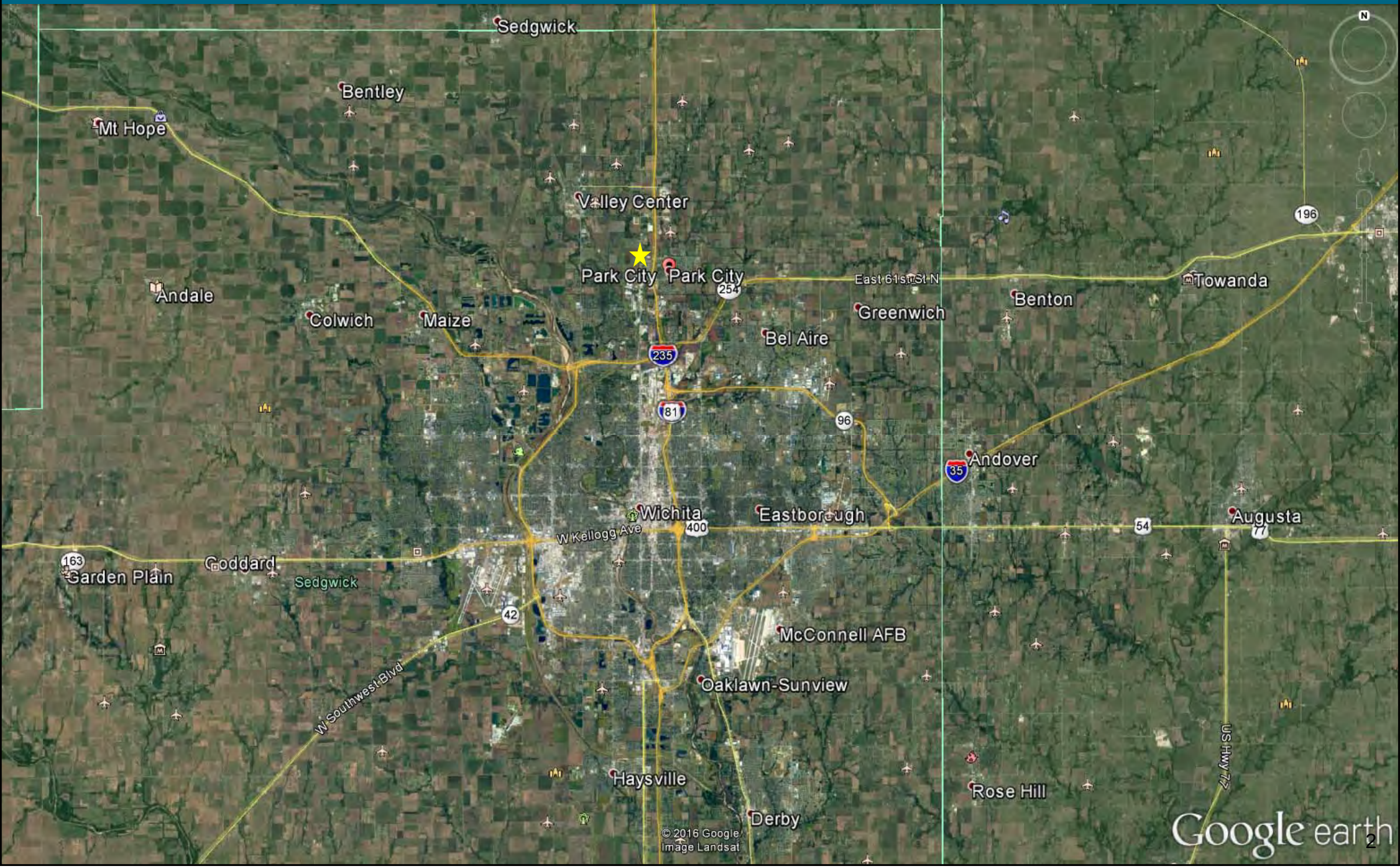
Lessons-Learned From Four Decades of Pipeline Spill Remediation – Park City, Kansas

