

# ASSESSING PERFORMANCE OF AN ENDOPHYTE-ENHANCED HYBRID POPLAR PHYTOREMEDIATION PROGRAM FOR TCE AT AN ARID, FRACTURED BEDROCK SITE

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 RAMBOLL



2019 BATTELLE BIOREMEDIATION SYMPOSIUM



## OVERVIEW

- Site Setting
- Pilot Study and Tree Selection
- Installation and Irrigation Design
- Monitoring and Mitigation
- Tree Health Results

## SITE SETTING

- Former testing facility
  - Rockets, military equipment/apparatus
- Approximately 429 acres, sparsely developed; majority of site acted as a buffer zone
- Site in east-west trending canyon
  - Steep granitic outcrops; veneer of sand and silt over canyon floor
  - Fractured bedrock “non-water-bearing”
- Surface water limited to ephemeral stream
- Groundwater beneath site not used for any purpose



View of site looking east

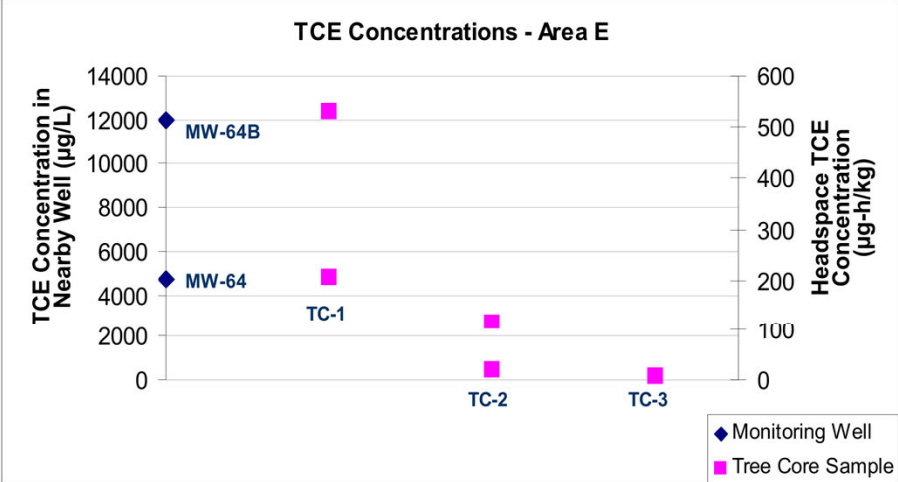
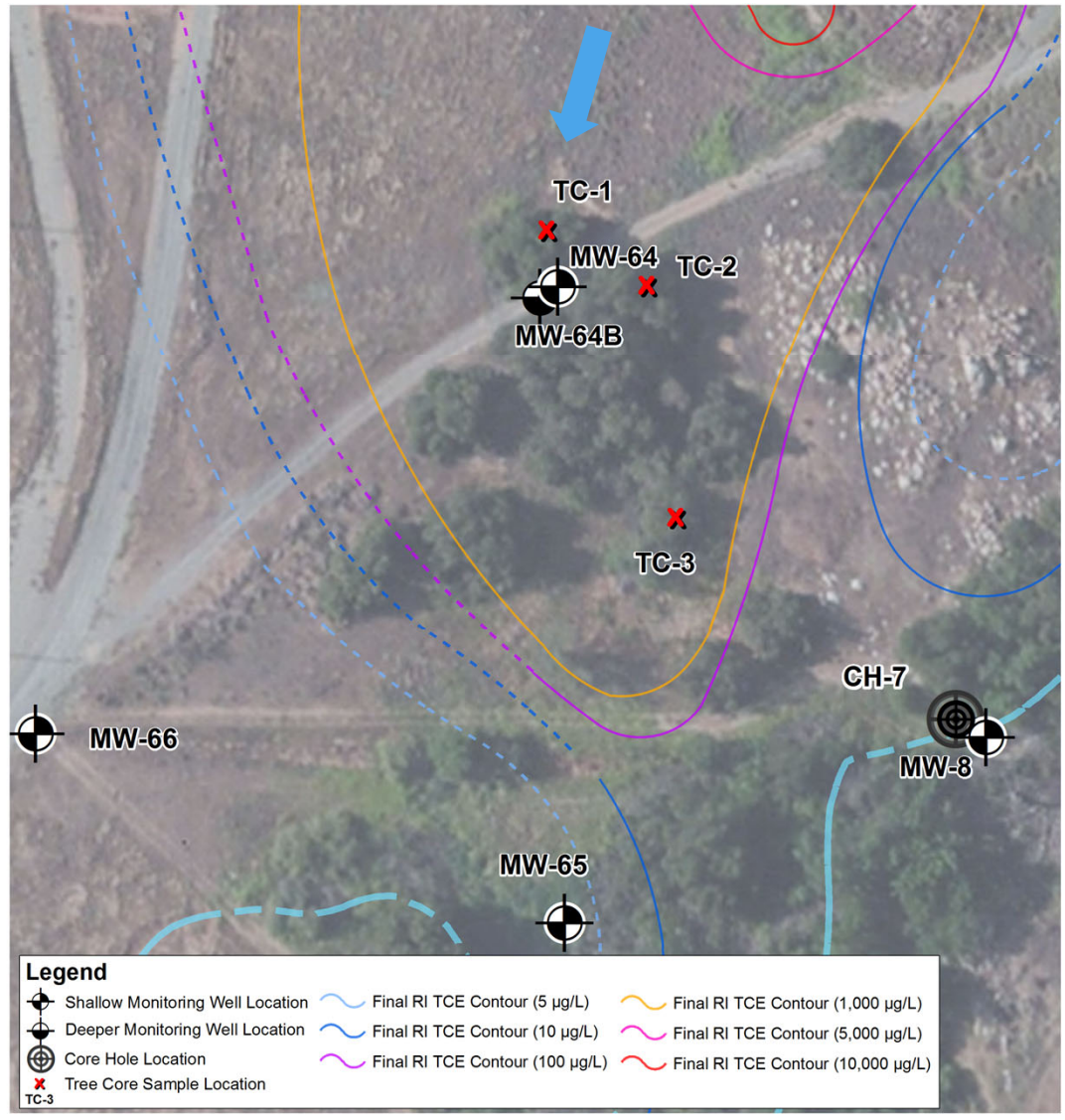


## PRELIMINARY STUDY (2009)

- Investigate native trees to look for TCE in tree tissue
- Collected 20 cores from native trees at the site
- Sample from near the base of the tree, on the side facing the upgradient portion of plume
- Analyze headspace for volatile organic compounds (VOCs), including TCE







	Tree Core Sample Number	TCE Headspace Concentration (µg-h/kg)	Sample Orientation	Notes
<i>Nearby Wells:</i> MW-64, MW-64B	TC-1a	205.7		Circ. : not measured
	TC-1b	529.7		Sp. : Pepper ( <i>Schinus molle</i> )
	TC-2a	115.1		Circ. : 6'1"
	TC-2b	20.4		Sp. : Pepper ( <i>Schinus molle</i> )
	TC-3a	6.7		Circ. : 4'3"
	TC-3b	5.6		Sp. : Pepper ( <i>Schinus molle</i> )

