# FIELD TESTING OF THE DYELIF™ HIGH-RESOLUTION CHLORINATED DNAPL LOGGING SYSTEM

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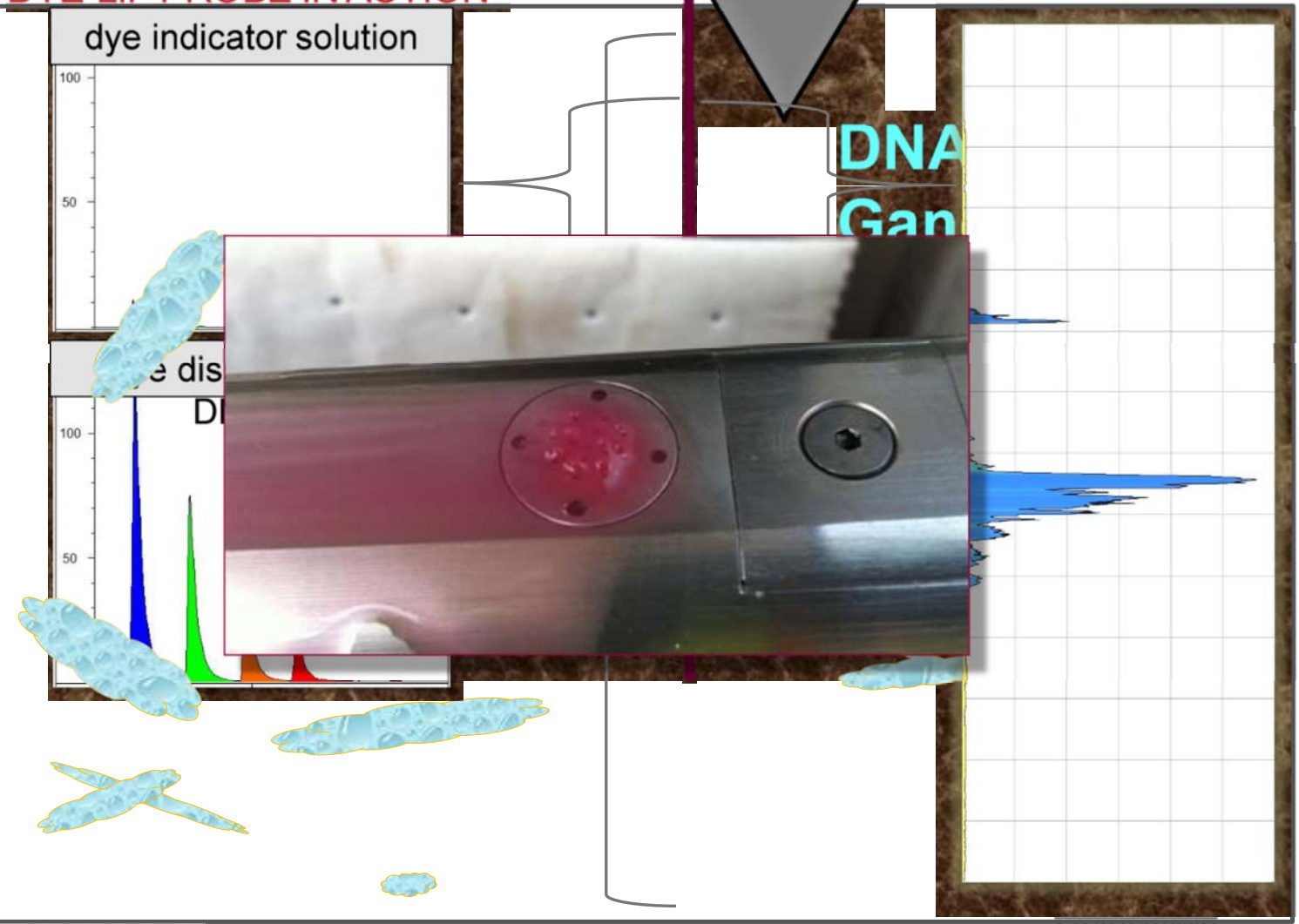
# BRIEF BACKGROUND

- laser-induced fluorescence (LIF) is a proven tool for delineating LNAPL, creosote, and coal tar, but does not respond to most chlorinated DNAPLs
- injecting an indicator dye ahead of the LIF window can "force" DNAPL ganglia exposed to the LIF probe to generate an LIF response
- DyeLIF™ uses an indicator dye – same concept as the Sudan IV or Oil Red O (ORO) dye "shake tests" used to determine absence/presence of DNAPL
- concept originally proposed by Dr. Stephen Lieberman et. al. at SPAWAR
- concept "reinvigorated" by Murray Einarson and Adrian Fure at AMEC Geomatrix (now with Haley & Aldrich)
- system development recently completed - with a capstone demonstration