By: Jeff TeGrotenhuis

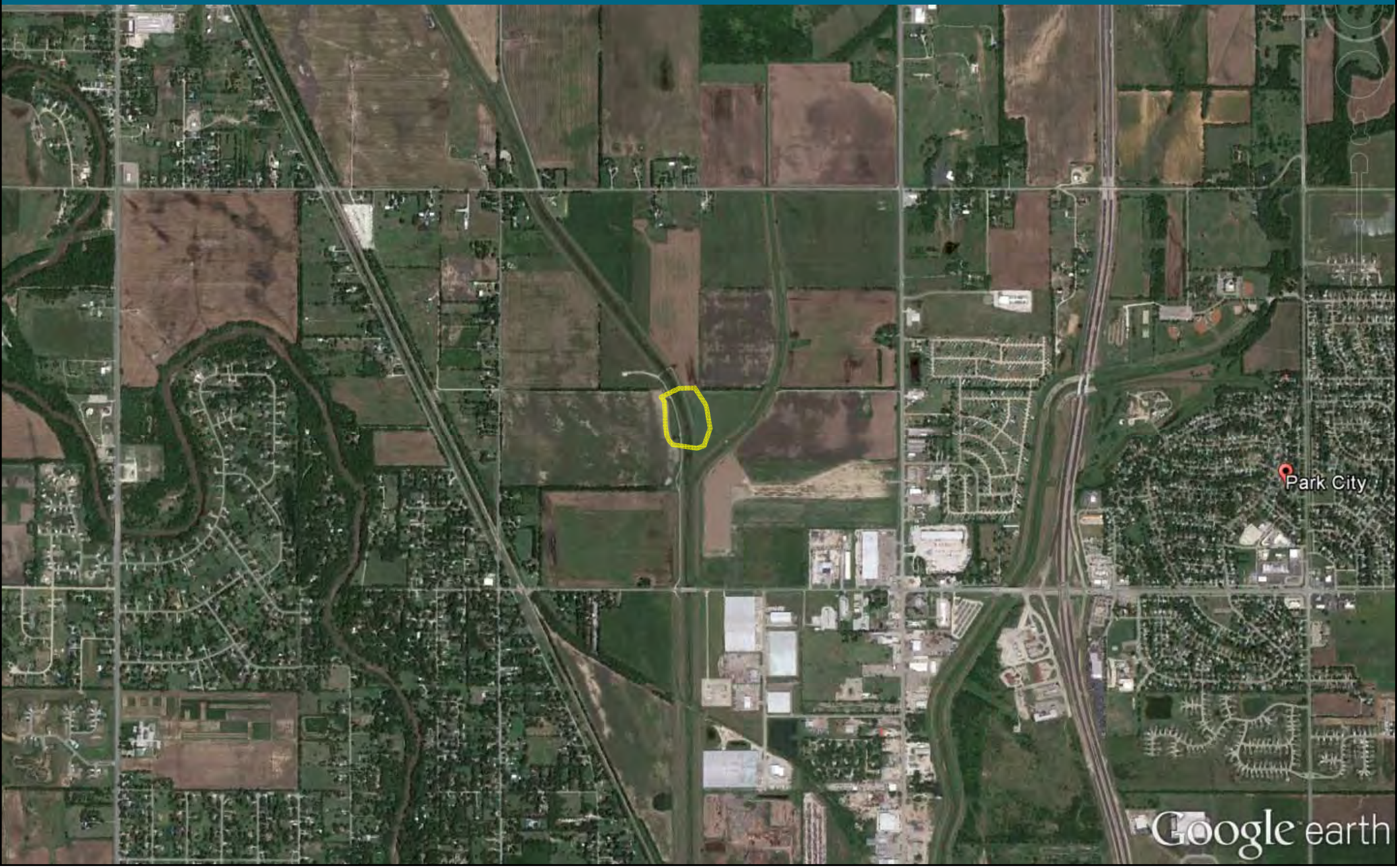
KINDER MORGAN

MWH. now part of Stantec

Site Location



Site Location



Site Location

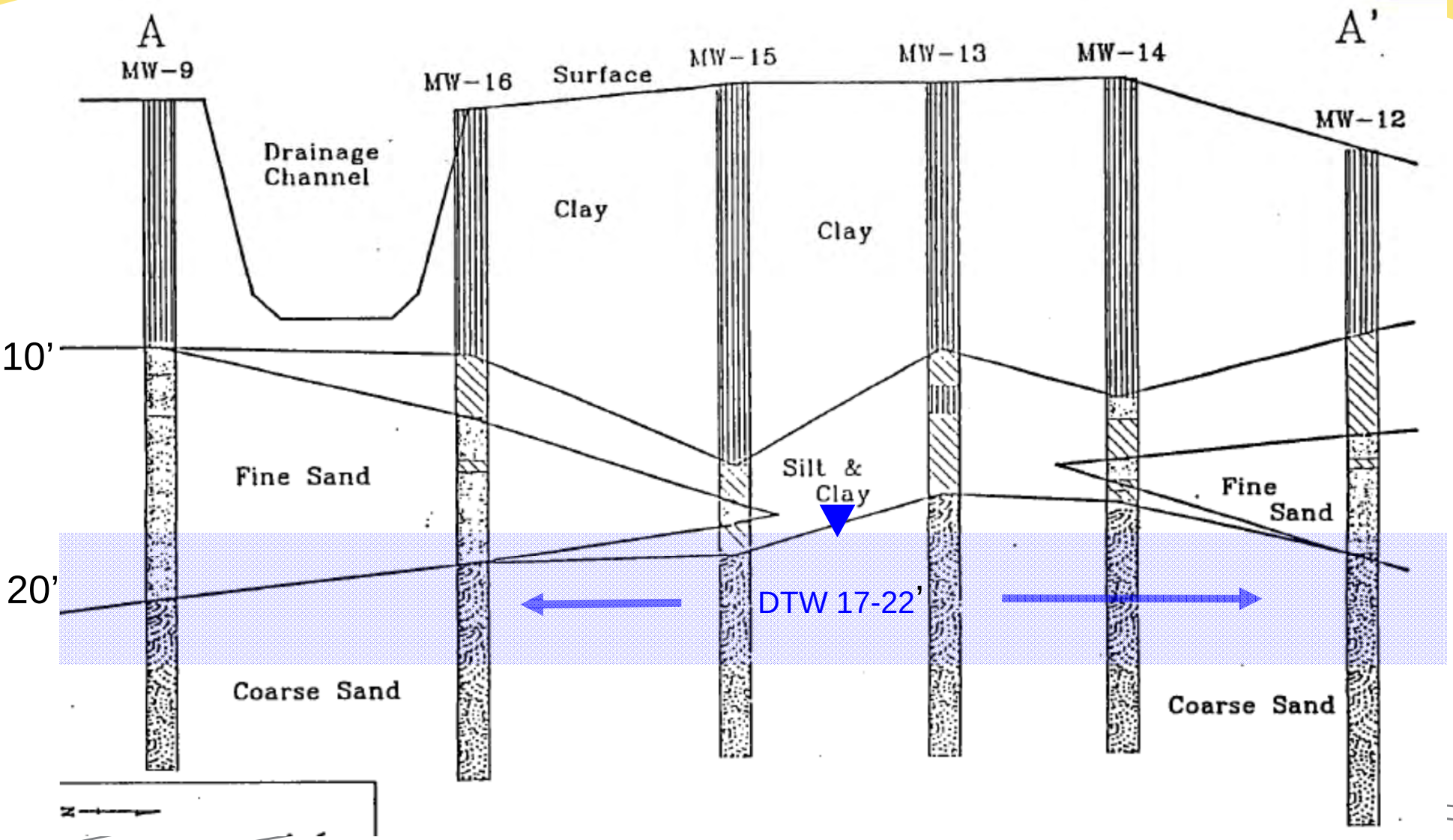
Release and Initial Remedial Actions

- Release in Late 1970s over an unknown time period
  - As a result, no volume estimate
  - Not discovered until 1980 when
- BTEX was detected in Park City Water Supply Well #6
  - Pumped and discharged through 1986 until low BTEX
  - A year pause, then resumed when concentrations increased
- 2 open trenches installed to recover hydrocarbons
  - East Trench installed Feb 1980, ignited & burned for >1 year
  - West Trench installed same year - No mention of LNAPL
  - Backfilled in Aug ‘82 (west) and Aug ’84 (east)

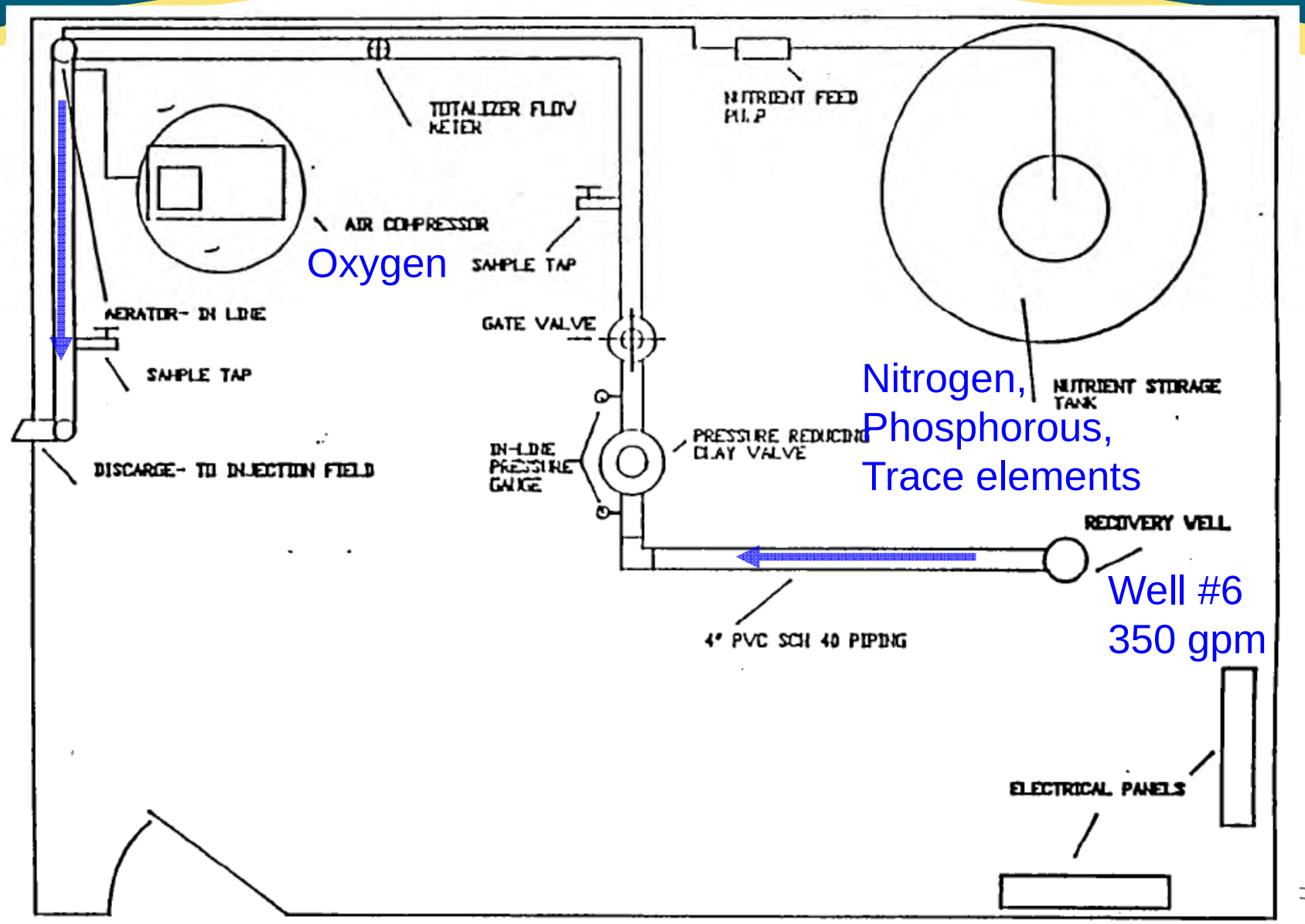
LNAPL Trenches

- Trenches approximately
  - 250’ long by
  - 60’ wide by
  - 24’ deep
- Locations approximate