- NOTES:**
- TCE is contoured down to the Maximum Contaminant Level (MCL), 5 µg/L.
  - Contours are dashed where inferred.
  - Contours derived from the Final RI Report, ENVIRON, 2008.
  - TCE = Trichloroethylene
  - µg/L = micrograms per liter
  - µg-h/kg = micrograms in headspace per kilogram wet core
  - Circ. = trunk circumference
  - Sp.=tree species, if known

# TREE SELECTION

## Pilot Growth Study

- Evaluate if boring method is feasible
- Collect site soil from 3 areas in Area E, analyze soil chemistry
- Evaluate growth of 3 poplar cultivars, including salt-tolerant variety
- Use 2 variations of amendments plus a control (i.e. no amendment)
- Two successful cultivars were identified:
  - United States Department of Agriculture “Red Rock Ranch” (USDA-RRR), DN-21

## Objective:

- Determine proper amendments for soil type(s)
- Determine which poplar cultivar grows best



# PLANTING

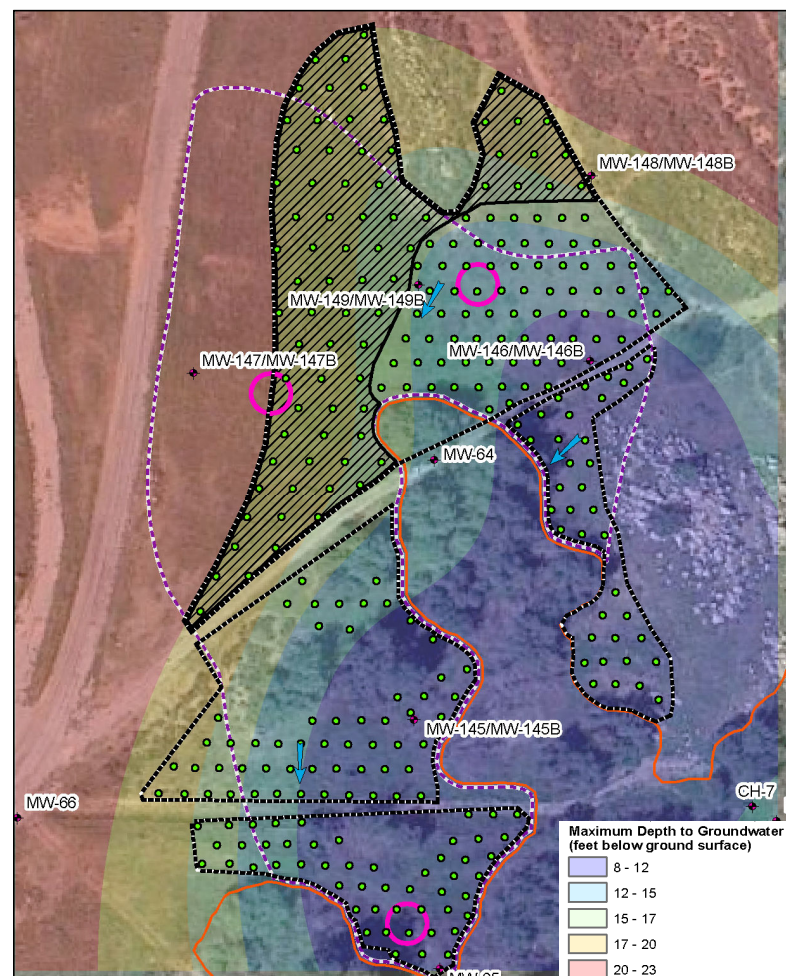
- Planted 312 trees (March 2016)
- Auger to 6-8 feet
- Mix soil with amendment (peat moss) and place in boring
- Used 10-14' poles, and some 6' poles
- Inoculated with PDN3 endophyte



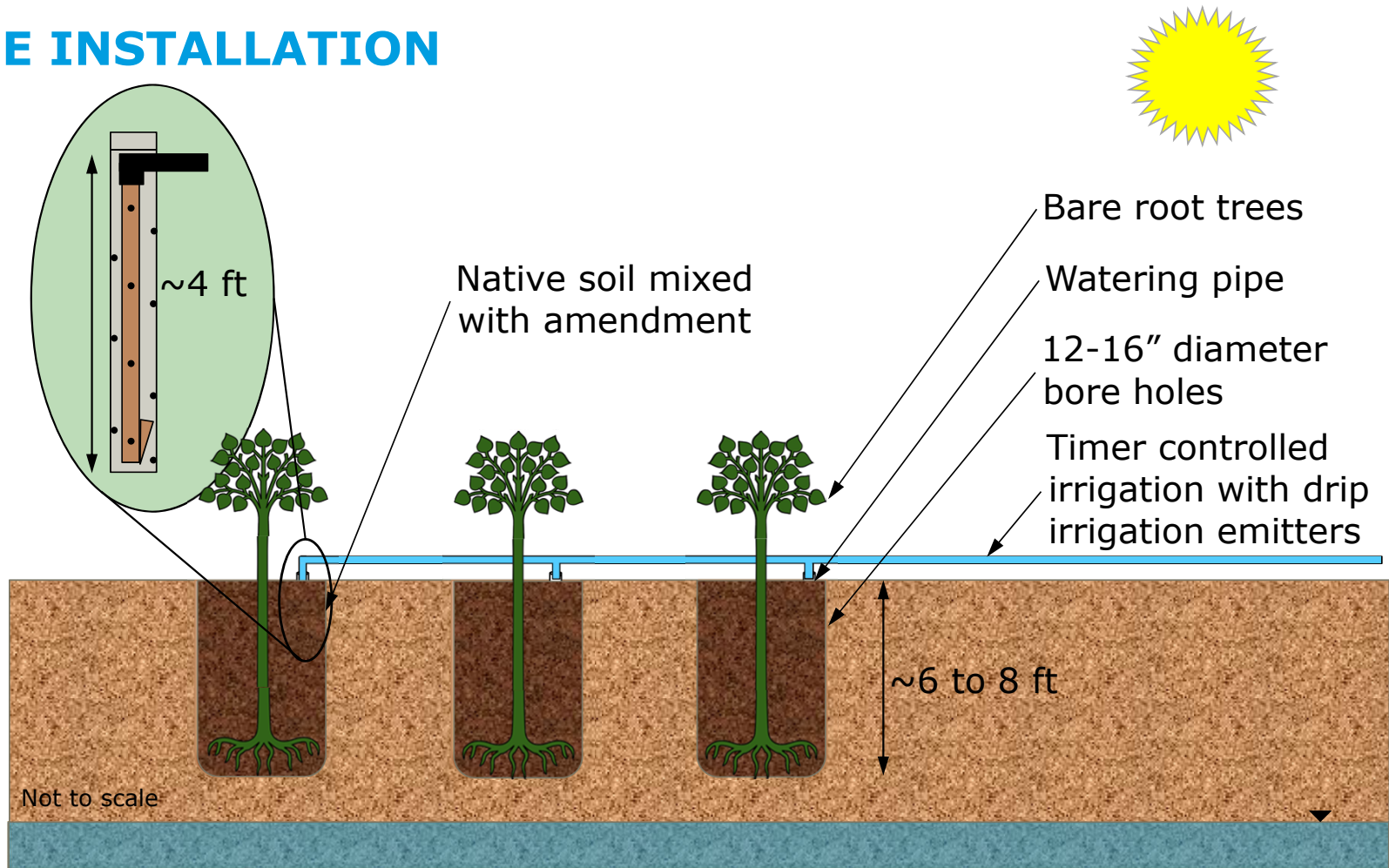


## PLANTING

- Planted 312 trees (March 2016)
  - 110 RRR, 202 DN-21
- Auger to 6-8 feet
- Mix soil with amendment (peat moss) and place in boring
- Used 10-14' poles, and some 6' poles
- "Deep rooting" technique



