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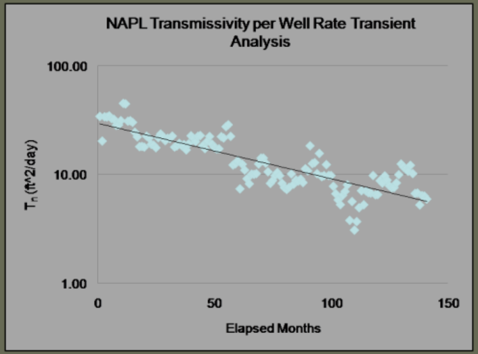
Mike Hawthorne has been working in the environmental industry for 25 years. His experience covers a diverse array of technical, regulatory and industrial sectors, with a strong background in the oil and gas industry. He is proud to be a Texan, and grateful to have had the opportunity to work across much of the United States over his career.

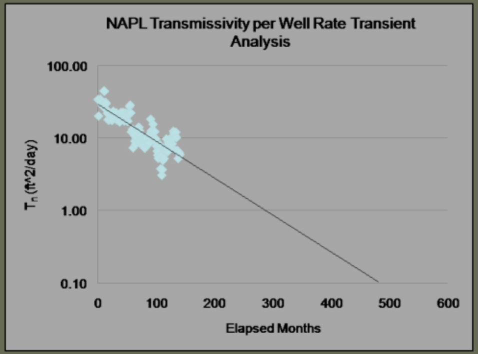
Mike is active in ASTM International, Inc., most recently participating in the development of the standard guide for calculation of LNAPL transmissivity, and currently helping to write the updated guide to development of LNAPL Conceptual Site Models. In addition, he assisted with development of the TCEQ TRRP 32 NAPL Management guidance, and worked on the (unpublished) TRRP-12A guidance team. Mike has also lead or participated in numerous advocacy and training efforts with Federal and State regulatory agencies. He is also an author with numerous published technical articles in geology and NAPL conceptual site modeling.

Mike is a frequent speaker at national and state level conferences, public and private webinars, and national/international webinars. In the last three years he has been a speaker at the Texas Commission on Environmental Quality Trade Fair, the Battelle Conference on Chlorinated / Organic Compounds (twice), the AEHS East and West Coast Conferences, and is a four time NGWA Webinar Presenter. He has given multiple presentations to USEPA Region 5 and Region 6, webinars to the Missouri Department of Environmental Quality, served as Session Chair and Presenter at the IPEC Environmental Conference, and given many private presentations.

In 2011 Mike founded Applied NAPL Science Review, a technical ejournal dedicated to demystifying NAPL science by publishing short articles in plain English on current NAPL science topics and tools that can be readily applied. In only two years ANSR has grown substantially with readers in over 80 countries and all 50 United States. ANSR is blessed to have the guidance of a highly experienced Technical Review Board with members from the University of Texas, United States Environmental Protection Agency, Los Angeles Regional Water Quality Control Board, BP, Chevron, ExxonMobil, Shell, and private consulting firms.

In his spare time Mike is an avid reader, a target shooter and bird hunter, a long-time basketball coach, and rides his Ducati motorcycle through the Texas countryside when he can get away. Spring and early summer always find him working with his wife Kay on their lawn and gardens, with help from their two boys, three dogs, two cats, three ferrets, and lizard.





Applying LNAPL Transmissivity at Texas Refineries to Improve LNAPL Management Under TRRP-32