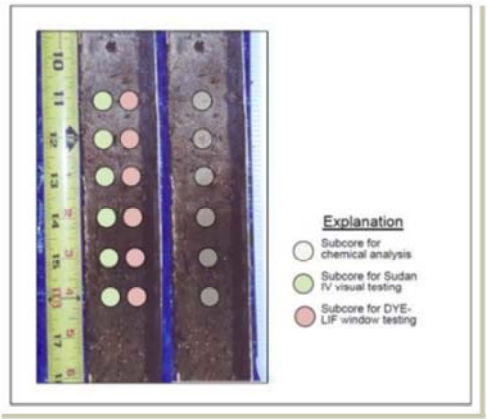
# DYE-LIF PROBE IN ACTION





# VALIDATION PLAN

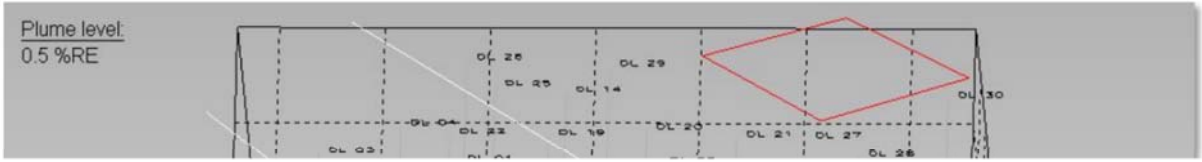
- located a site that had a confirmed DNAPL release (59% trichloroethylene, 34% 1,1,1-trichloroethane) - fine sand and silt with intermittent silt and clay layers and groundwater at ~20 ft bgs
- teamed with University of Guelph for validation process (expertise in high resolution sampling)
- planned DyeLIF deployment the first week, co-located sampling and analysis the second week
- validation sampling to be taken next to and across depths where DyeLIF logging had identified DNAPL the prior week
- planned to sub-sample cores at high density horizontals then analyze the samples with ORO, PID, lab analysis and bench-top DyeLIF