# TREE INSTALLATION



# IRRIGATION DESIGN CHALLENGES

- No water infrastructure – try to minimize amount of piping and valves
- Trade-offs: can't control individual trees, use a "zone" system (three zones)
- Commercial emitters on each tree provides some adjustability
- Goal was to deliver ~1 to 1.5 gallons per tree per day





# IRRIGATION SYSTEM PIPING



- Force main (red) delivers water from on-site remediation system to storage tank located on elevated pad
- Gravity drains through Supply Headers (pink) and into Supply Lines (blue) and lateral feeders

## MONITORING APPROACH

- Observe:
  - Impacts of irrigation on groundwater levels
  - Overall tree health/growth
  - Changes in microbial community
  - Uptake/phytodegradation of TCE
  - Eventual decline in VOC concentrations
- “Process” (first two years after planting) versus “Performance” (starts in third year after planting)



## PROCESS MONITORING

Metric	Observation (Year 1/2)
Groundwater Levels	No impact (consistent with sitewide trends)
Tree Growth/Health	Variable

- Significant mortality after first year
  - Certain areas of plantation more difficult than others
  - Sudden pest infestation took large toll







**Initial Planting**



**10 weeks**



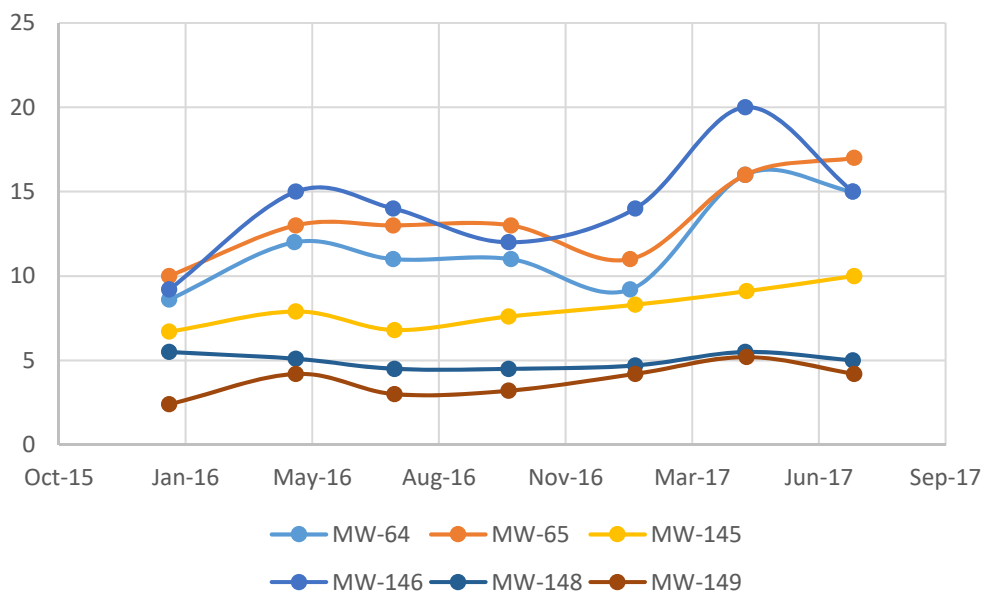
**16 months**



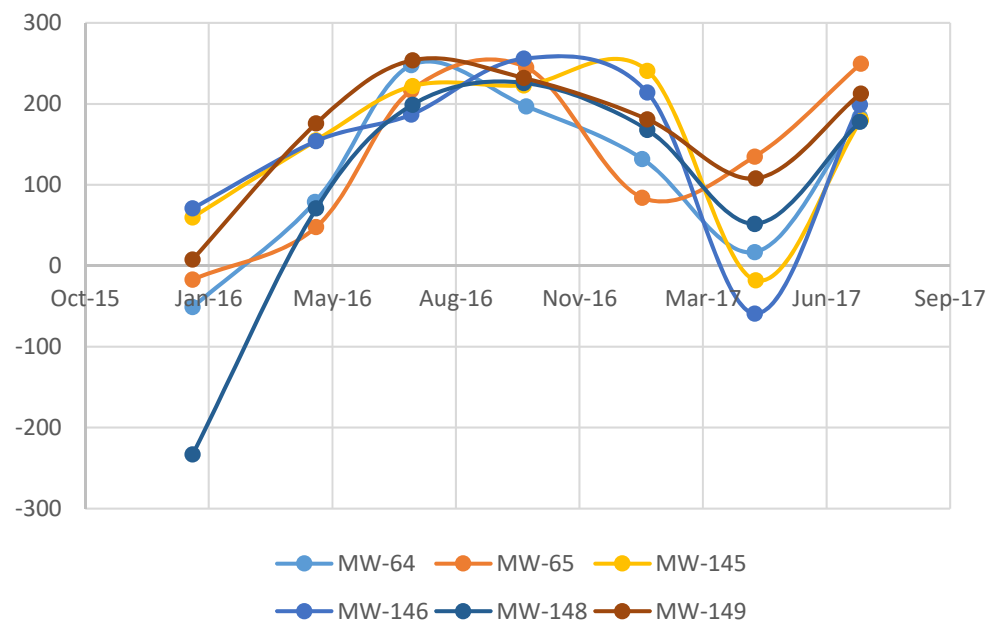
**30 months**

# PROCESS MONITORING

## Dissolved Organic Carbon (mg/L)

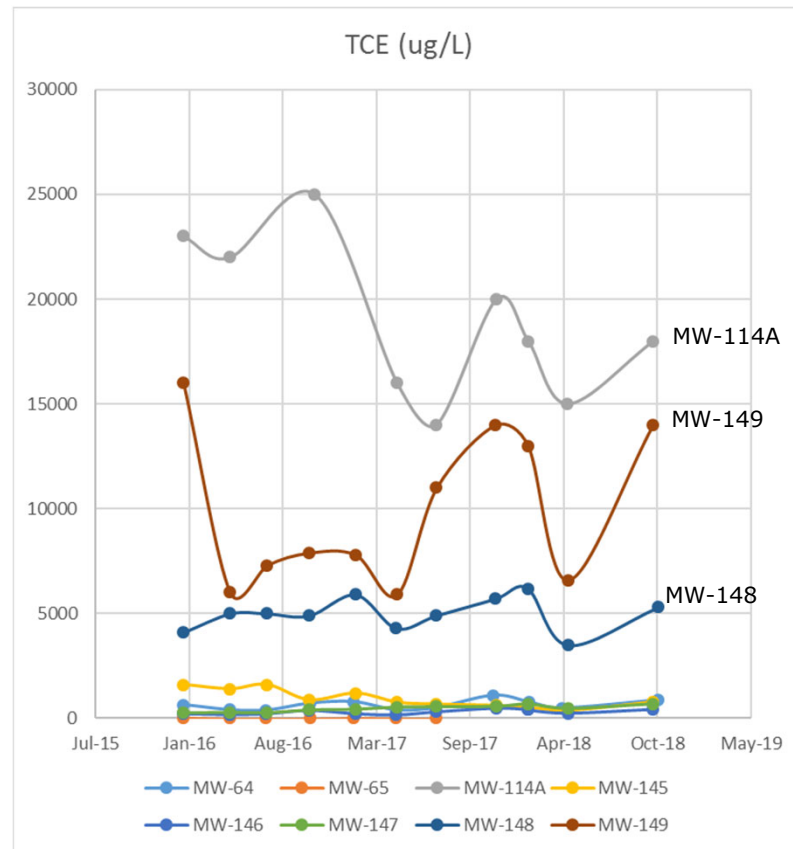


## ORP (mV)



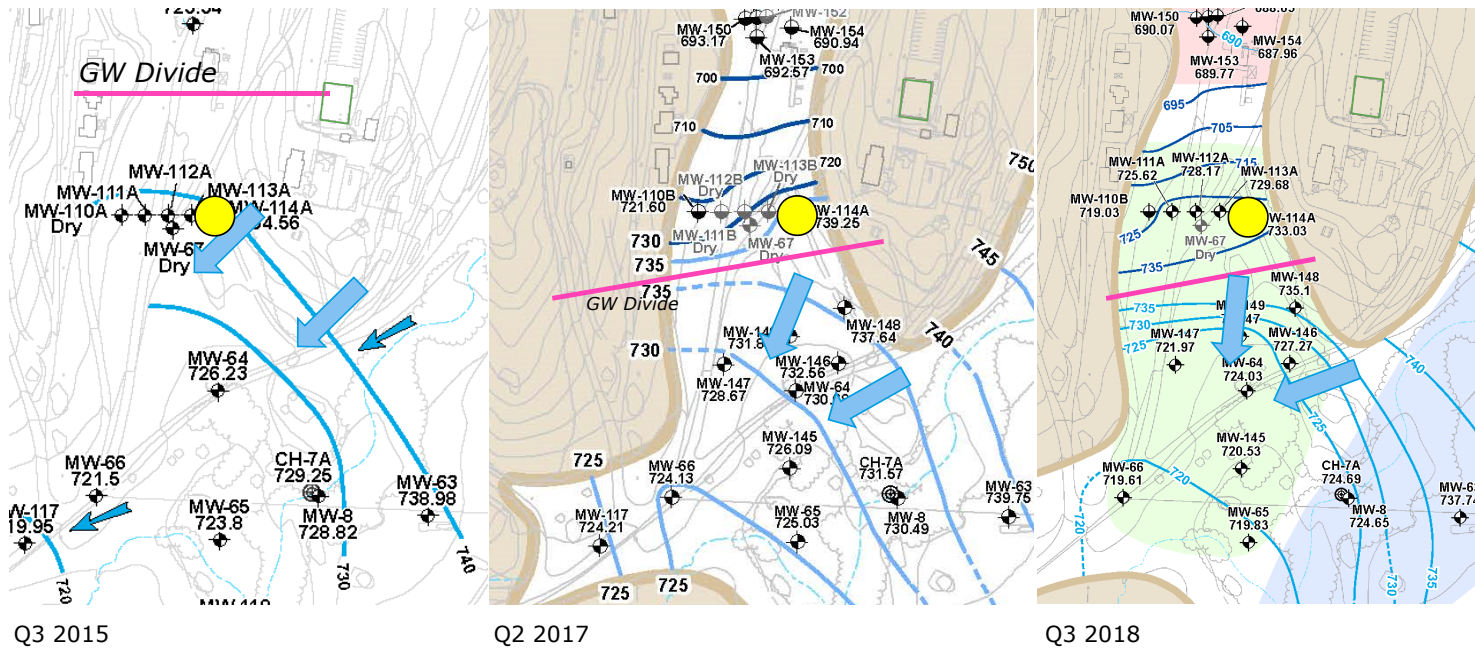
## TCE CONCENTRATIONS IN GROUNDWATER

- TCE concentrations have shown recent fluctuations at northern portion of plantation
- Seasonal, but influence from nearby in-situ thermal remediation operation





# NEARBY INFLUENCES ON GROUNDWATER



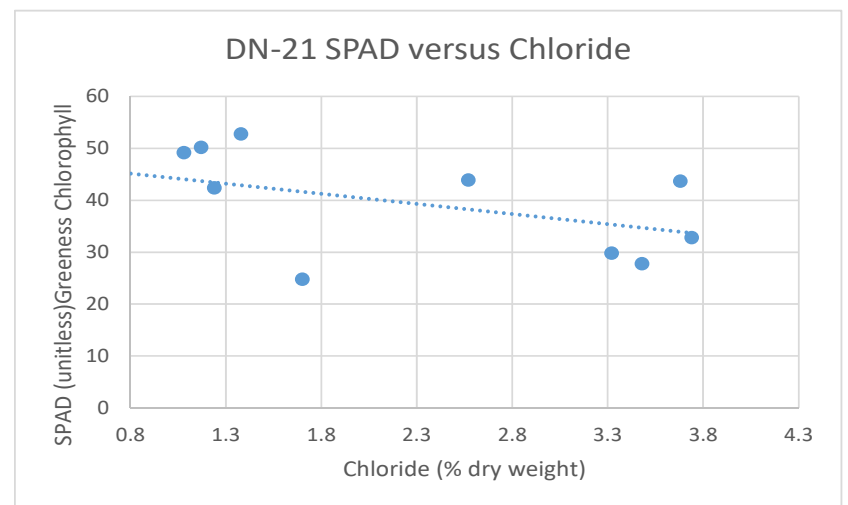
## TREE HEALTH - MITIGATION

- Pyola oil spray, malathion (aphids)
- Manual removal, nematode treatment and systemic insecticide (borers), sealers
- Tensiometers, visual observation for irrigation, zone adjustments
- Evaluate water treatment options
  - Limited options
- Fertilizer design based on tissue results