Texas Association of Environmental Professionals
May 16, 2013
Houston, Texas

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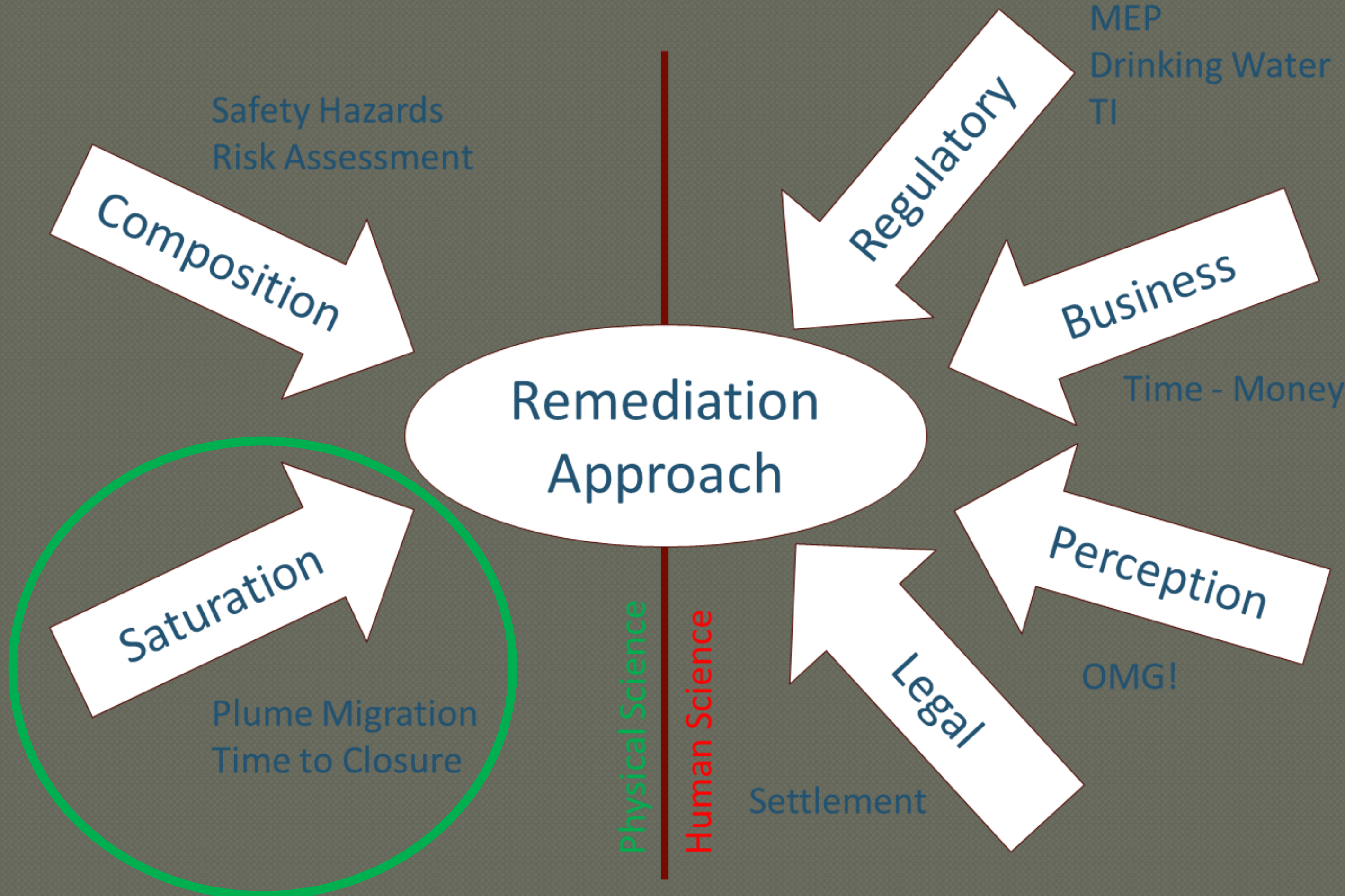
Drivers and Metrics