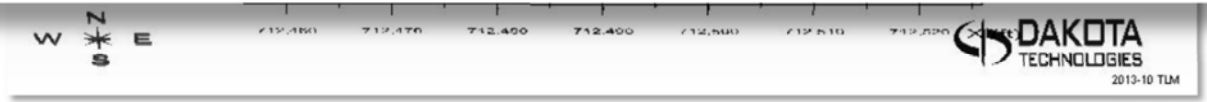

# ESTCP DEMONSTRATION PROJECT

## DYELIF LOGGING – WEEK ONE



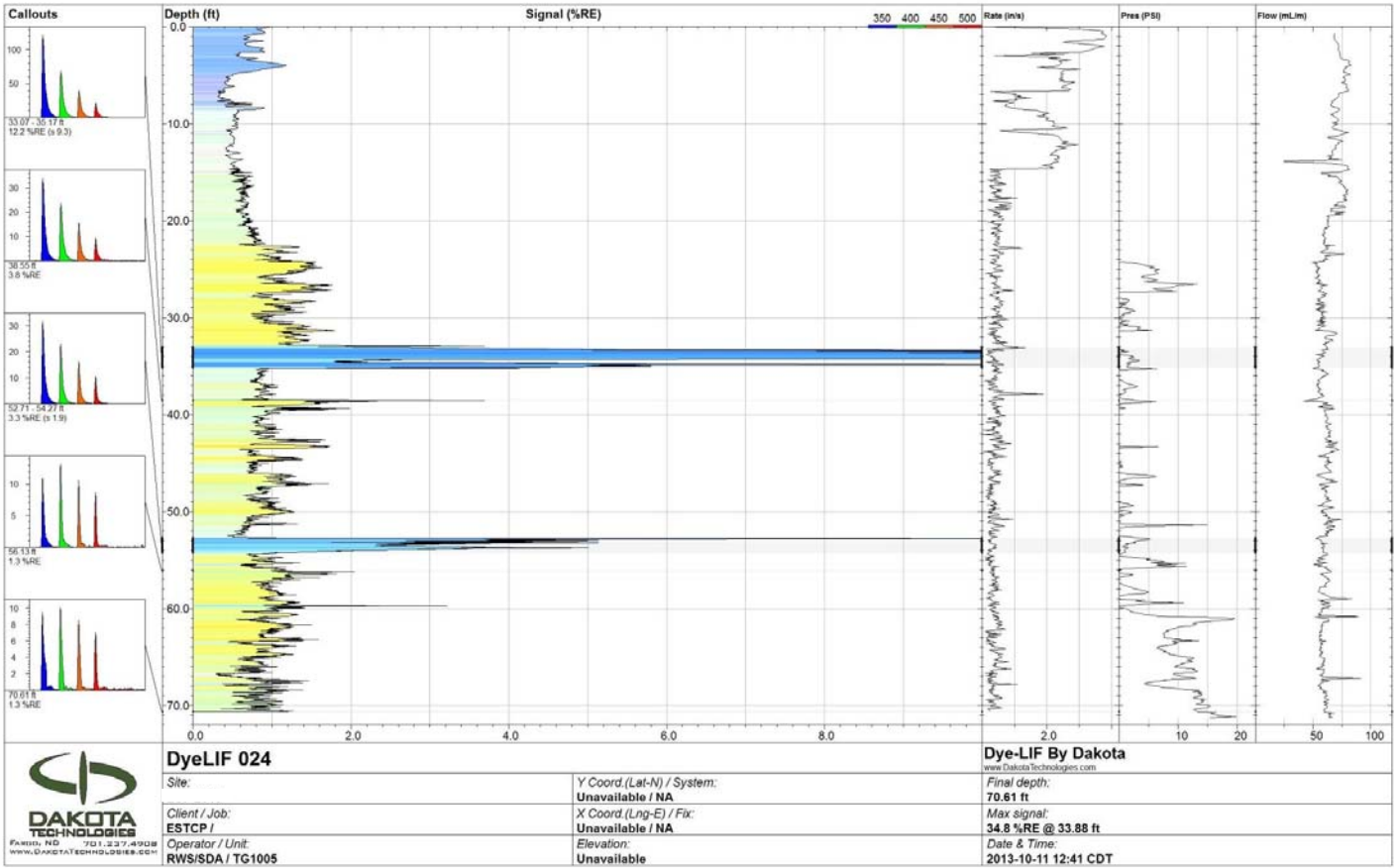



- conducted 25 DyeLIF locations to an average depth of 70 ft (21.3m)
- averaged 395 ft/day (<10 hour days)
- rate of penetration averaged 0.4 inch/second (1 cm/sec)
- 0.01 g/second dye solution delivery rate (equates to ~2-3 g per log)
- pushed majority of locations with a Geoprobe® 5400 – remainder with 7720
- no “downtime” - i.e. no damaged tooling with exception of one parabolic mirror adjustment during the week of DyeLIF probing
- successfully ‘bounded’ the DNAPL - with the exception of under a small building