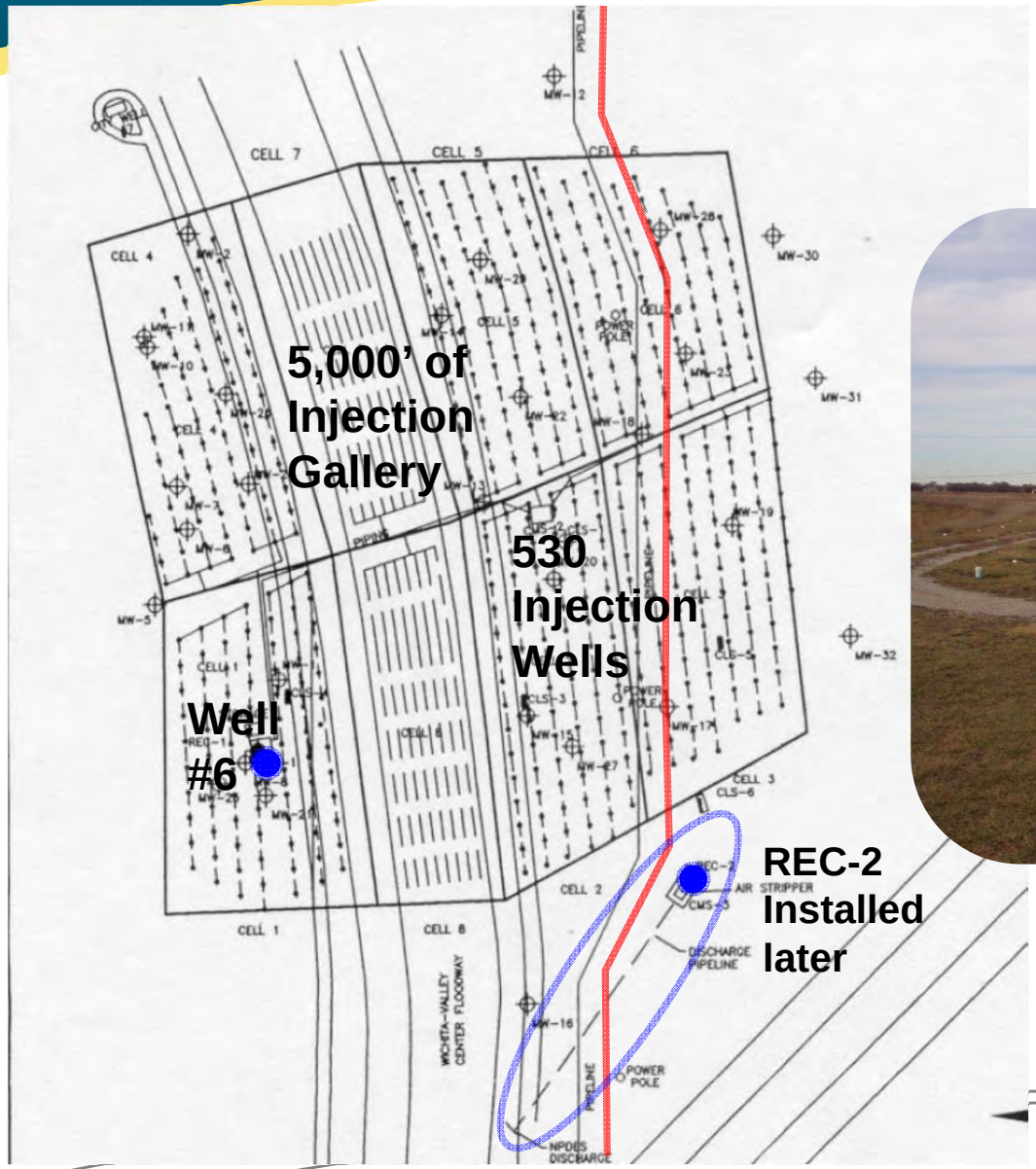
W-E Cross-Section



1989 Bioremediation System



Bioremediation System Injection Field



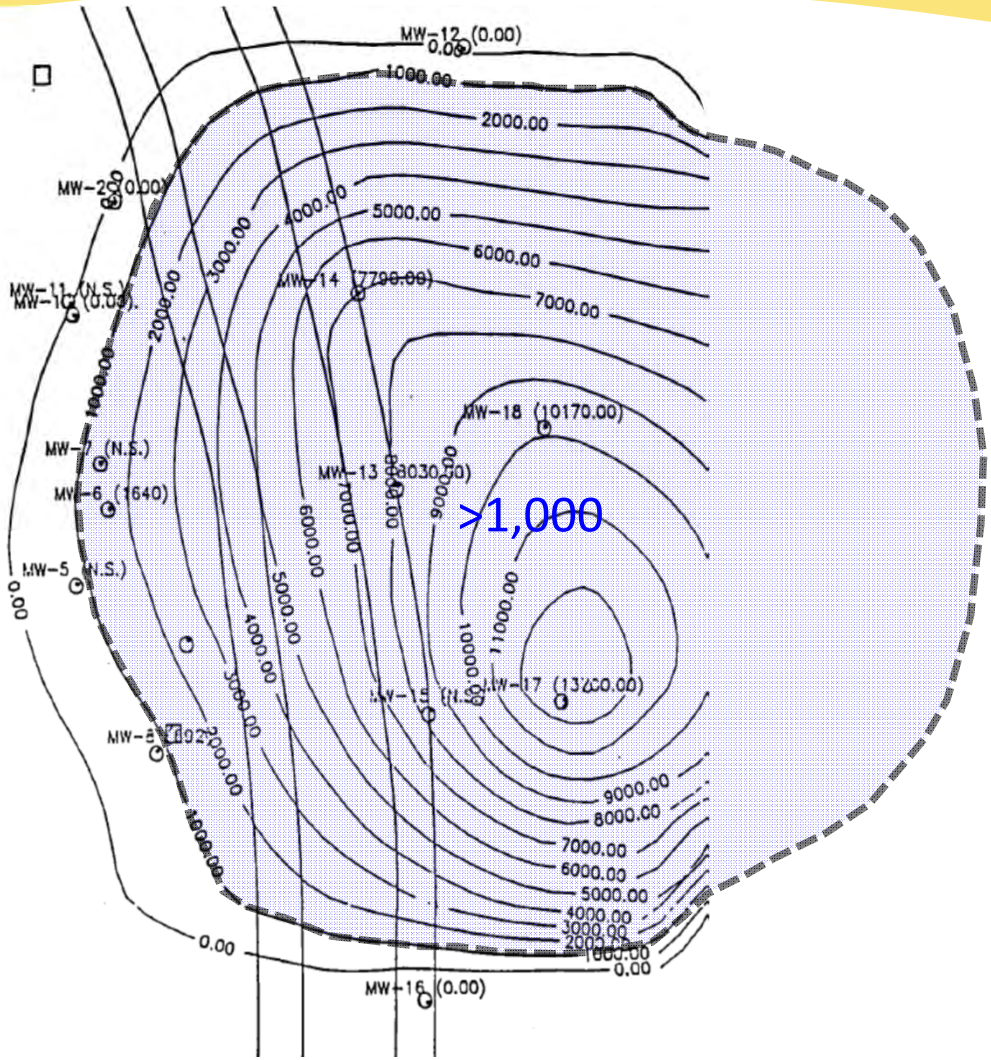
Bioremediation System O&M

- Operated 1 month
- Shut-down due to loss of injection capability
  - Air entrainment
  - **Iron precipitation**
  - **Bacteria growth**

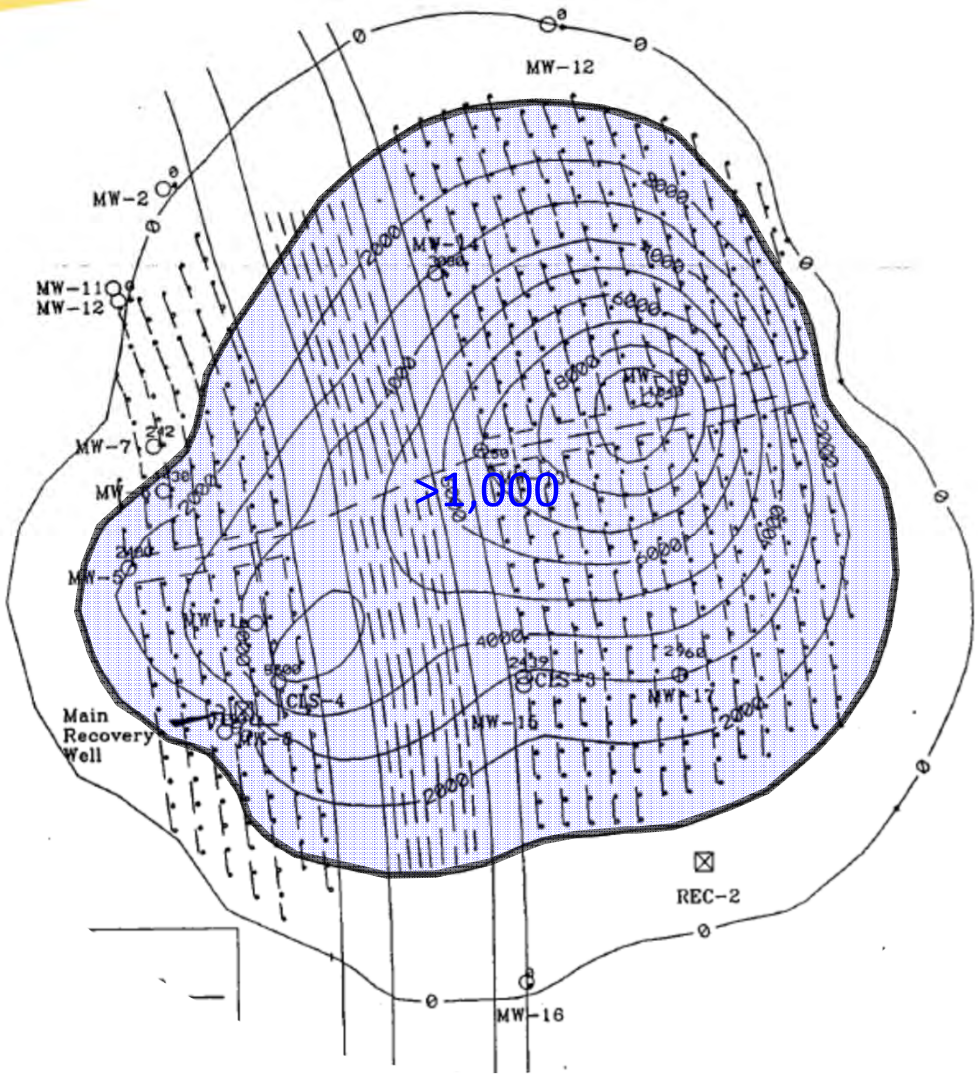
Bioremediation Resumed in 1993

- Added downgradient P&T well, REC-2
  - 30MM gallons/yr, air stripper tower, and NPDES discharge
- Injection resumed June 1993
  - 1993-1995
    - Added iron chelating agent & ammonium *chloride*
    - 32MM gallons/yr - ave 120 gpm
  - 1995-2002
    - Changed to ammonium *nitrate* in 1995 and in weeks
    - Flow reduced to 15 gpm to individual cells (rotated among them)
    - REC-2 at 140 gpm