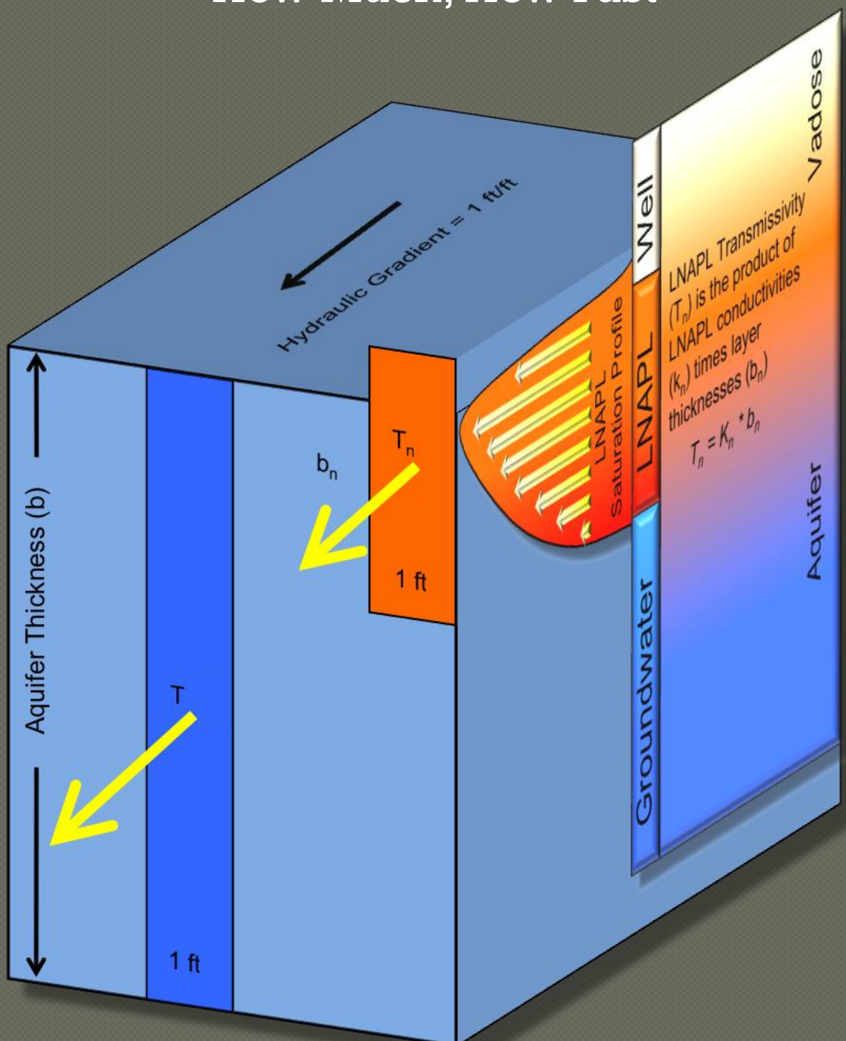
LNAPL Remediation Drivers



LNAPL Transmissivity

Groundwater vs. LNAPL Transmissivity

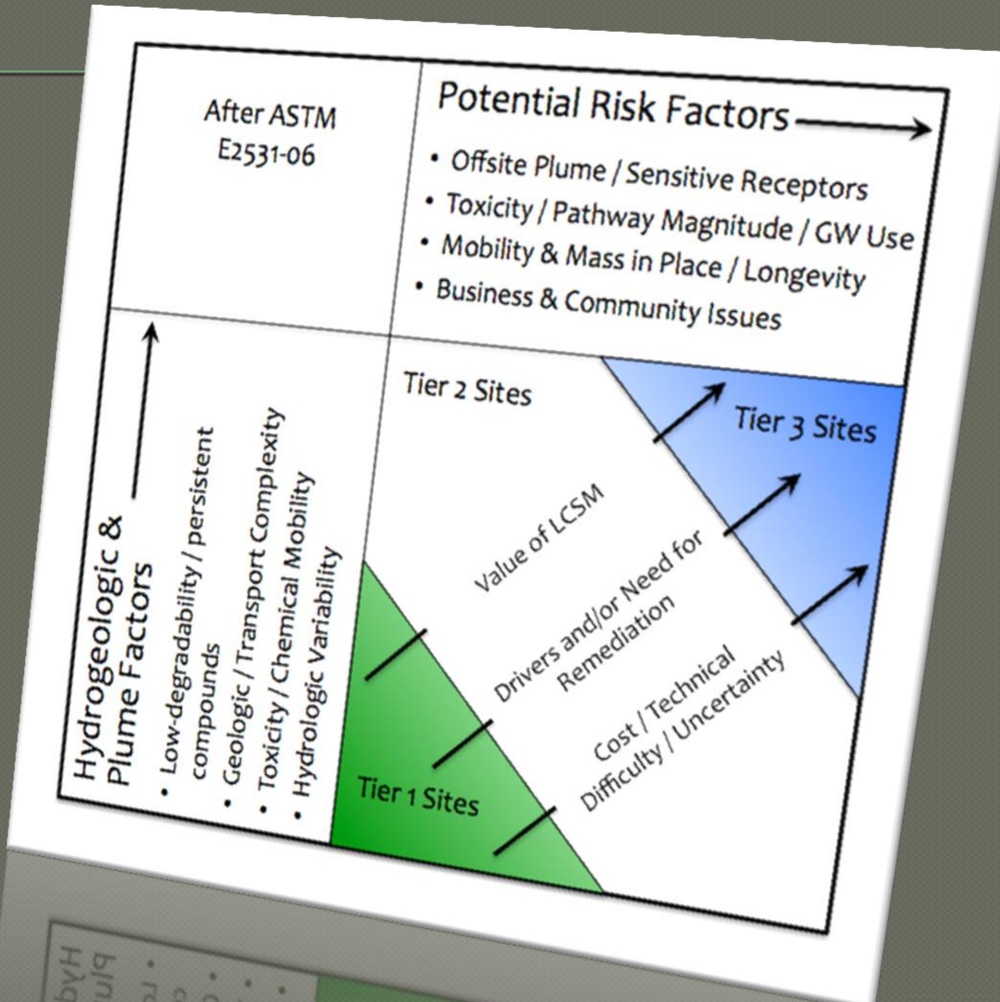
"How Much, How Fast"