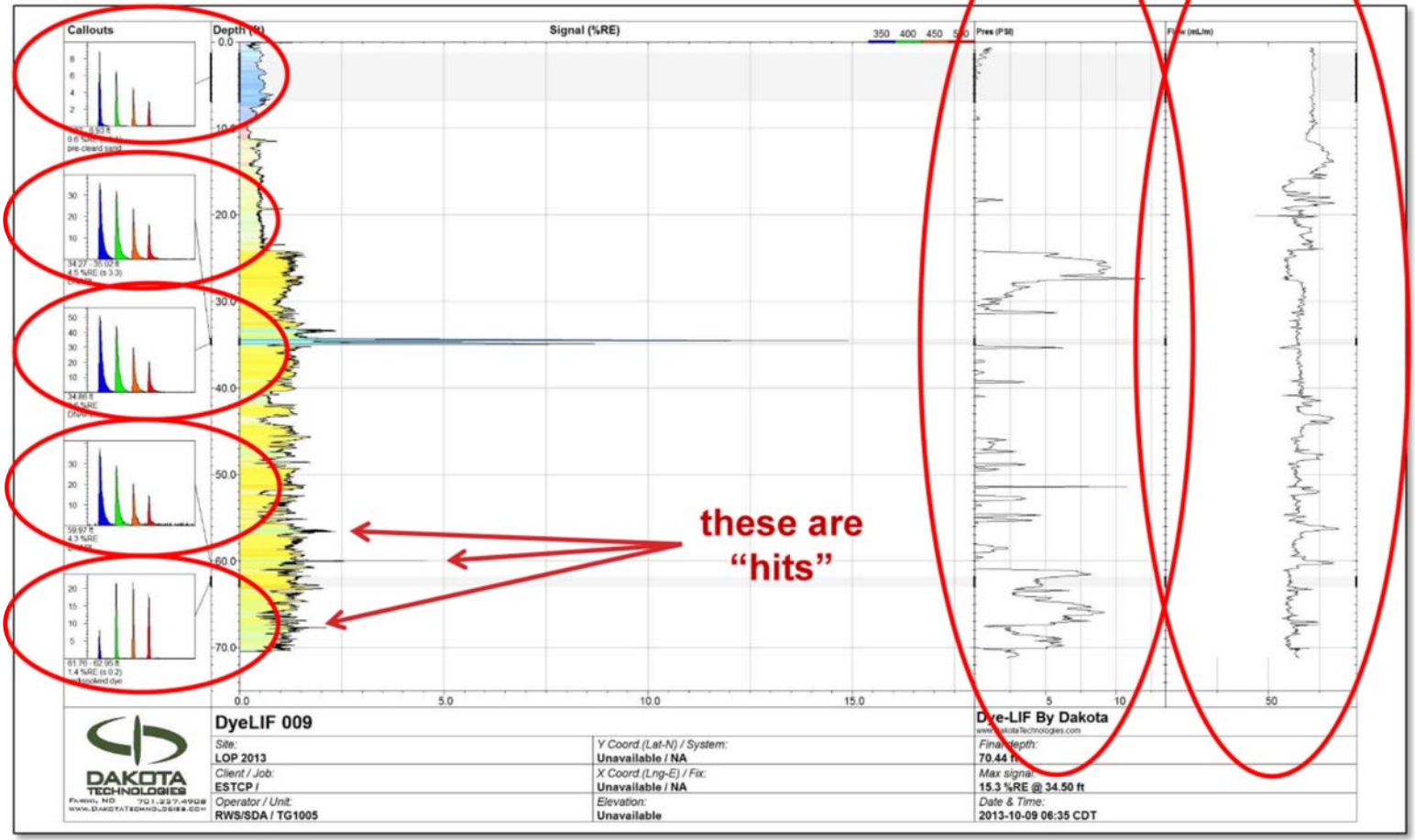
# EXAMPLE DYELIF LOGS

## DYELIF RESPONSE RANGED FROM NON-DETECTS TO MAJOR HORIZONS OF PERCHED DNAPL

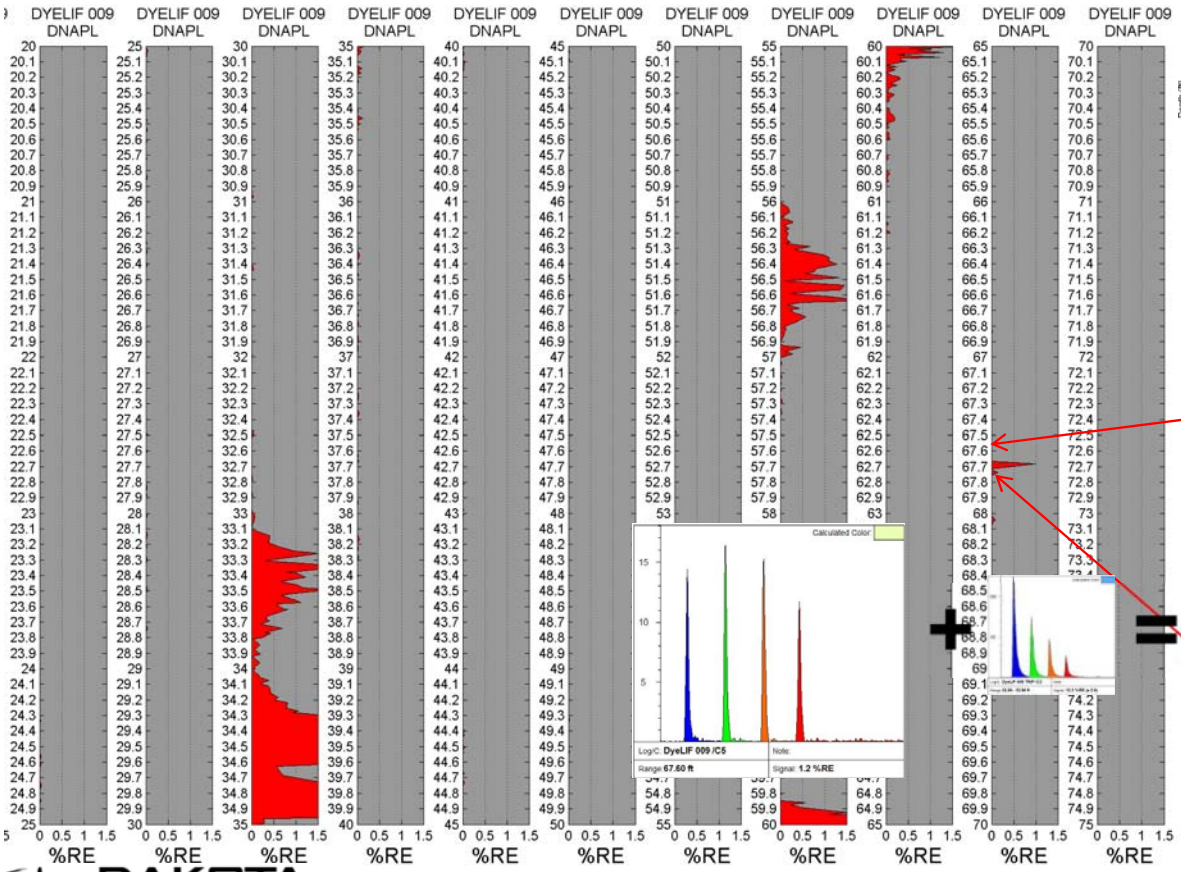


# EXAMPLE DYELIF LOG

## EXAMPLE WITH SMALL TO MEDIUM RESPONSES



# NON-NEGATIVE LEAST SQUARES POST-PROCESSING
# ON-SITE, 5 MINUTE PROCESS
# CRITICAL FOR ISOLATING SMALL "HITS" AT HIGH RESOLUTION (0.5 cm)