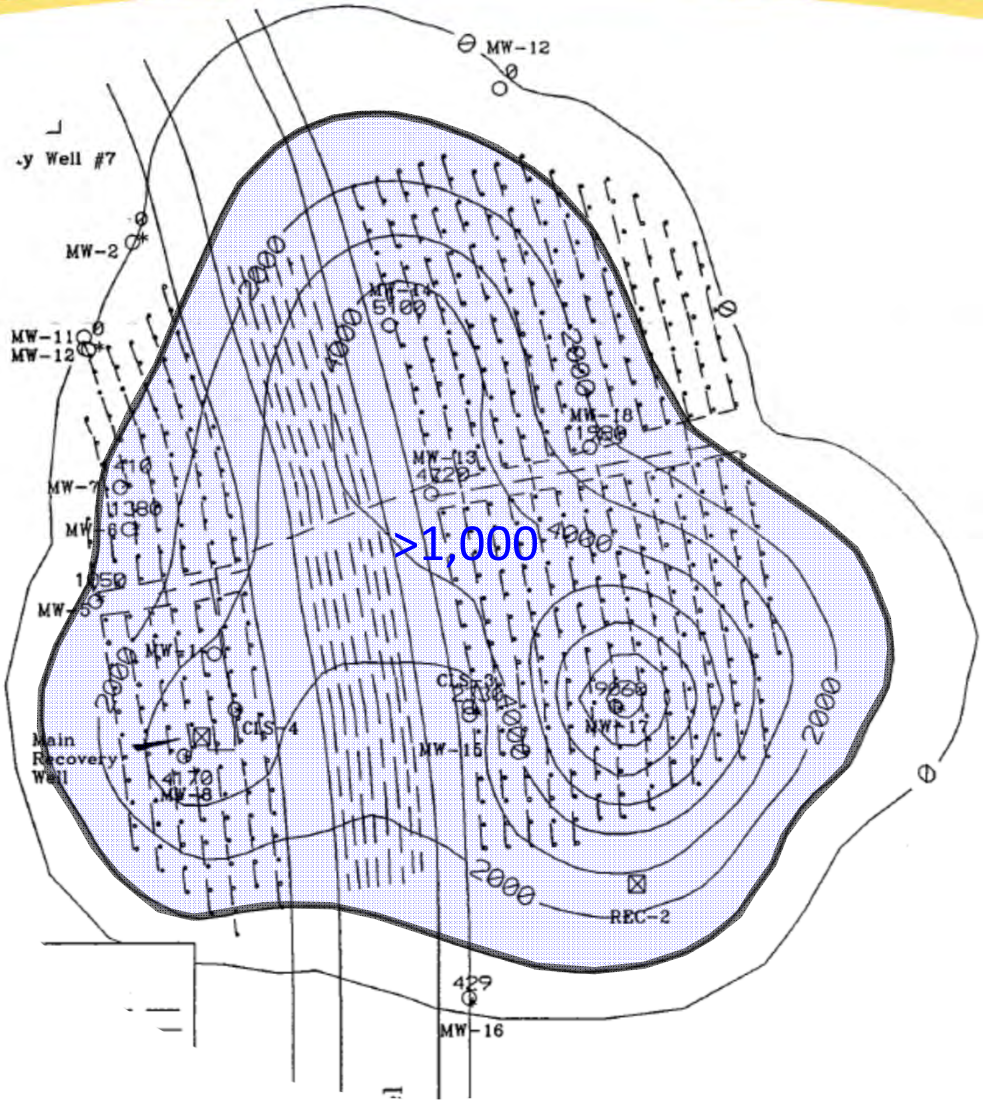
1990 BTEX (µg/L): Pre-Treatment



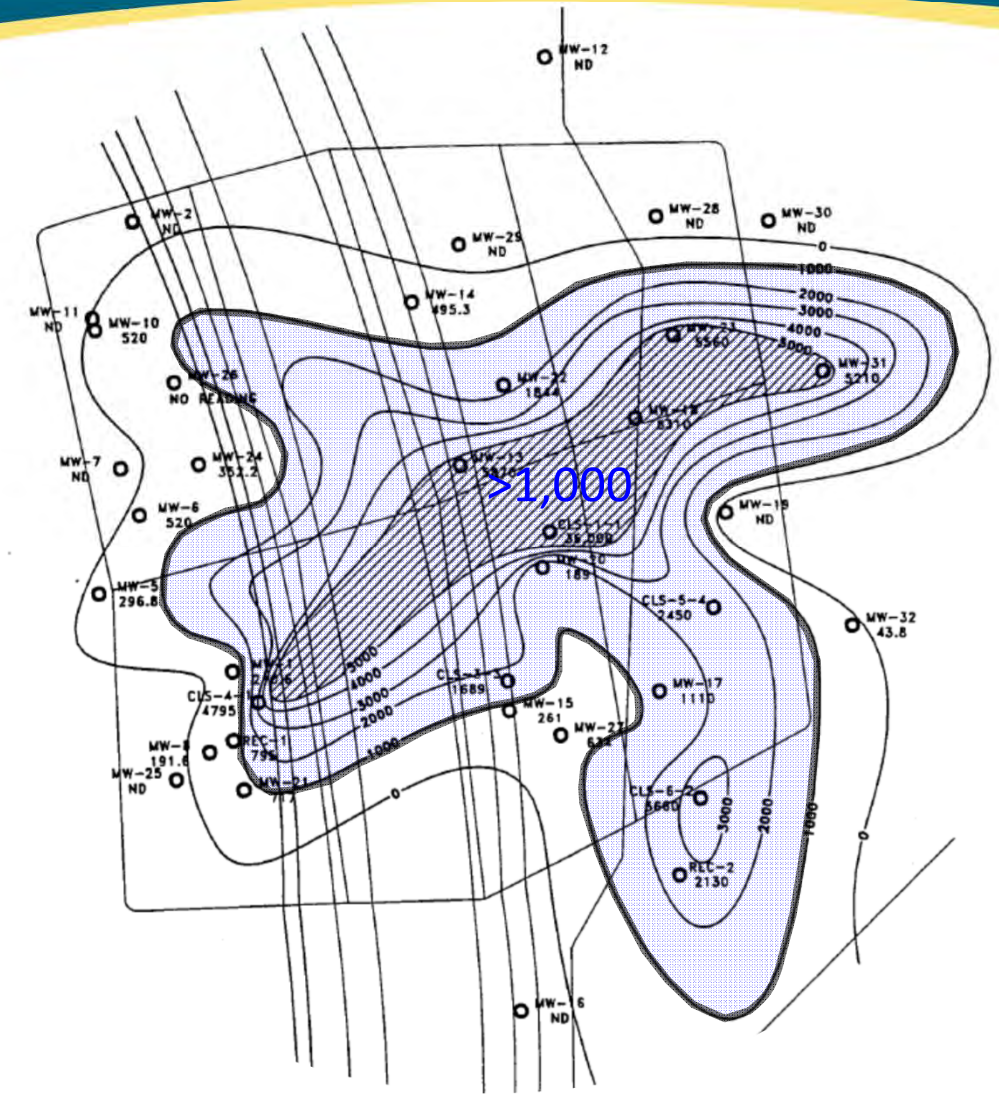
1990 BTEX – 1 mth Bio System Operation (HF)