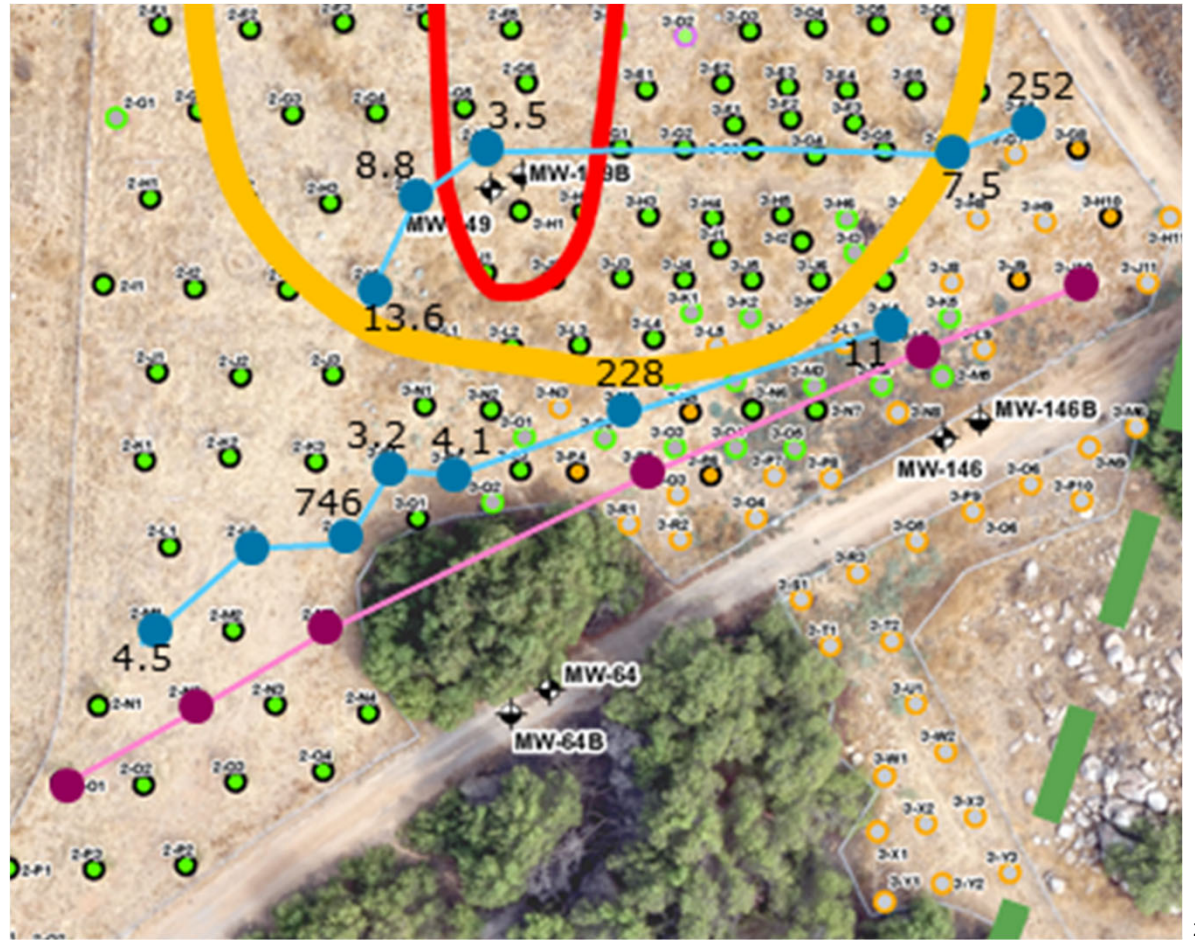
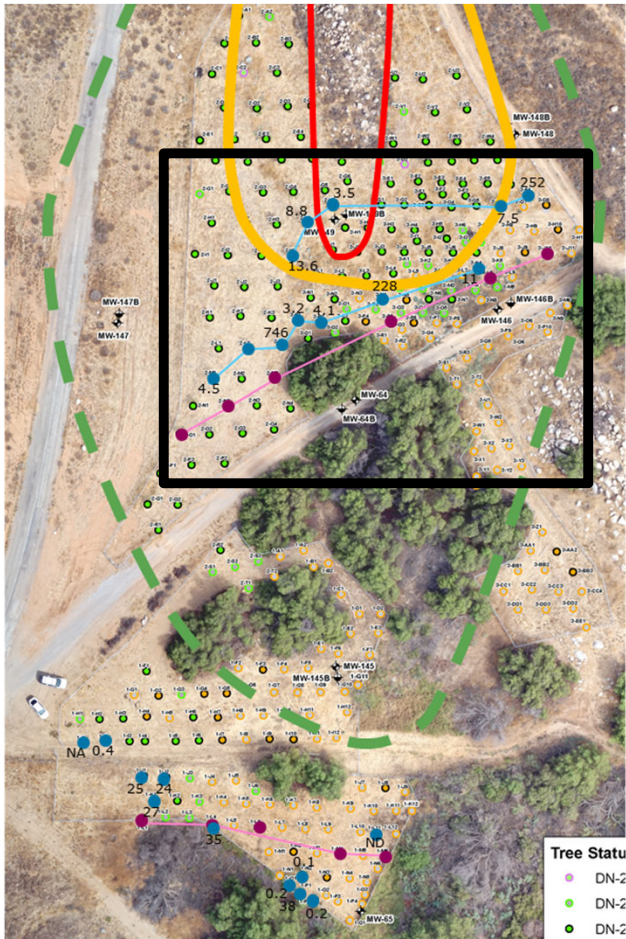
## TISSUE STUDIES

- First year tissue sampling (leaves)
  - High: sodium, sulfur, chloride, boron, and magnesium (toxic)
  - Low: calcium, potassium, copper, and phosphorus
- Applied a no boron, low magnesium 20-10-20 (N-P-K) fertilizer beginning spring 2017
- Second year tissue sampling (leaves)
  - Elements remained similar, boron notably higher
  - “Green-ness” index (SPAD) generally correlates with element abundance
  - Also analyzed for TCE in branch fibers