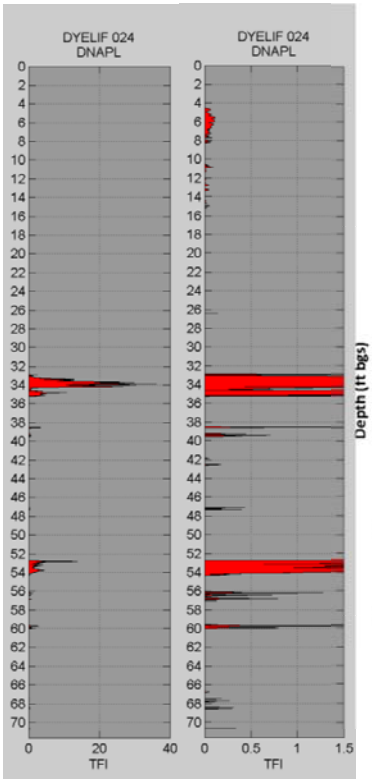
# ESTCP DEMONSTRATION PROJECT
## SAMPLING/SCREENING – WEEK TWO

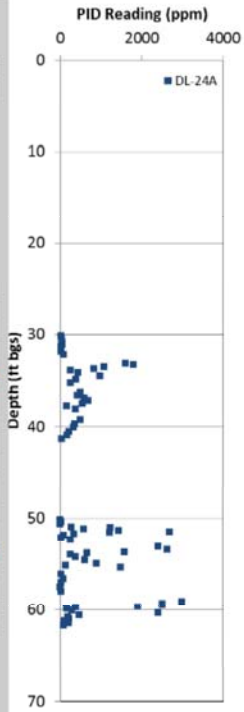


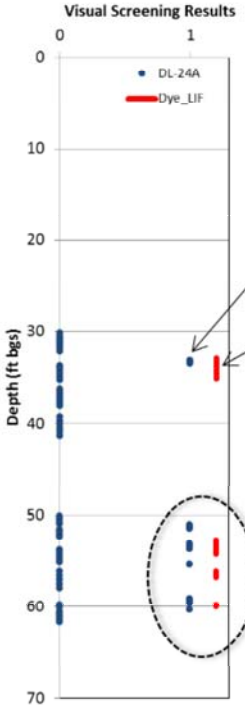
# ESTCP DEMONSTRATION PROJECT
## VALIDATION - WEEK TWO

- extremely challenging sampling conditions – even with an experienced team of high-resolution sampling experts with site-specific experience
- after trying numerous techniques arrived at Geoprobe MC7™ sampler with sealed piston adaptation to improve recovery
- after three days of technique refinement (and anguish), average recovery climbed to 65% (actually impressive in light of the difficult geology)
- lateral heterogeneity made stepping off the DyeLIF location <2 ft and encountering Dye-LIF-identified DNAPL a “hit/miss” affair
- persistence eventually yielded a sufficient number of cores –those were sampled to produce 260 depth-discrete sub-sample horizons
- PID, ORO visual, and DyeLIF were run on high-resolution sub-samples
- 50% of the sub-sampled horizons (133) were sent to lab for VOC analyses (based on what was observed with screening tools