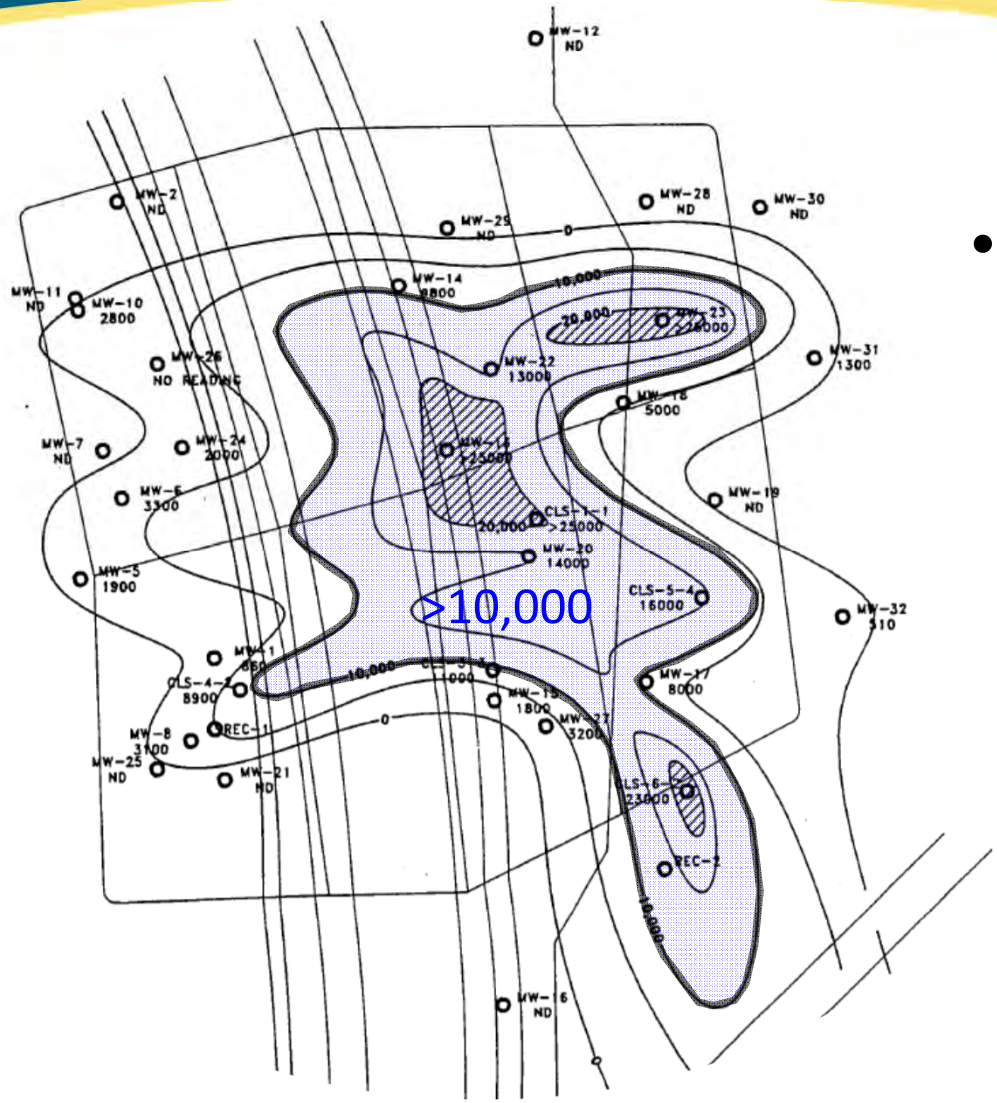
1991 BTEX – Not Operational



1993 BTEX – Bio Injection (HF) and P&T (HF)

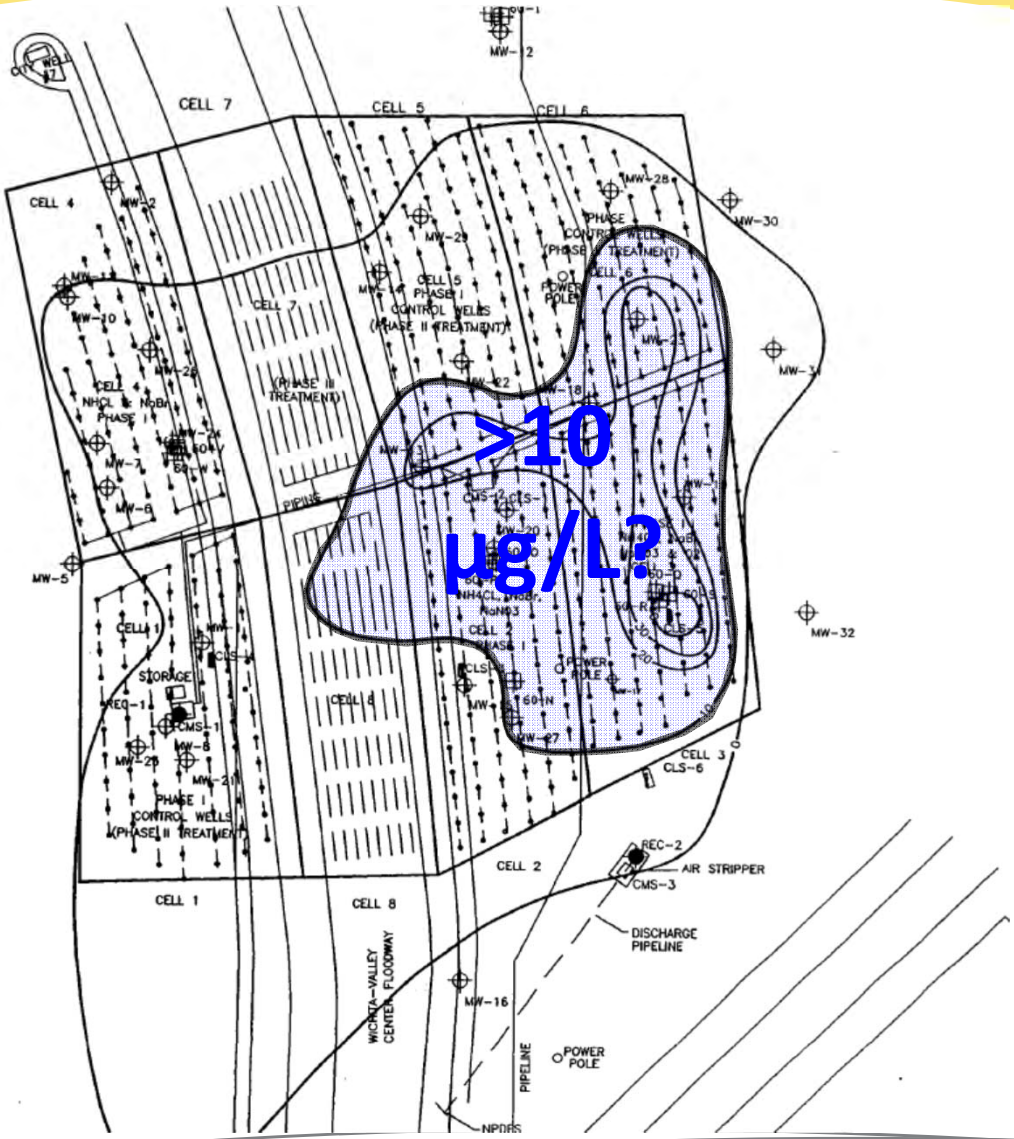


1993 TPH-GRO – Bio Injection (HF) + P&T (HF) (µg/L)

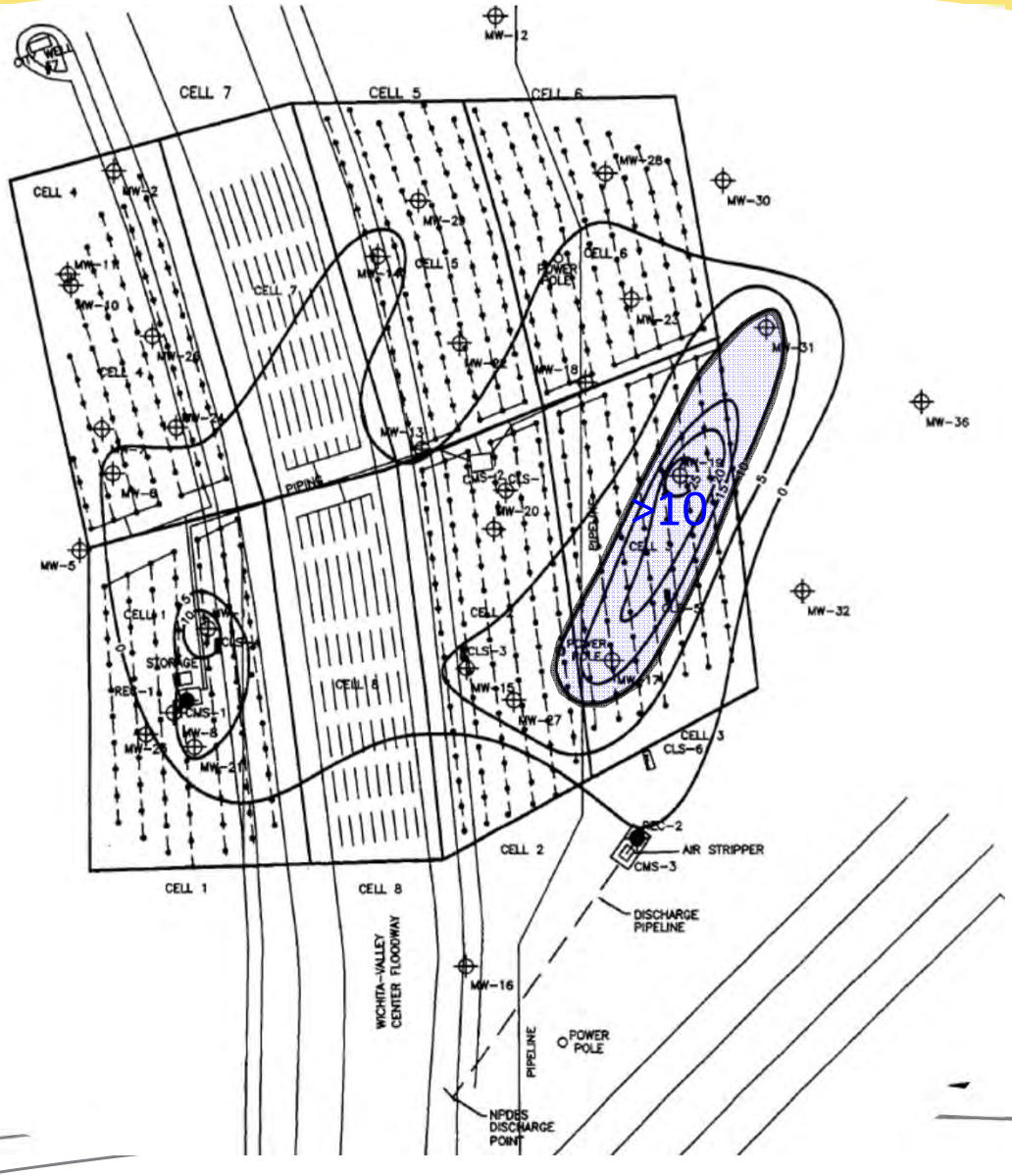


- Same year but a switch to TPH-GRO because we have figures for it through this year (total BTEX eventually dropped)

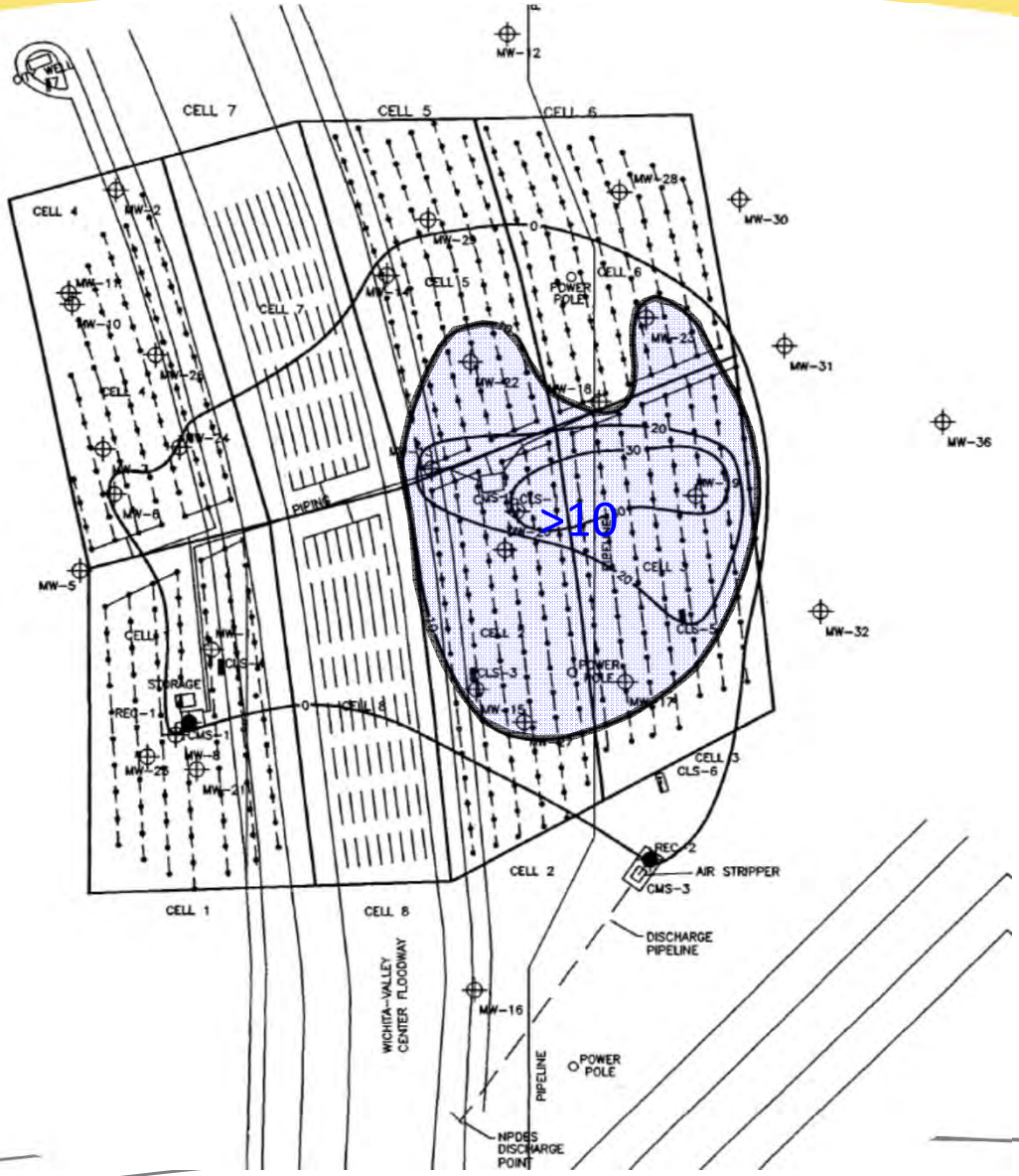
1995 TPH-GRO – Bio Injection (LF) + P&T (HF)



