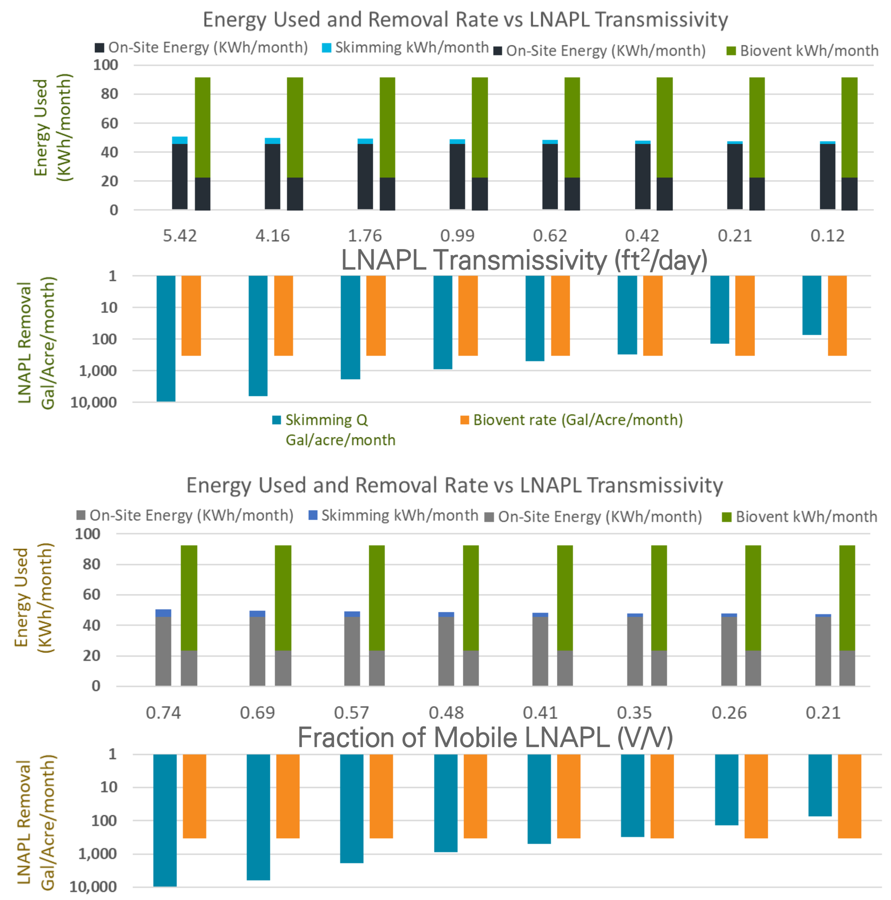
- Analysis was repeated at a number of sites with various initial $T_n$
- LNAPL recovery rates diminish with time, $T_n$ is a predictor of asymptotic recovery
- Once $T_n$ is below 0.8 the majority of LNAPL is at residual saturation
- Limited benefit to additional recovery compared to remaining NAPL in formation




ITRC, 2018

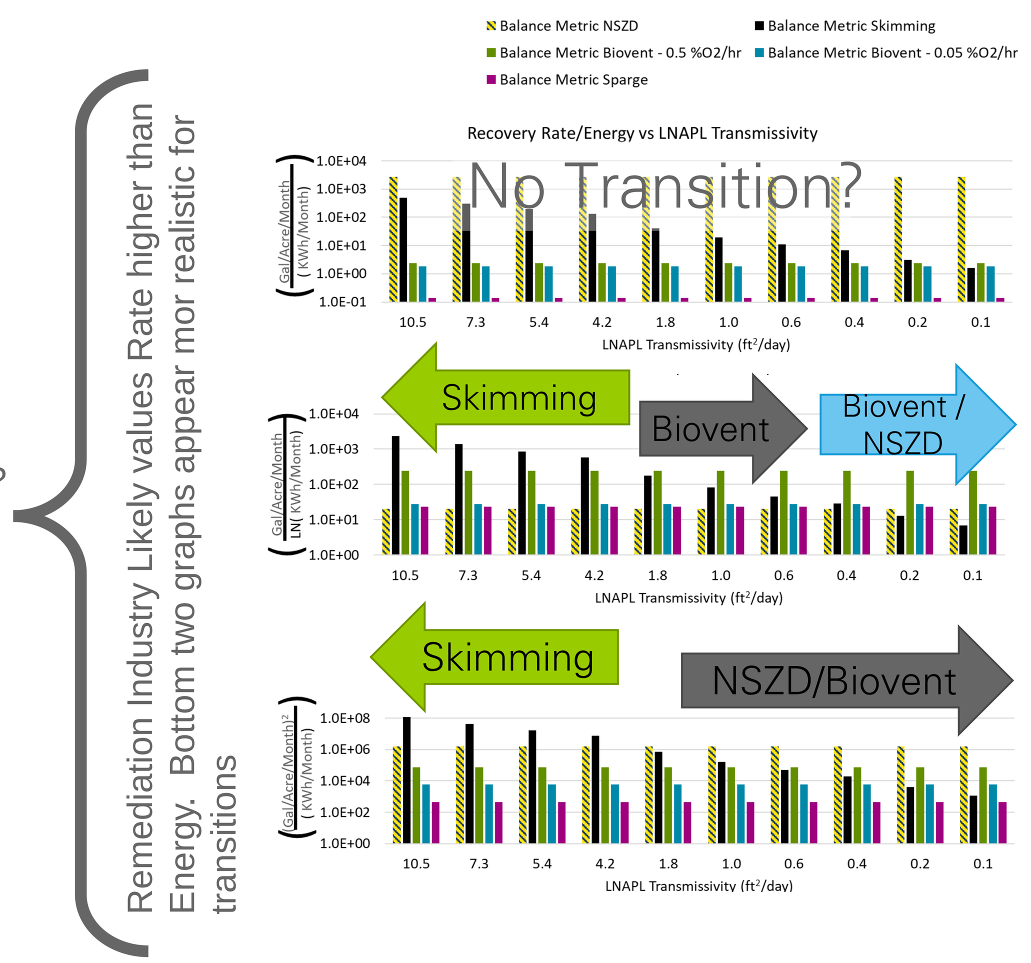
## Sustainability: Valuing Resources Used vs. Volume Removed