# EXAMPLE - DYELIF & VALIDATION AT LOCATION #24



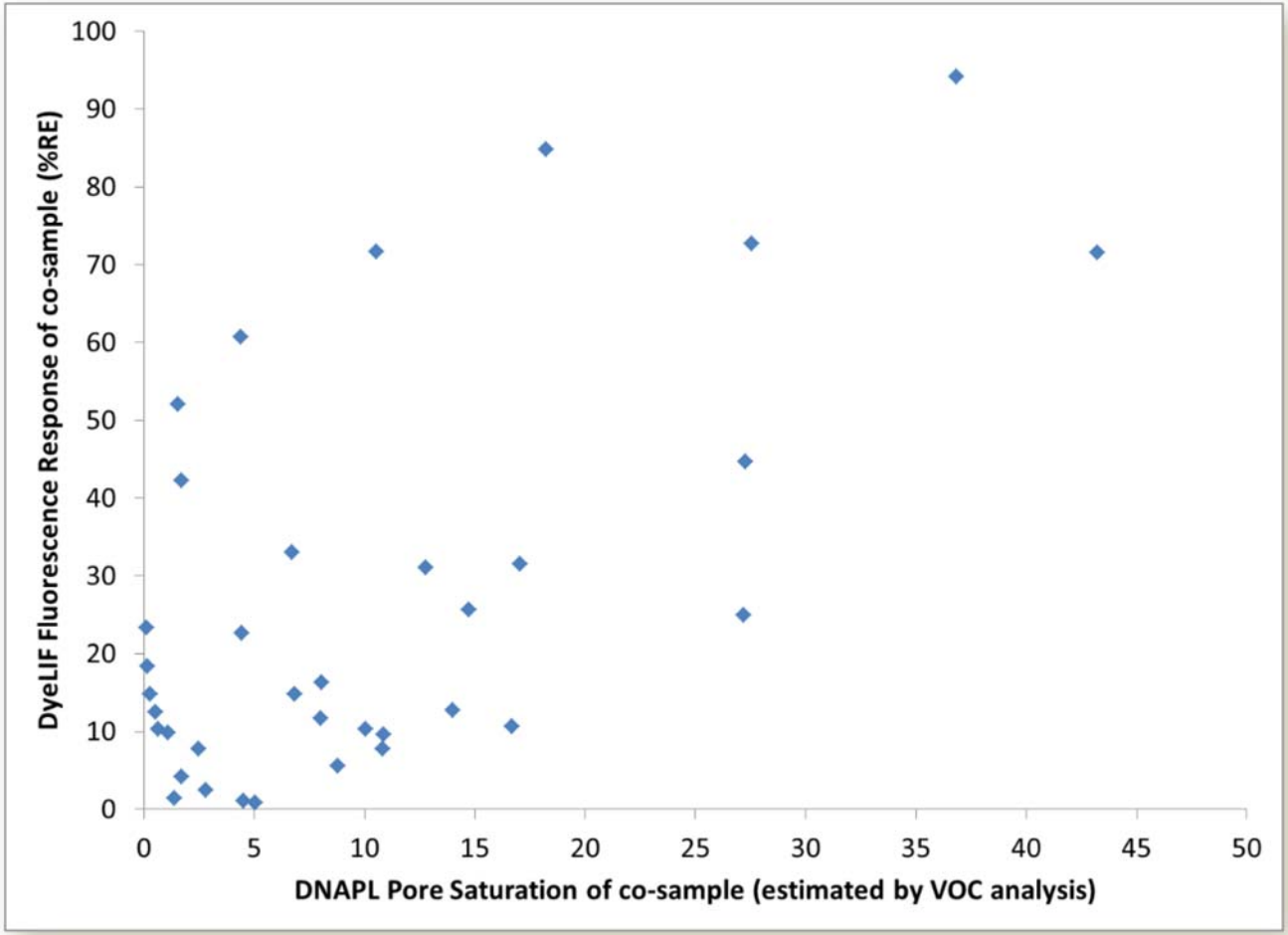




positive ID with DYE shake test

positive ID with DYE-LIF (adjacent log, sub-core data not fully processed yet

DYE-LIF is able to see thin lamina of DNAPL with NNLS processing; consistent with ORO dye test

# DYELIF BENCH TOP FLUORESCENCE VS. ESTIMATED DNAPL PORE SATURATION



# CORRELATION BETWEEN DYELIF & SAMPLING

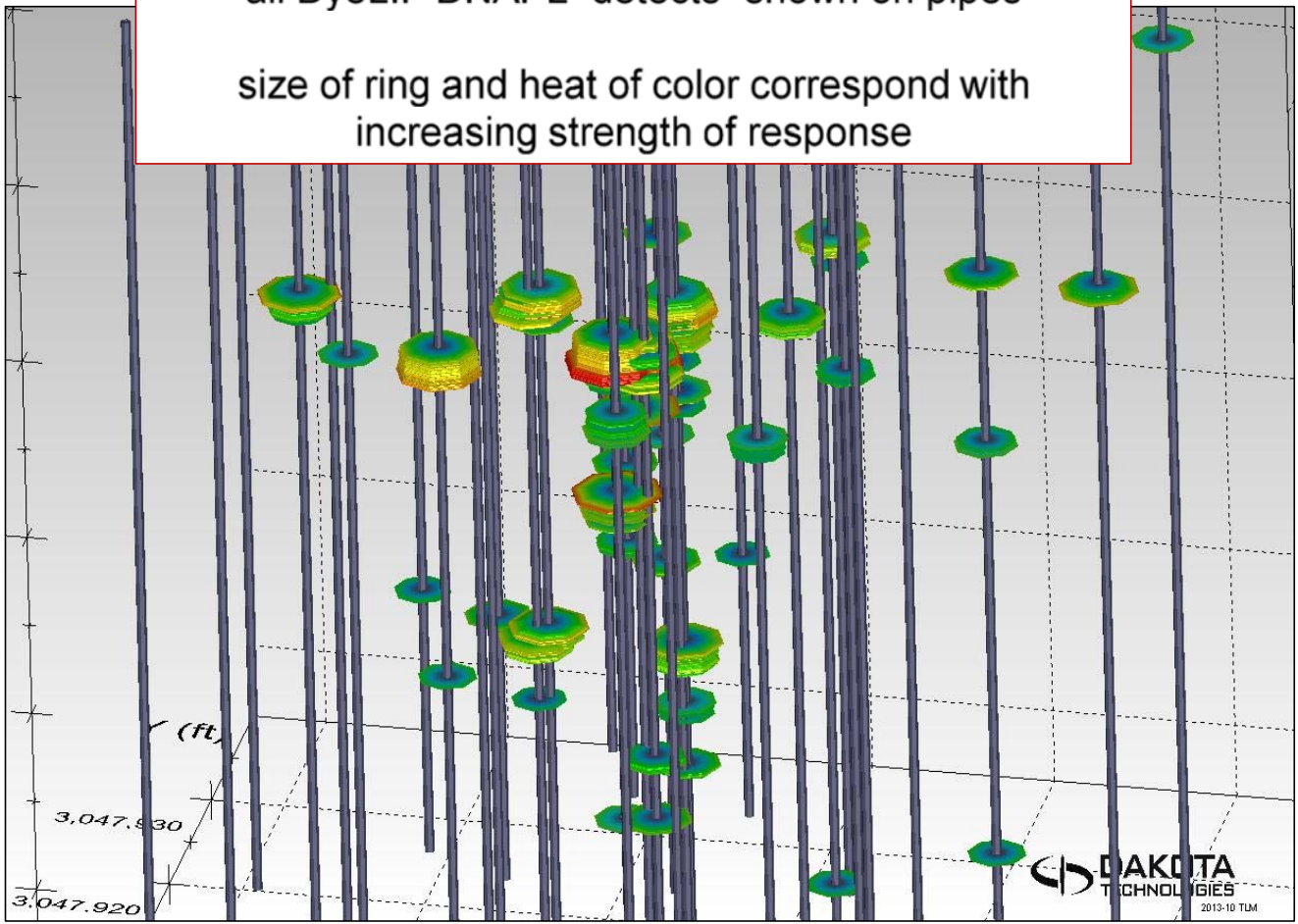

- generally eLIF logs (heteroge
- DyeLIF b O visual - this was l – not the technolog
- up-hole " eved excellent
  - 100% match for samples of > 2.5% pore saturation DNAPL
  - 98% match fo ation DNAPL
- while results not y detection limit of between 1.0% and L vary site-to-site with Lowell test site bei