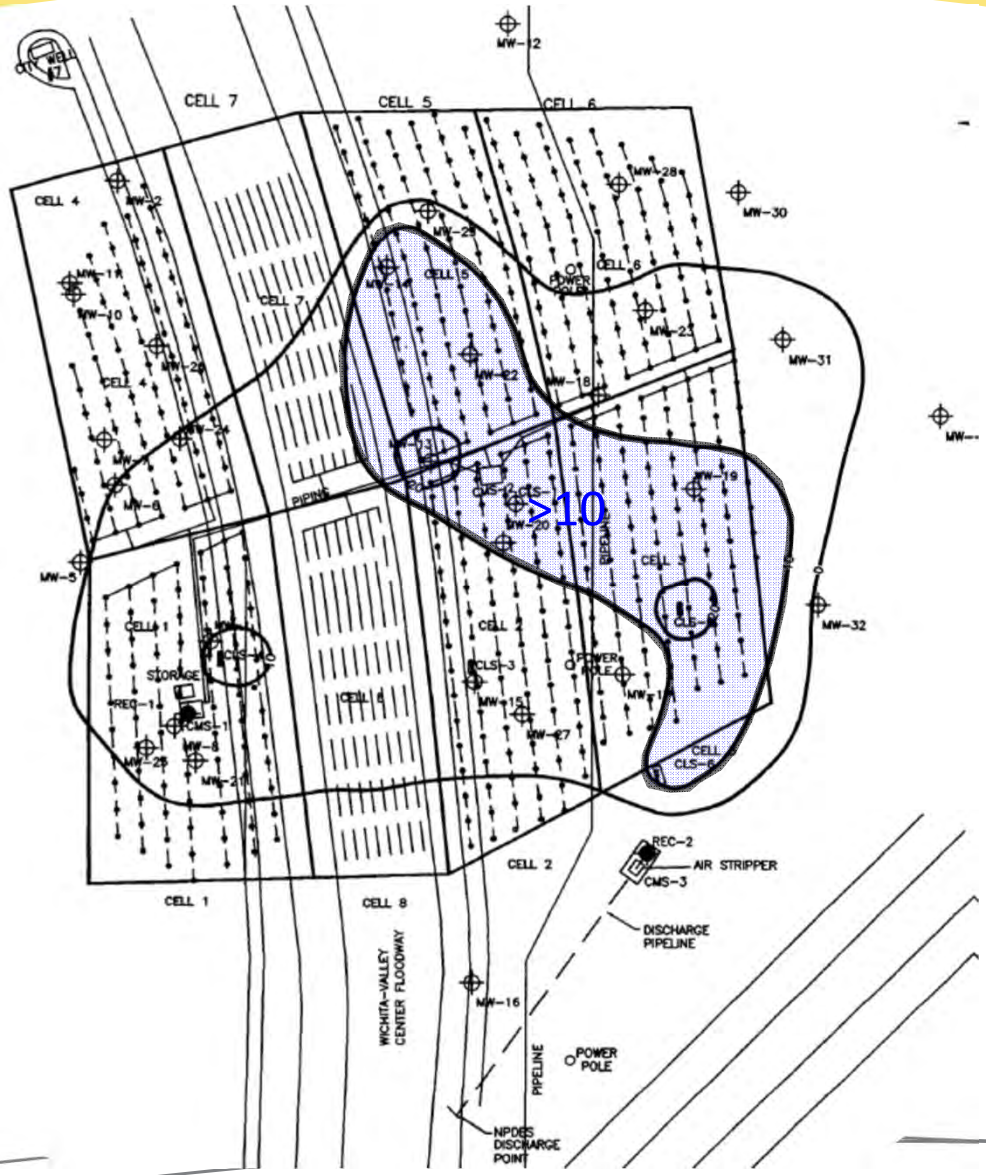
1996 TPH-GRO – Bio Injection (LF) + P&T (HF)



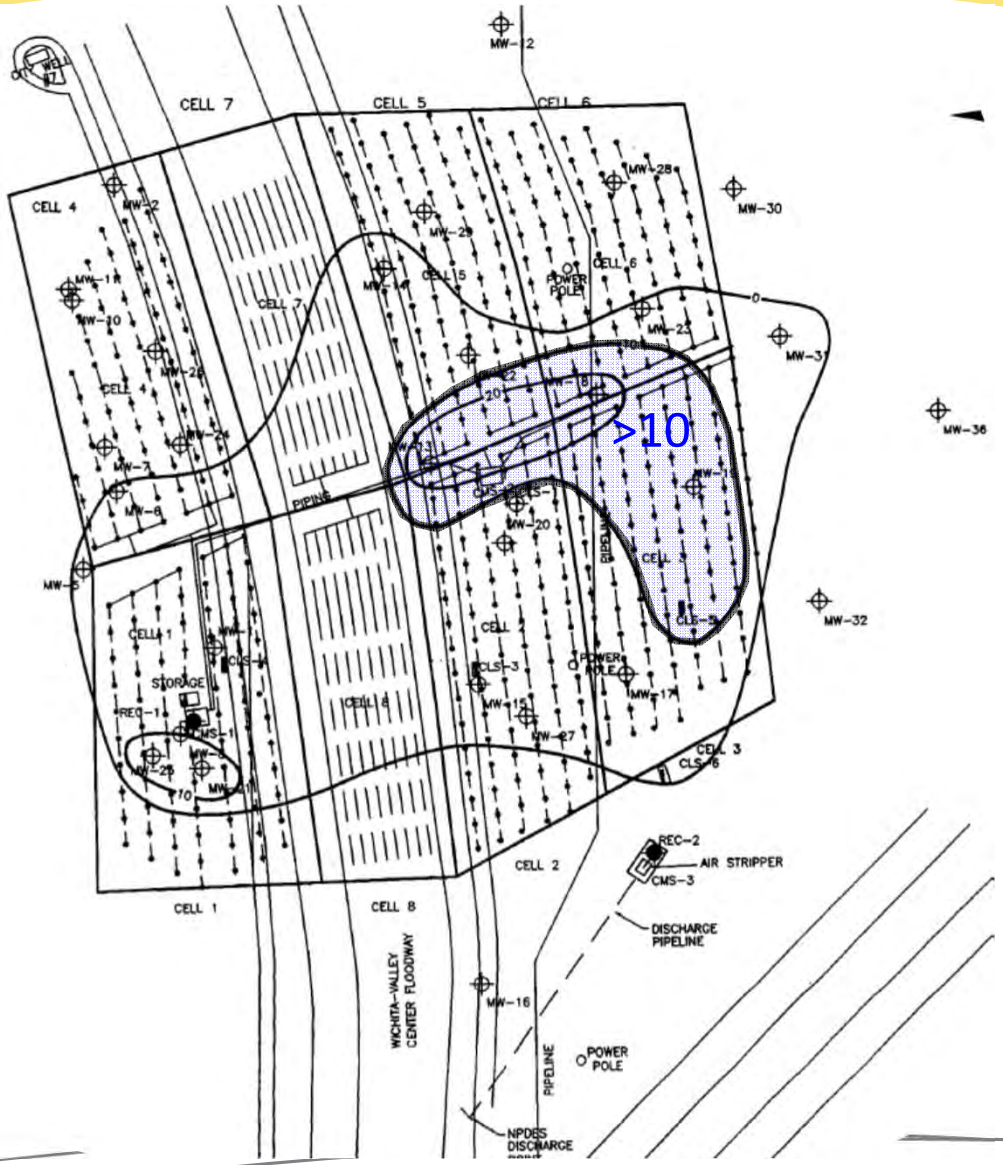
1997 TPH-GRO – Bio Injection (LF) + P&T (HF)



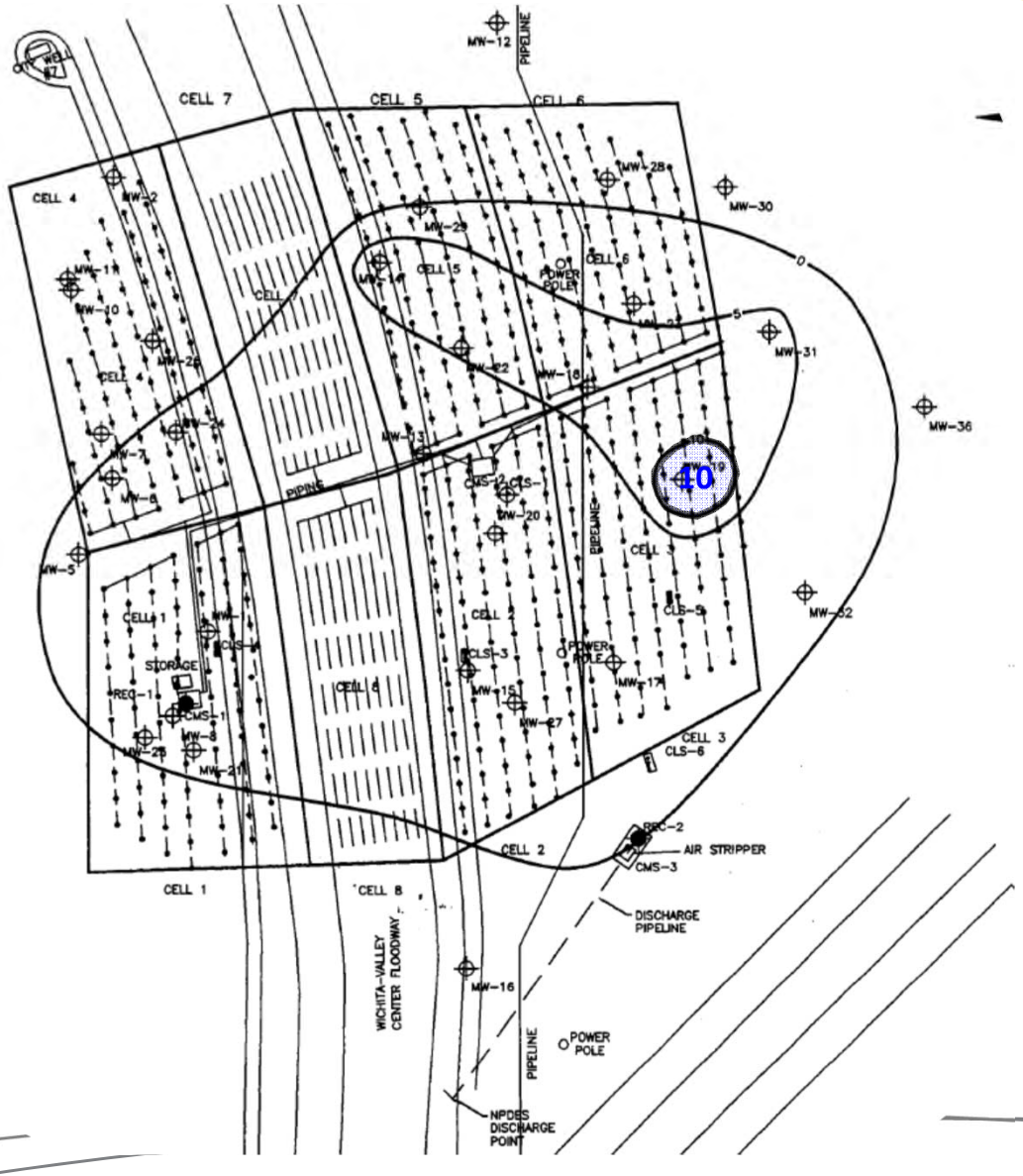
1998 TPH-GRO – Bio Injection (LF) + P&T (HF)