T_n Advantages
• Direct numeric measure of hydraulic recoverability
• Varies directly with LNAPL saturation / mass
• Normalizes all sites to a single measurement standard
• Multiple measurements methods
• Measurable prior to, during, and after remediation

Limitations / Considerations

- LCSM Critical
- Regulatory Acceptance
- Threshold Values Evolving
- T_n applies only to hydraulic removal of LNAPL to the extent practical
- T_n does NOT address dissolved or vapor phase risk-based drivers
- T_n measures recoverable, not residual or total LNAPL, and therefore measures progress towards $soil_{res}$



How is LNAPL Transmissivity Used?

Application	Direct	Indirect
Leading Metric (>0.8 ft^2/d) – START hydraulic recovery	X	
Progress Metric for Hydraulic Recovery – EVALUATE progress	X	
Lagging Metric (<0.1 to 0.8 ft^2/d) – STOP hydraulic recovery	X	
Recovery Optimization Metric – OPTIMIZE recovery	X	
DESIGN – Equipment Sizing (calculate recovery by technology)		X
CALIBRATE Multiphase Models (e.g., LDRM)		X
ASSESS RISK – Migration Potential		X

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TRRP-32: Risk-Based Management of NAPL

TRRP-32 Process (Table 3 Excerpt)

	STEP
STEP 1	Conduct NAPL Assessment
STEP 2	Identify NAPL Response Triggers
STEP 3	Determine NAPL Response Objectives and Endpoints
STEP 4	Develop NAPL Management Strategy
STEP 5	Implement NAPL Management Strategy and Evaluate NAPL Response Effectiveness

LNAPL Transmissivity and TRRP-32

TRRP-32 NAPL Management
T_n Application

Endpoints (TRRP-32)	Migrating NAPL Zone Trigger	Recovery Only	• T_n time-series analysis
		Control (via TI)	• Model Calibration Parameter • Hydraulic Recoverability Metric
		Recovery	• T_n time-series analysis
	NAPL Contact w/ GW Zone Trigger	Recovery Only	• Design Parameter • "Readily Recoverable" Metric
Design	• Technology Selection Based on Hydraulic Recoverability of LNAPL • Model Calibration Parameter to Generate LNAPL Production Curves • Equipment Sizing, Volumetric Waste Mgmt. Plans • Fixed Base / Mobile Infrastructure Cost-Benefit Analysis		
Performance Evaluation	• Operational Performance Metric • Model Calibration Parameter • Hydraulic Recoverability Metric		

Conventional vs. Alt. Technologies

Tier 1 Approach (T_n is Tier 2/3)

Potential for NAPL Recovery by Conventional Technologies

1. by SOIL TYPE

Clay - Silt	Silt - Sand	Sand - Gravel	SCORE
-1	0	+1	

2. by MAX TRUE NAPL THICKNESS

< 2 in	2 in - 12 in	> 12 in	+
-1	0	+1	

3. by NAPL VISCOSITY

HIGH (mixed-phase DNAPL PCBs, coal tar)	MEDIUM (heavy refined petroleum (e.g., no. 6 fuel oil)	LOW (light refined petroleum (e.g., gasoline)	+
-1	0	+1	