Sustainability is a growing consideration in remedial decisions - how should sustainability be incorporated? Select the technologies that can meet objectives, then consider sustainability? Should the rate of CO2 emissions be a consideration of the remedial technology? The charts below show how the prioritization of pace of remediation or energy use prioritizes rate of removal affects the remedial decision making.




How is energy use versus time evaluated, are they equal parameters, does the pace of remediation outweigh energy usage?

Perhaps Time or rate of remediation is higher value when risk exists and lower value when there is no risk to receptors




## Conclusions

Hydraulic LNAPL recovery is an effective technology, but as LNAPL transmissivity approaches 0.8 ft²/day, the majority of the LNAPL is at residual saturation. Current practices often require LNAPL recovery beyond the physical limitations of hydraulic recovery, resulting in either continued operations of asymptotic systems or initiation of hydraulic recovery at sites where the majority of LNAPL is at residual saturation. Identifying where the site is along the LNAPL lifecycle and balancing resources versus mass reduction can lead to implementation of appropriate remedial technologies to meet the objective of maximum extent practicable.

## References

API. 2001. Methods for Determining Inputs to Environmental Petroleum Hydrocarbon Mobility and Recovery Models. Regulatory and Scientific Affairs. API Publication Number 4711. July 2001.

API, 2014. LNAPL Distribution and Recovery Model (LDRM2). Regulatory and Scientific Affairs. Release Version 2. January 2014.

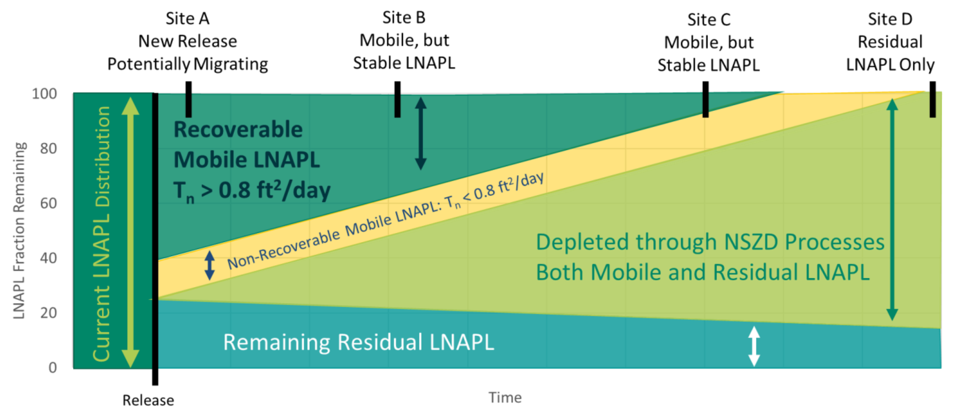
ASTM. 2016. LNAPL Transmissivity ASTM Training Course – LNAPL Transmissivity Application Section 2. ASTM. 2016.

ITRC. 2009. Evaluating Natural Source Zone Depletion at Sites with LNAPL. LNAPL-1. Washington, D.C.: ITRC, LNAPLs Team. www.itrcweb.org.

ITRC. 2018. LNAPL Site Management: LCSM Evolution, Decision Process, and Remedial Technologies. LNAPL-3. Washington, D.C.: ITRC. LNAPL Update Team. https://lnapl-3.itrcweb.org.

ITRC. 2021. Connecting the Science to Managing Sites, Part 2: LNAPL Conceptual Site Models and the LANPL Decision Process. Washington, D.C.: ITRC, LNAPL Update Team. www.itrcweb.org.

## LNAPL Lifecycle and Natural Processes




Conceptualization of the LNAPL lifecycle plotted as the fraction of LNAPL on the y-axis that is recoverable ($T_n$ greater than 0.8 ft²/day, non-recoverable ($T_n$ greater than 0.8 ft²/day), depleted by NSZD processes, and remaining residual LNAPL over time. Over the LNAPL lifecycle NSZD processes deplete LNAPL and the recoverable and residual LNAPL fractions are reduced.

Immediately after a release, Site A, the majority of LNAPL is recoverable and potentially migrating. The fraction of recoverable LNAPL is much larger than the residual fraction and LNAPL recovery is highly effective.

Sometime after a release, mobile LNAPL is present, but the LNAPL body is stable. The recoverable fraction varies depending on the age of the plume, size of the release, LNAPL and soil type, LNAPL distribution, and NSZD processes. In the two examples on the right, the Recoverable fraction at Site B is approximately 50% of the remaining LNAPL, while at Site C, only 15% is recoverable. Quantifying the LNAPL transmissivity would support remedial decision making.

At Site D, the majority of the LNAPL has been depleted, through natural processes or remedial efforts, if conducted, and exists in a residual state. This residual LNAPL can source a dissolved- or vapor-phase plumes and composition change remedial technologies are necessary to reduce concerns associated with the remaining LNAPL.

While Tn may be greater than 0.8 ft²/day at Sites B and C, hydraulic recovery may not be the most effective technology to achieve remedial objectives, a comparison of hydraulic recovery vs. the effectiveness of other technologies combined with an evaluation of resources required is recommended to achieve an objective of maximum extent practicable.