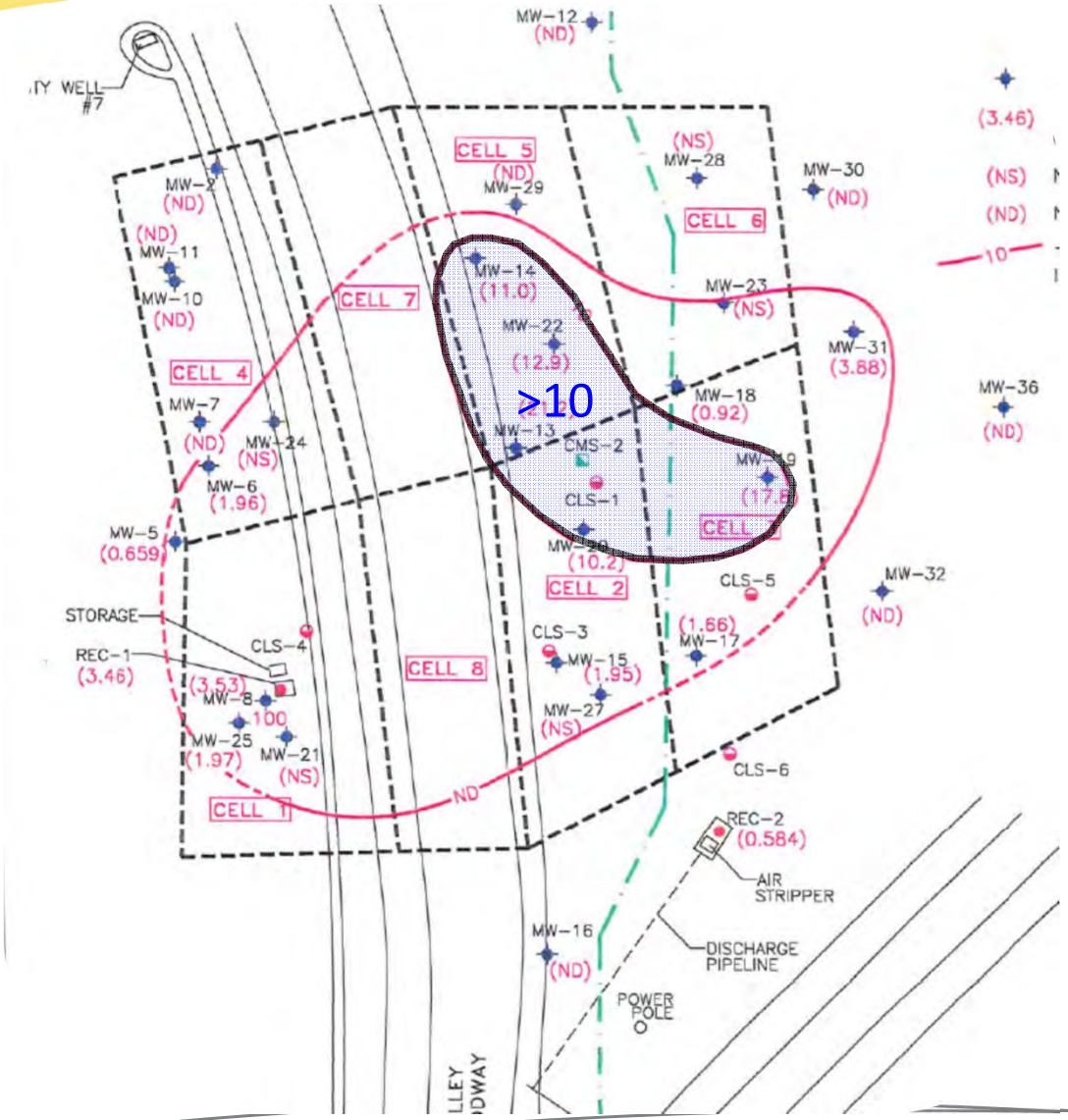
1999 TPH-GRO – Bio Injection (LF) + P&T (HF)



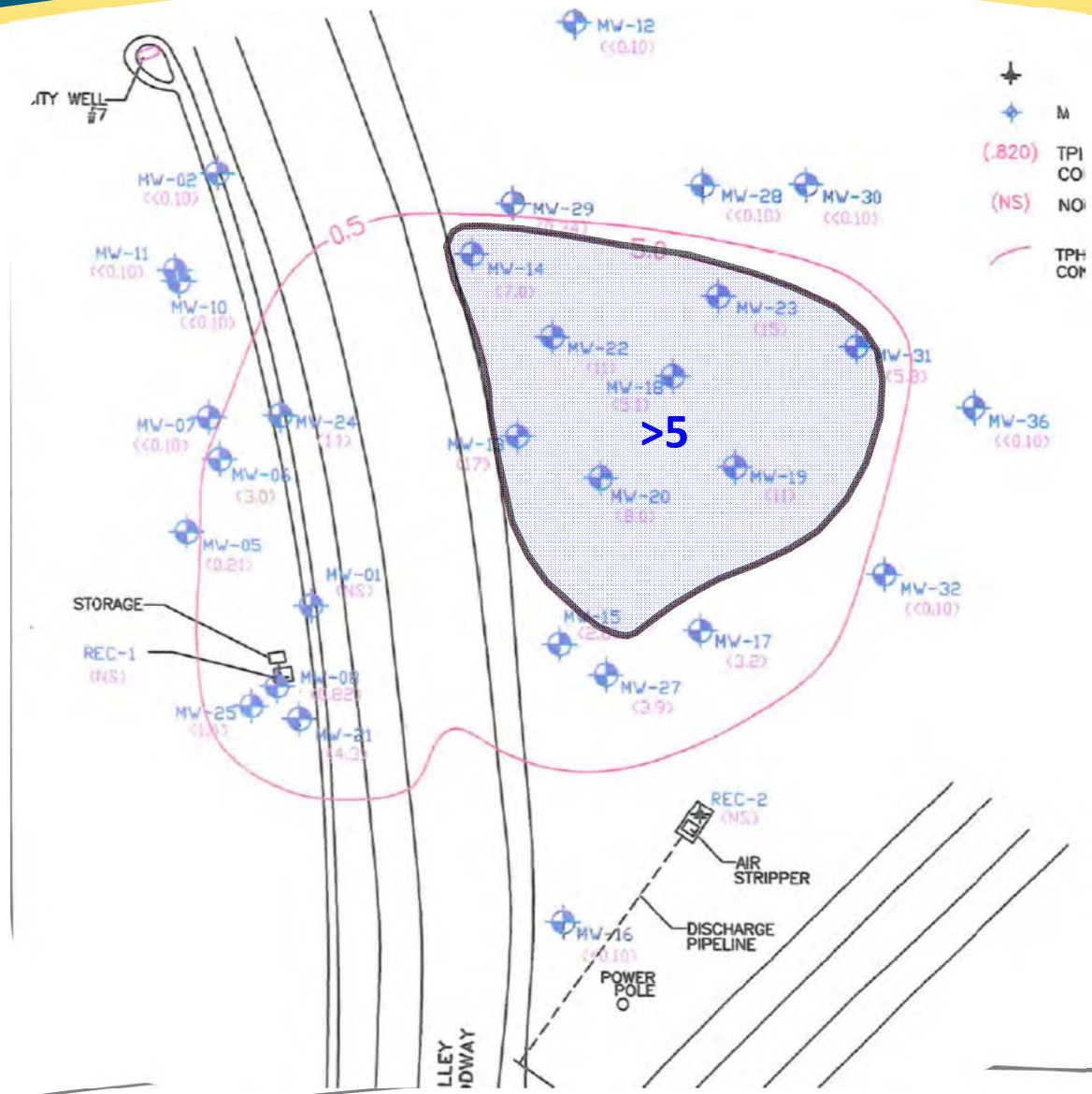
2000 TPH-GRO – Bio Injection (LF) + P&T (HF)