# 3D VISUALIZATION



all DyeLIF DNAPL "detects" shown on pipes

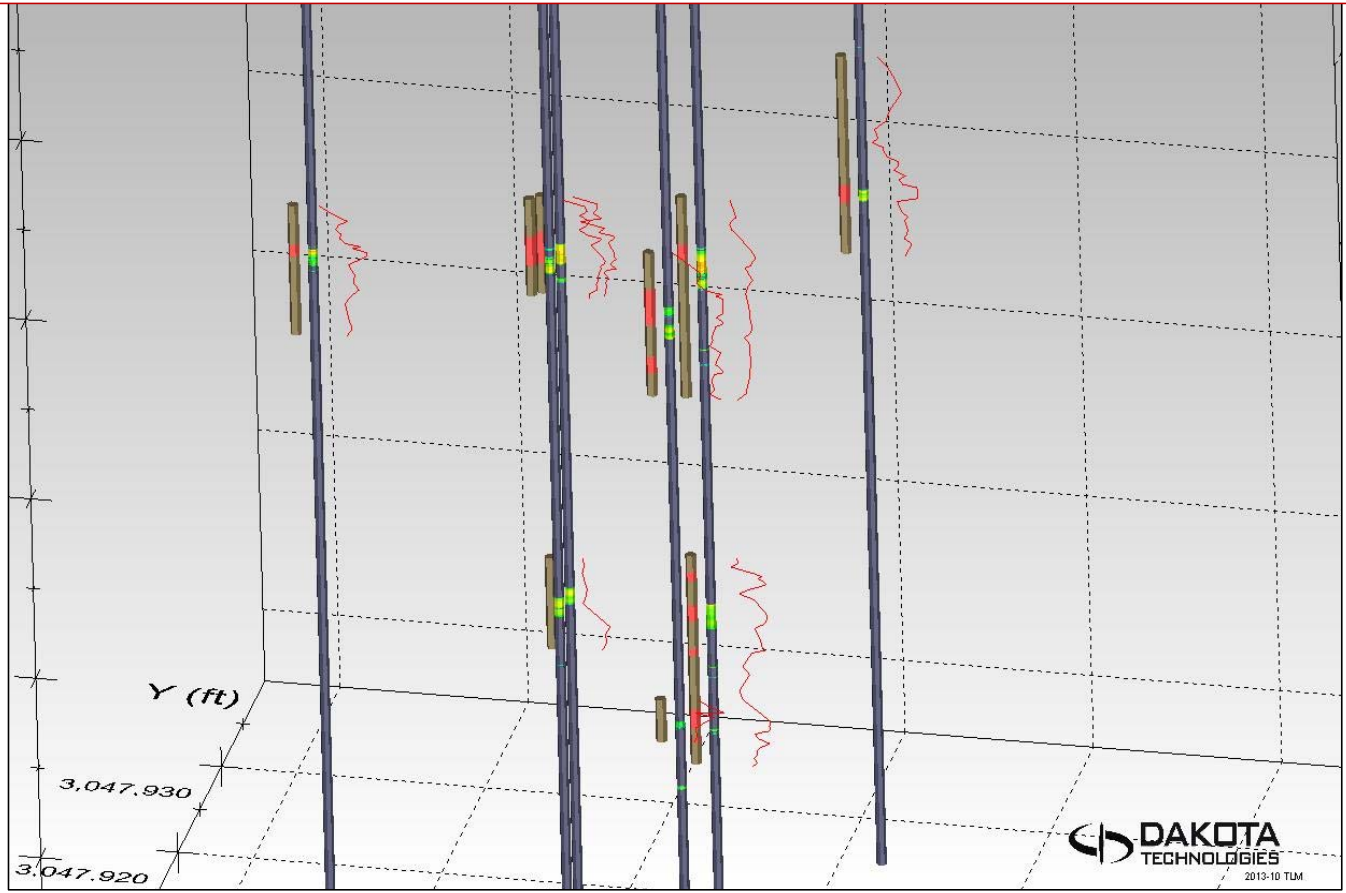
size of ring and heat of color correspond with increasing strength of response