4. by NAPL OCCURRENCE

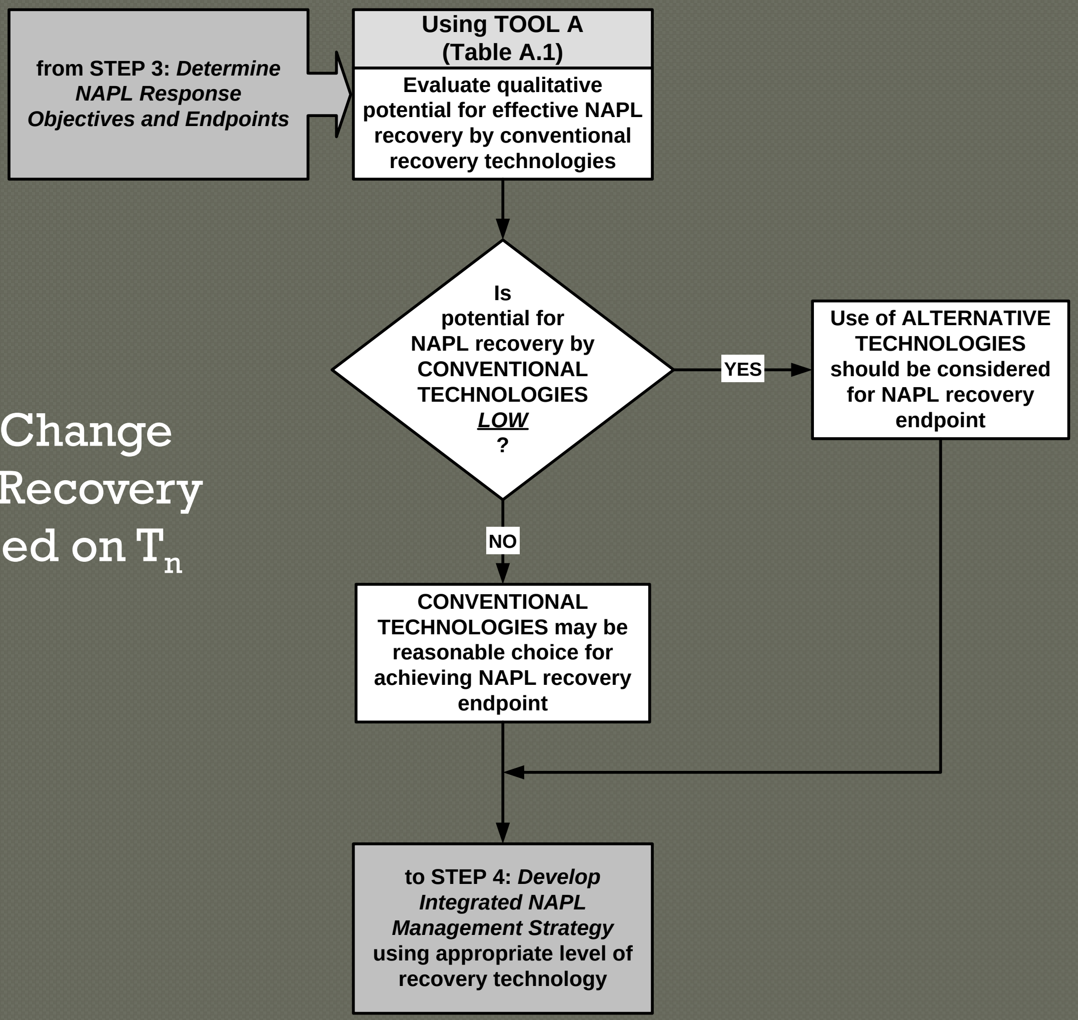
LOW (in saturated zone with double porosity)	MEDIUM (in other saturated zone)	HIGH (in coarse-grained capillary fringe)	+
-1	0	+1	

Potential for NAPL Recovery by Conventional Technology	TOTAL SCORE
HIGH: recovery likely	+2 to +4
MODERATE: recovery possible	-1 to +1
LOW: consider alternative tech	-4 to -2

⇦ TOTAL SCORE

Conventional vs. Alt. Technologies

Decision Pt. for Change from Hydraulic Recovery Technology Based on T_n



Remediation Design and T_n

- Direct Measure of Hydraulic Recoverability
  - Hydraulic vs. Pneumatic vs. Alternative Technology Selection
  - Defines the design zone of effective hydraulic recovery
- Modeled LNAPL Recovery Technologies
  - Calibrated to Readily Obtained Site Wide T_n Values
  - Technology-Specific Production Curves
  - Sustainability
  - Predicted Decline Curve Analysis for Rate and Total Volume Data
  - Relative Technology Performance Data – Technology Selection
- Design Cost-Benefit Analysis
  - Projected Operational Lifetime
  - Capital vs. Mobile Infrastructure
- Design Considerations
  - Technology specific equations with T_n as input
  - Equipment Sizing
  - Waste Mgmt / Recycling Volumes