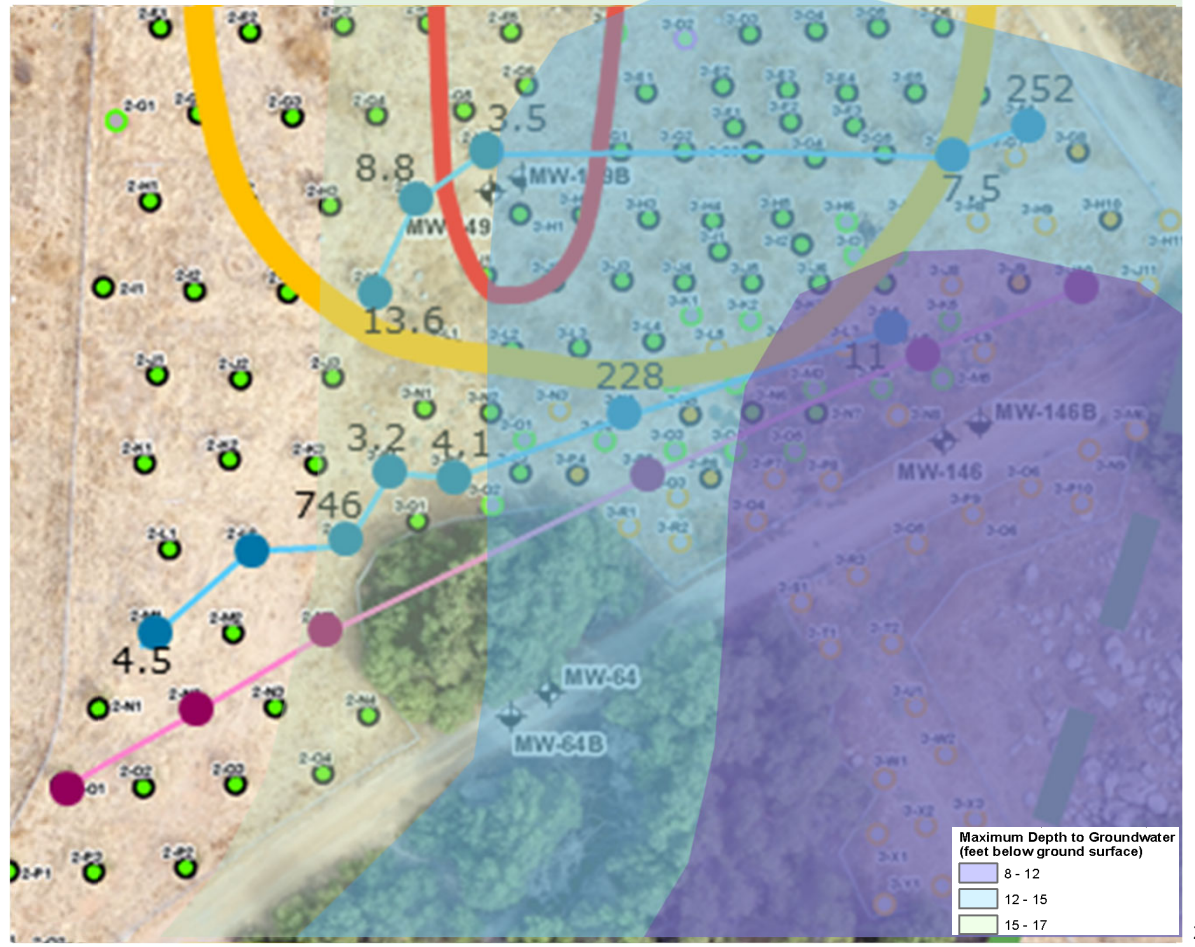
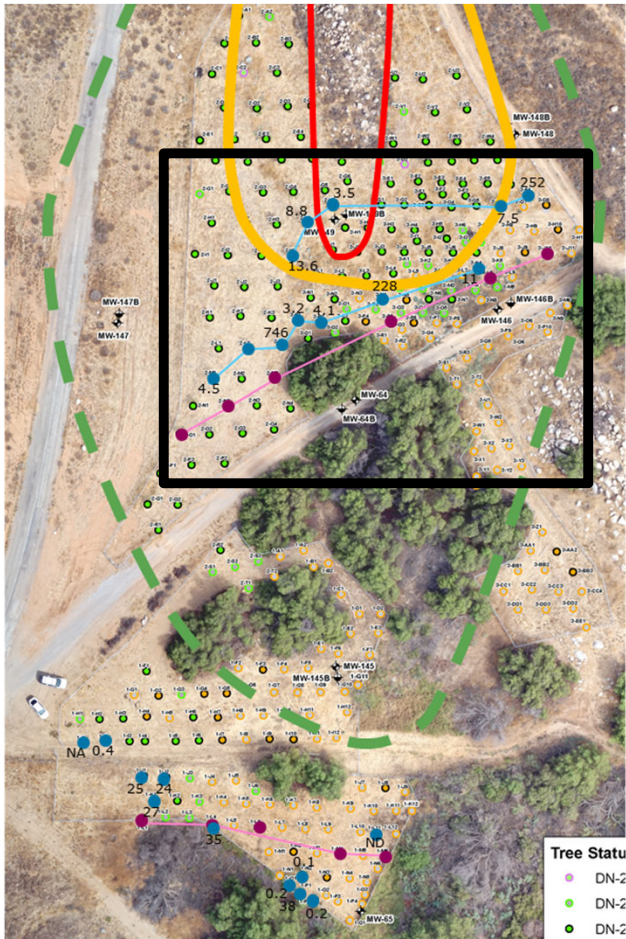
# TISSUE STUDIES – NORTH TRANSECTS (YEAR 2)



● Branch Sample Location (2017)



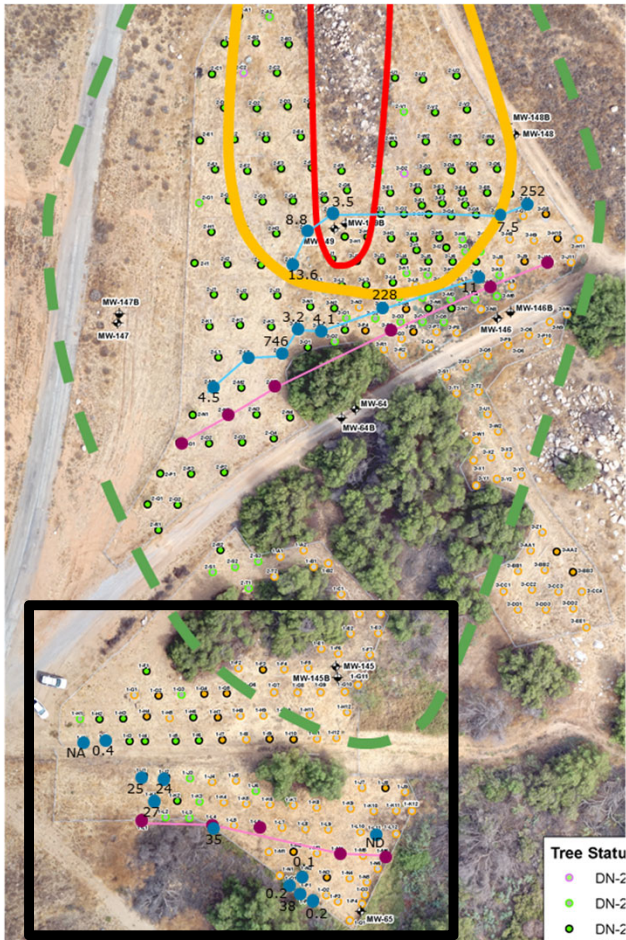
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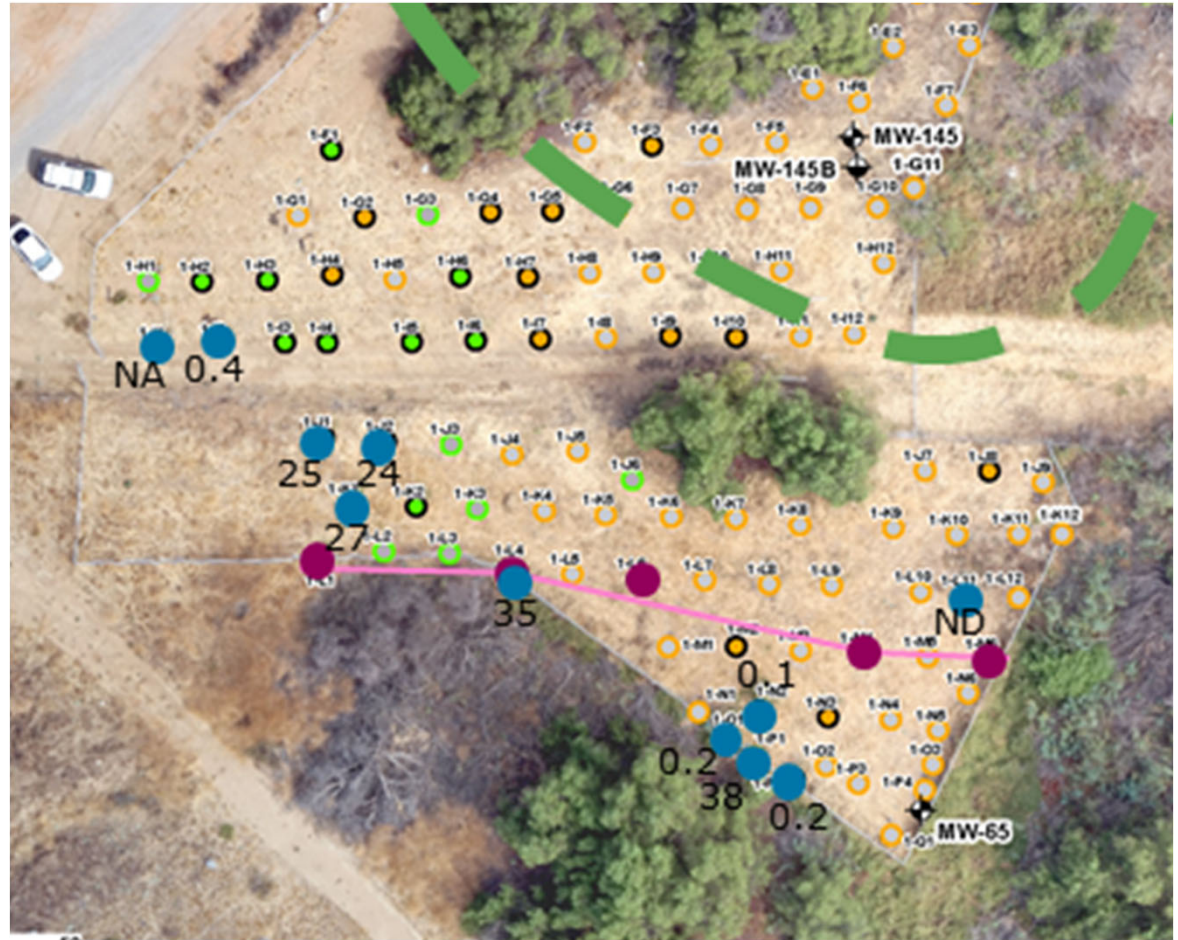
● Branch Sample Location (2017)