# 3D VISUALIZATION



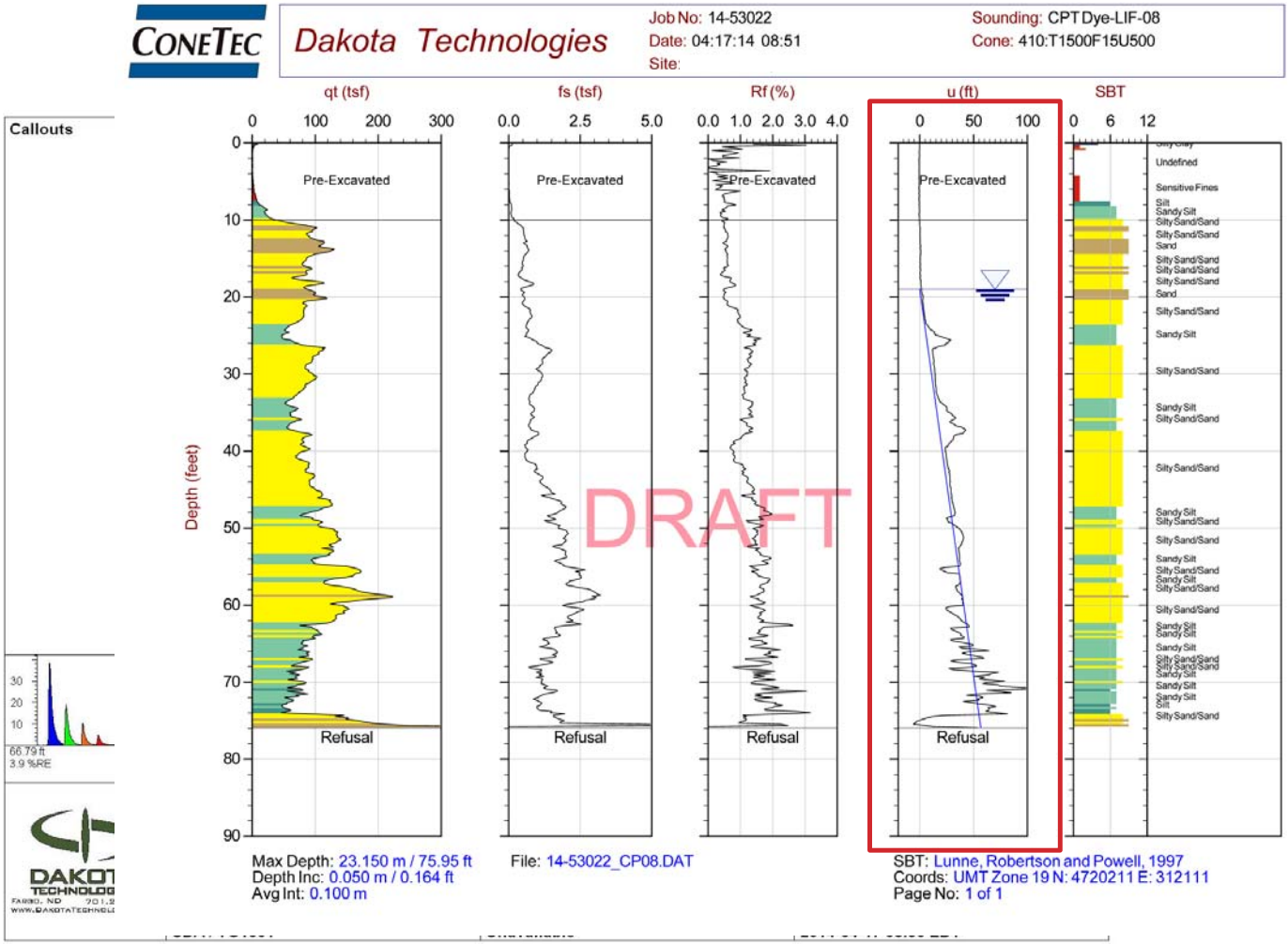
all DyeLIF DNAPL 'detects' with core screening results plotted alongside positive ORO and PID in red



# CPT DELIVERY 3 DAYS IN MARCH, 2014

- Pushed 11 logs to >68 ft, total of 805 ft in 3 days which included integration and takedown of DyeLIF system
- maximum penetration was 78 ft (bedrock)
- unfortunately we were not allowed to push in “the heart” (wanted to compare to 2013 DyeLIF percussion logs)
- pushed at 1.5 cm/sec (ASTM bottom limit) – we feel 1.0 cm/sec would be optimal (desire higher resolution to detect smaller ganglia)

# CPT DELIVERED DYELIF & CPT DATA



# CONCLUSIONS

- DyeLIF produced the equivalent of an ORO shake test at 0.5 cm spacing with an average daily production of 395 ft
- DyeLIF responded preferentially to DNAPL with no dissolved or vadose phase response (as expected)
- field LoD of ~1.0%-0.1% DNAPL pore saturation
- in other words, under these site conditions the DyeLIF generated the equivalent of >10,000 ORO shake tests per day - with 100% “recovery”
- DYELIF has a monotonic response - more fluorescence equates to higher pore saturation of DNAPL
- tracking the indicator dye solution injection pressure reveals details of hydraulic conductivity with depth
- DyeLIF data is going to ‘challenge’ the 3D visual community

# ACKNOWLEDGMENTS – THANKS EVERYONE!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