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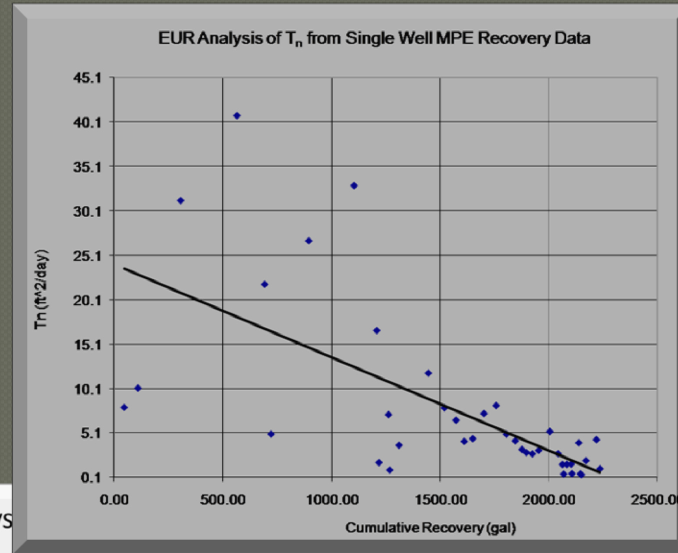
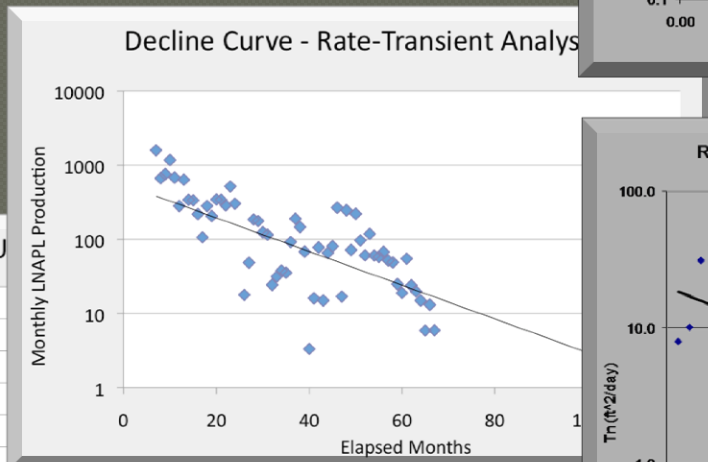
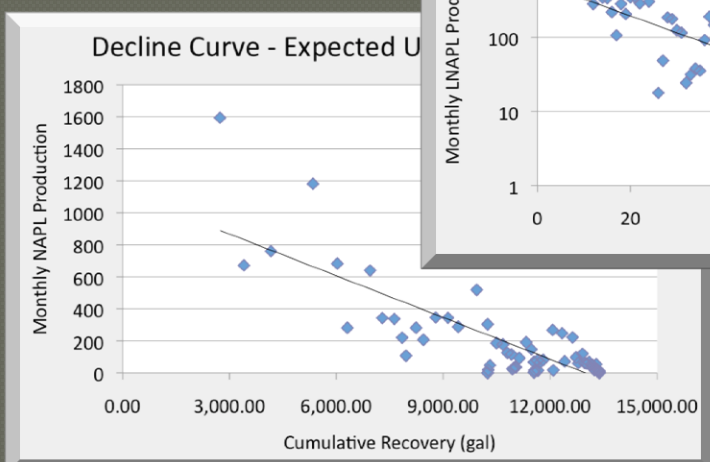
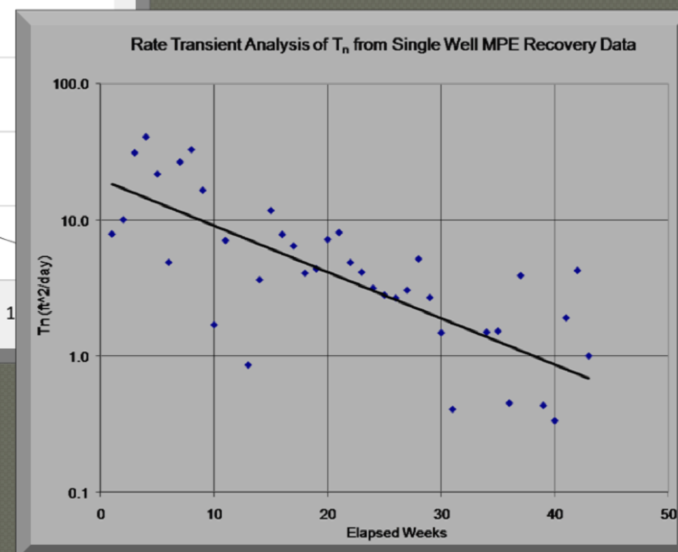
Operational Performance Metric