# TISSUE STUDIES – SOUTH TRANSECTS (YEAR 2)



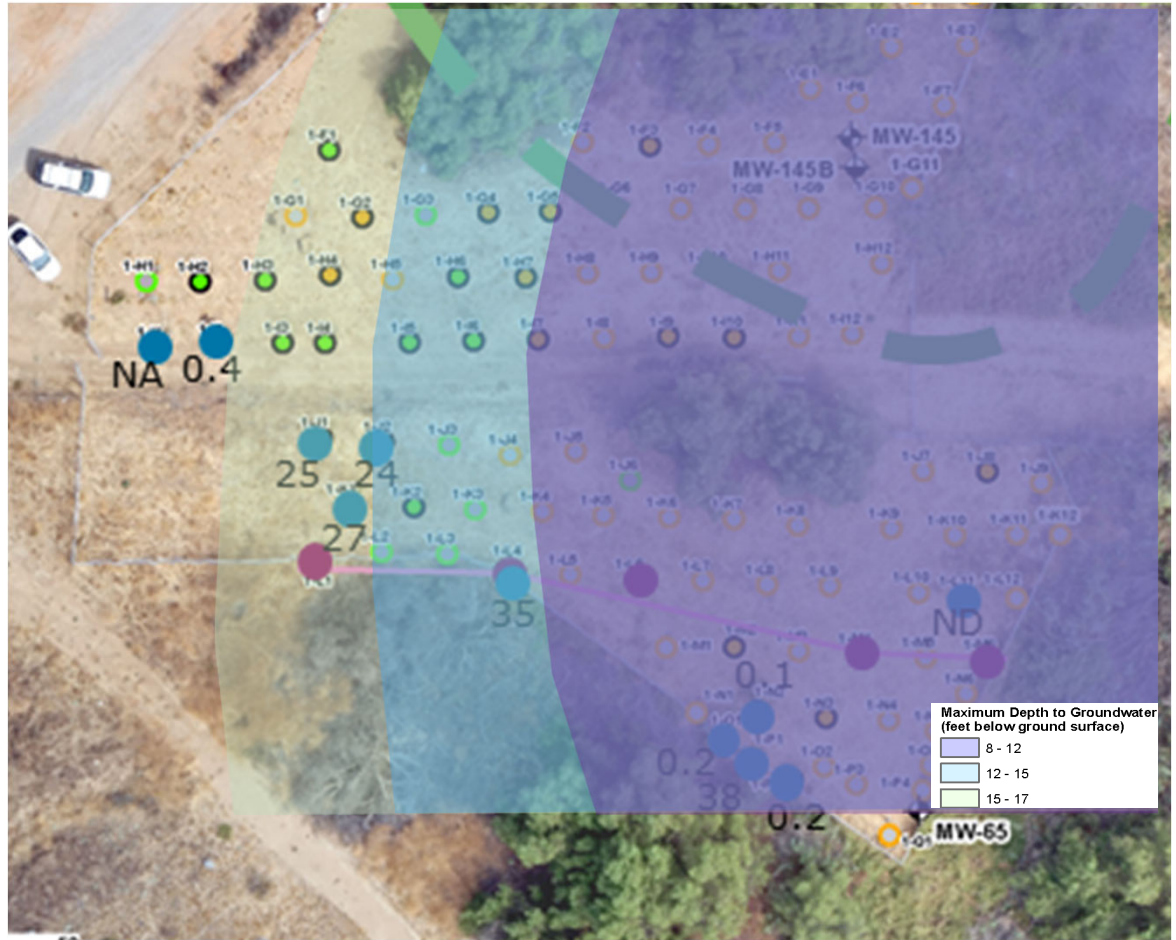
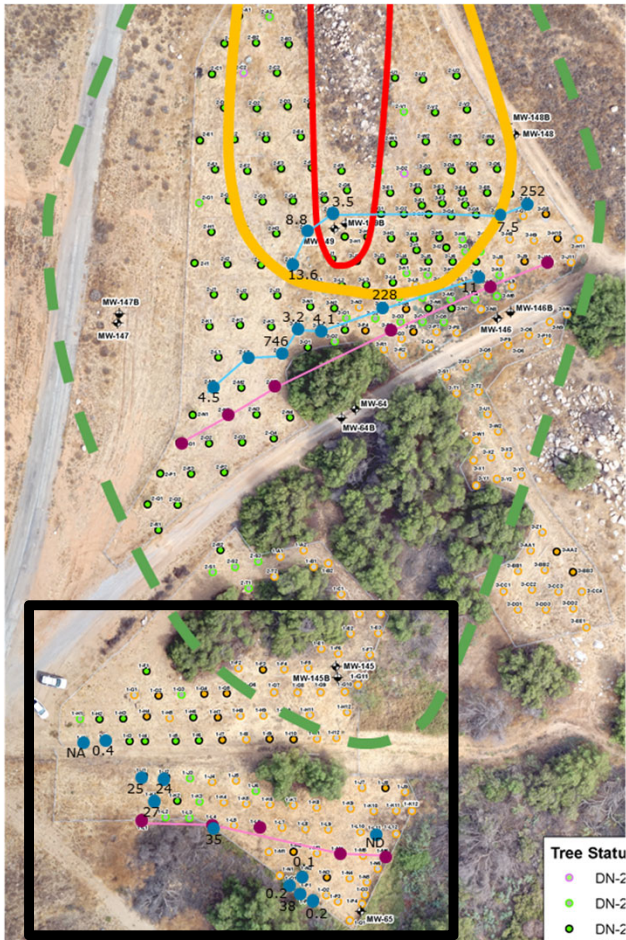
2016



2017



# TISSUE STUDIES – SOUTH TRANSECTS (YEAR 2)





## TISSUE SAMPLING (THIRD YEAR)

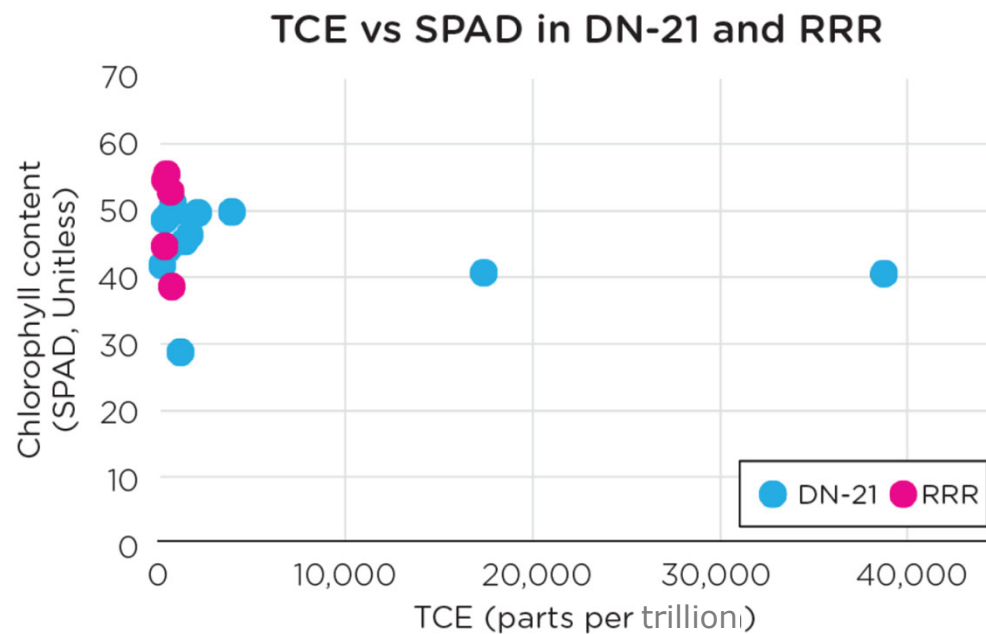
- Tissue sampling (leaves and branches)
- All trees located within the contoured TCE plume (based on groundwater) had TCE in tissue
- TCE concentrations
  - Increased in 9 of 11 trees that were resampled
  - Decreased in 1 tree
  - Non-detect (both rounds) in 1 tree
- Similar results to year 2 – higher TCE values in northern area

Tree	TCE (2017) ppt	TCE (2018) ppt	Relative TCE Increase
3-F4	251.91	38,741	>100
3-G6	7.46	17,335	>1000
3-J8	<1	412	>100
3-K4	11.05	582	>50
3-P1	3.2	1	<1
2-M1	4.52	1,778	>100
1-N2	<1	<1	<RL (both)
1-M2	<1	703	>1,000
1-K1	27.46	1,409	>50
1-I3	<1	1,189	>1,000
1-I1	38.2	553	>10

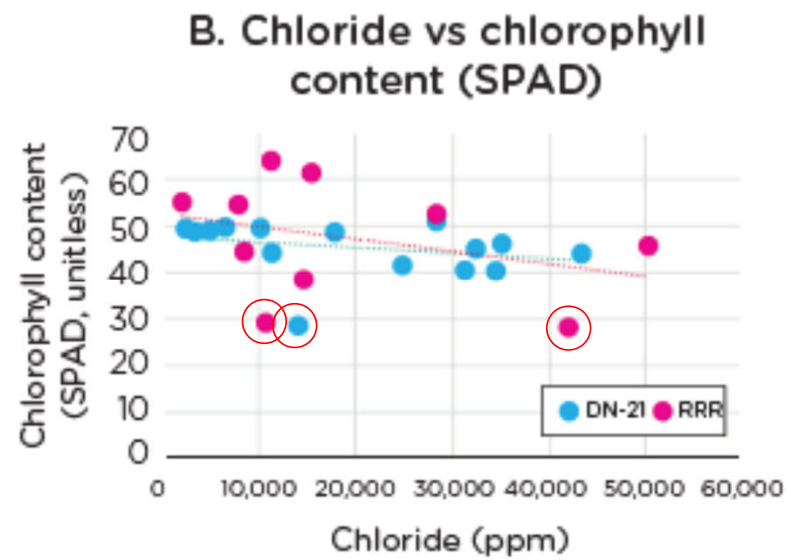
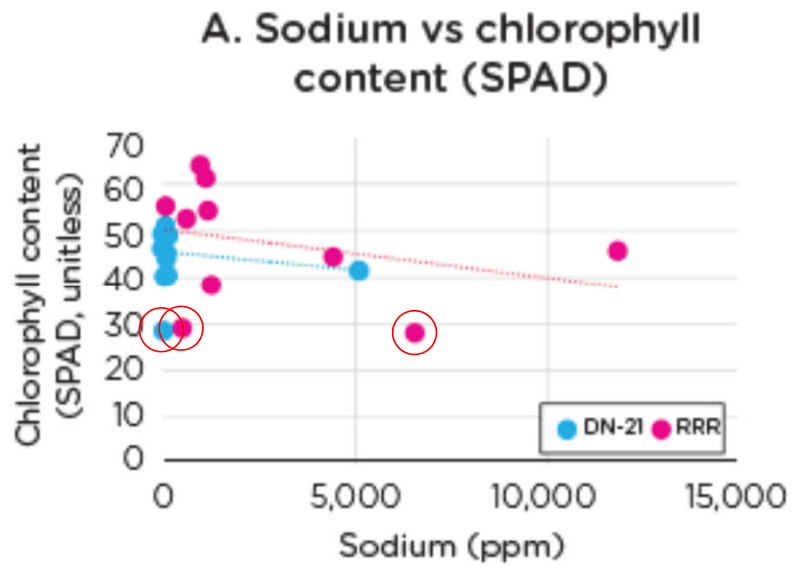


## TOXICITY EFFECTS?

- No significant correlation (TCE/SPAD)
- Increasing chloride trend (eastward)
  - Higher TCE concentrations on east side
  - Endophytes provide protection from TCE phytotoxicity?



# ASSISTANCE FROM ENDOPHYTE?



○ PDN3 not detected

## BIOTRAP SAMPLER RESULTS

- Tested shallow wells for DHC, functional genes and PLFAs
  - DHC identified in only MW-65 (closest to ephemeral stream)
  - Slight increase in biomass compared to baseline (year 0)
  - Slight increase in firmicutes (responsible for production of hydrogen for reductive dechlorination)
- Only slight changes, but in the right direction!



## WHAT HAVE WE LEARNED?

- Uptake of groundwater with TCE is occurring!
- Environmental toxicity, pests, climate can pose significant and dynamic challenges for phytoremediation/performance assessment
- Deep rooting approach in fractured media has shown success through third year of growth
- Phyto can work in arid, nutrient poor environment



**THANK YOU**

**RAMBOLL**