- Single or Multiple Well Recovery Data Analysis During System Operation to Monitor T_n Progress
- Combine with EUR and Rate-Transient Decline Curve Analysis to Evaluate Progress Towards Hydraulic Recovery Endpoint









Strategic Use of LNAPL Transmissivity at Texas Refineries

Refinery A

- Leading Threshold Metric
  - LNAPL Transmissivity Action Levels
    - $T_n > 3$ ft²/d or High Risk: Fixed Base Recovery System
    - 1 ft²/d $< T_n < 3$ ft²/d: Episodic Removal
    - $T_n < 1$ ft²/d: Evaluate / Monitor Stability

Refinery B

- LNAPL within Facility Operations Area (FOA)
  - Migration Control
  - Progress Metric – Decline Curves for Active Recovery
  - Migration Risk Evaluation Metric T_n <0.8 ft^2/d
- LNAPL outside FOA
  - TRRP-32
  - Multiple Plume Management Zones (PMZ)
  - Leading Metric T_n >0.8 ft^2/d
  - Readily Recoverable NAPL Metric

International Airport: Hydrant System

- Jet Fuel – No Dissolved-phase PCLE
- Native Clay – Fuel Occurs in Fuel Line Backfill
- Current Use:
  - Leading / Lagging metric to start / stop hydraulic recovery (conservatively low 0.1 ft^2/d)
  - Migration risk potential metric
  - Progress metric for active recovery
- Proposed Use to Identify
  - Current / new releases
- Since No PCLE, if No PMZ then No Recovery Required
  - TRRP-32 Quirk

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Refinery C

- Large Scale Hydraulic Recovery System
- Progress Metric / Decline Curves of Annual T_n Values
  - Plume scale
  - Individual well scale
- Optimization Metric
  - LNAPL transmissivity calculated annually from recovery
  - Focus hydraulic recovery where effective
  - Demonstrate control
- "Truthing" Metric – T_n Maps Annually
  - Apparent NAPL thickness highly exaggerated – thickness maps misconstrue recoverability zones
  - LNAPL transmissivity accurately identifies recoverability zones

Refinery D

- Mature Hydraulic Recovery and Control System
  - Interception line of recovery wells to remain operational immediately adjacent to surface water
  - NAPL and dissolved plumes stable so all other wells evaluated for shutdown using LNAPL transmissivity
- SCOR™ Program Based on T_n
  - Combination of annual recovery based T_n and short term test T_n (baildown, manual skimming, ratio tests)
  - Flowchart implementation – annual test of each well for T_n versus 0.8 and 0.1 ft^2/d thresholds
  - Each well must requalify each year to continue operation
  - Awaiting TCEQ approval

Refinery E

- Class 1 Drinking Water Aquifer with LNAPL
- Wells with 20+ feet of gauged LNAPL
- LNAPL Transmissivity Use:
  - Eliminate OMG factor
  - HSGs and DGPs to identify mobile NAPL interval
  - T_n via baildown, manual skimming or ratio tests
  - Provide a true recoverability metric instead of exaggerated thickness metric
  - Focus characterization and recovery ($$$$)
  - Eliminate over-regulation due to OMG factor

Refinery F

- Terminal Surrounded by Active Refineries
- >$1,000,000 Historical Remediation Efforts
- Used T_n to Identify Offsite Refinery Sources
- Implemented CPT/ROST Confirmation
- Created 3D Model to Demonstrate ALL NAPL ORIGINATED OFFSITE
- Closure Requested – Agency Pursuing 3rd Parties

Questions / Comments

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