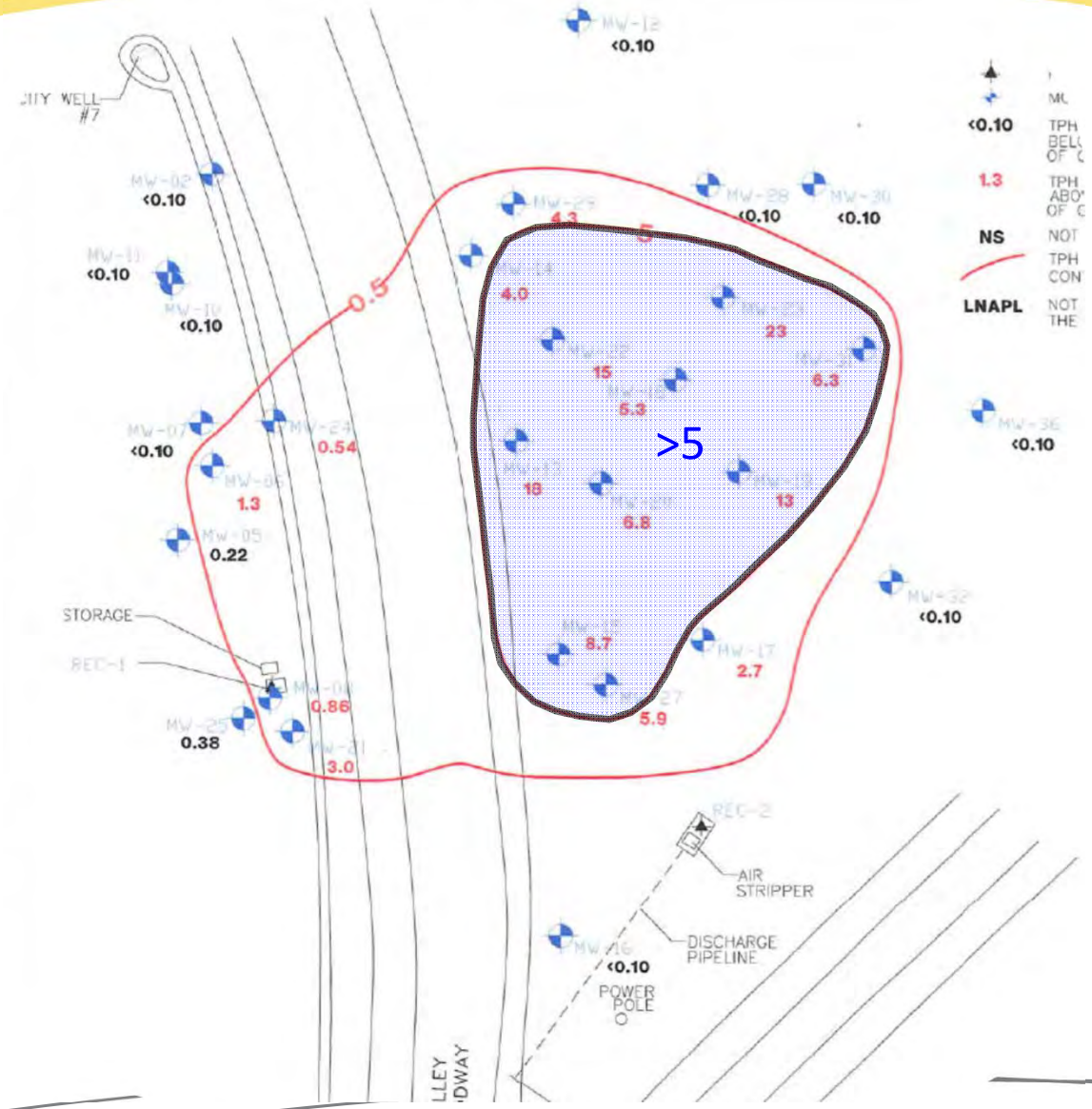
2001 TPH-GRO – Bio Injection (LF) + P&T (HF)



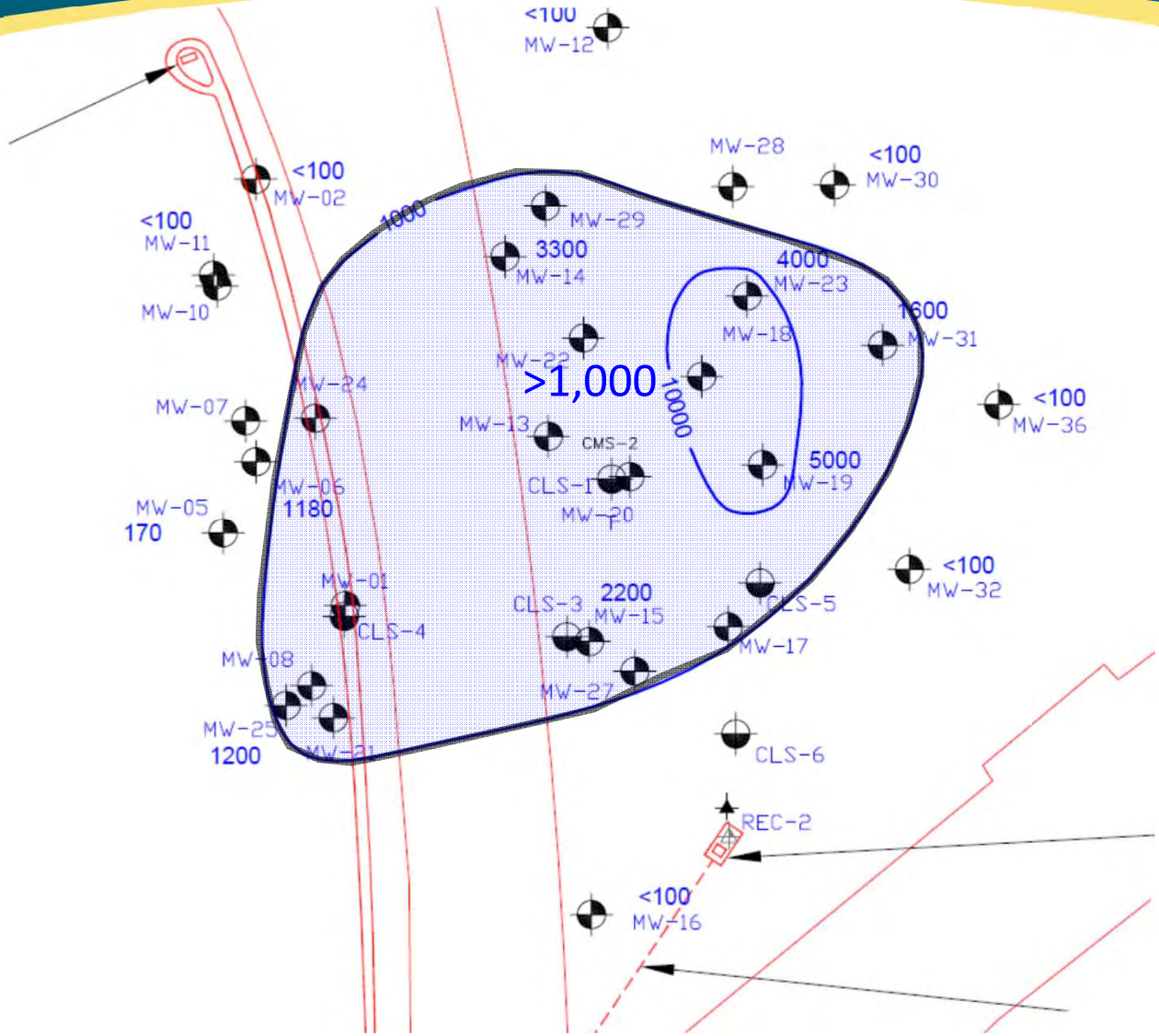
2002 TPH-GRO – Bio Injection (LF) + P&T (HF)



2003 TPH-GRO – Bio Injection (LF) + P&T (HF)



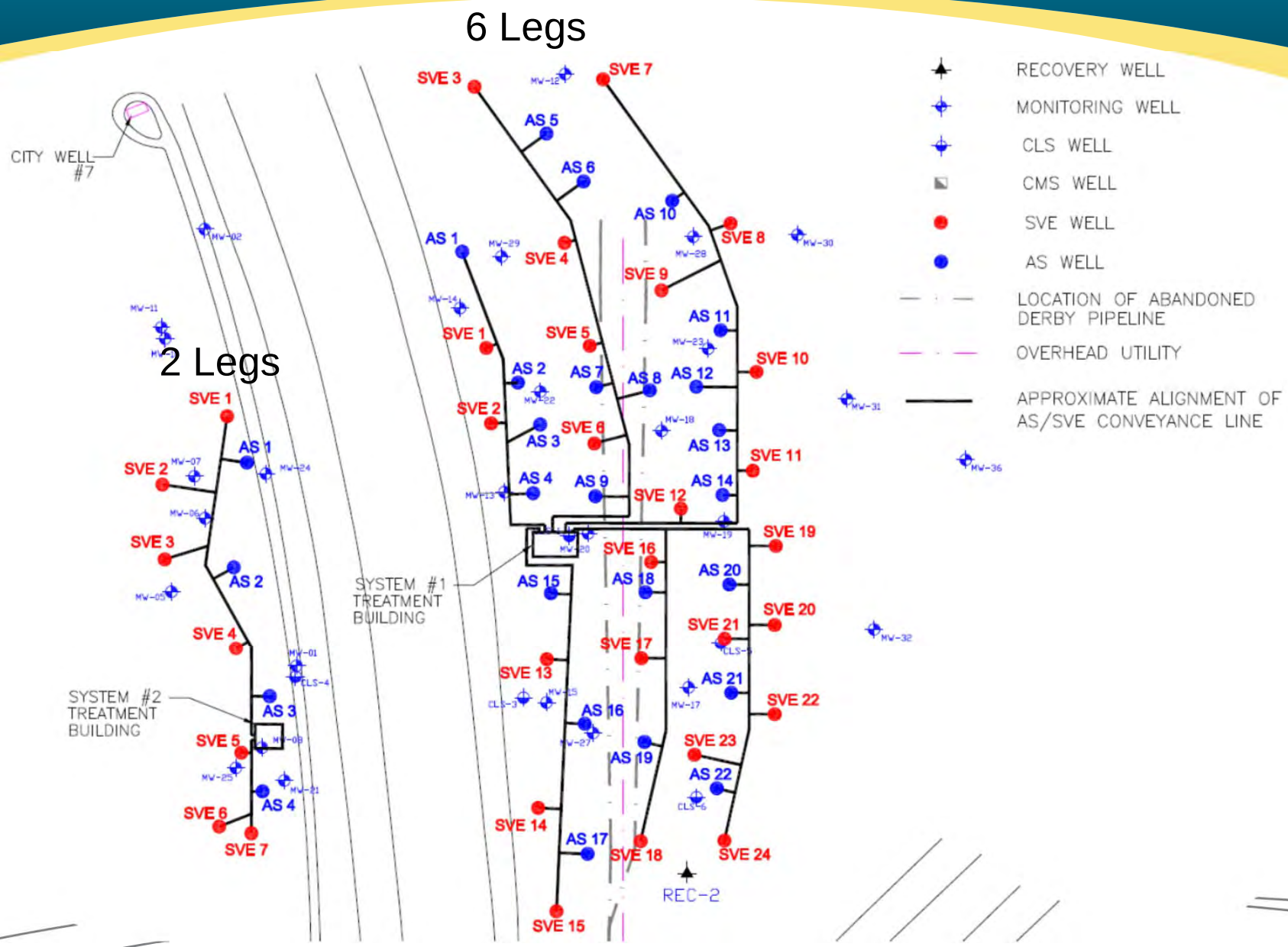
2004 TPH-GRO – Rebound Study



SVE-AS System – Installed Late 2004

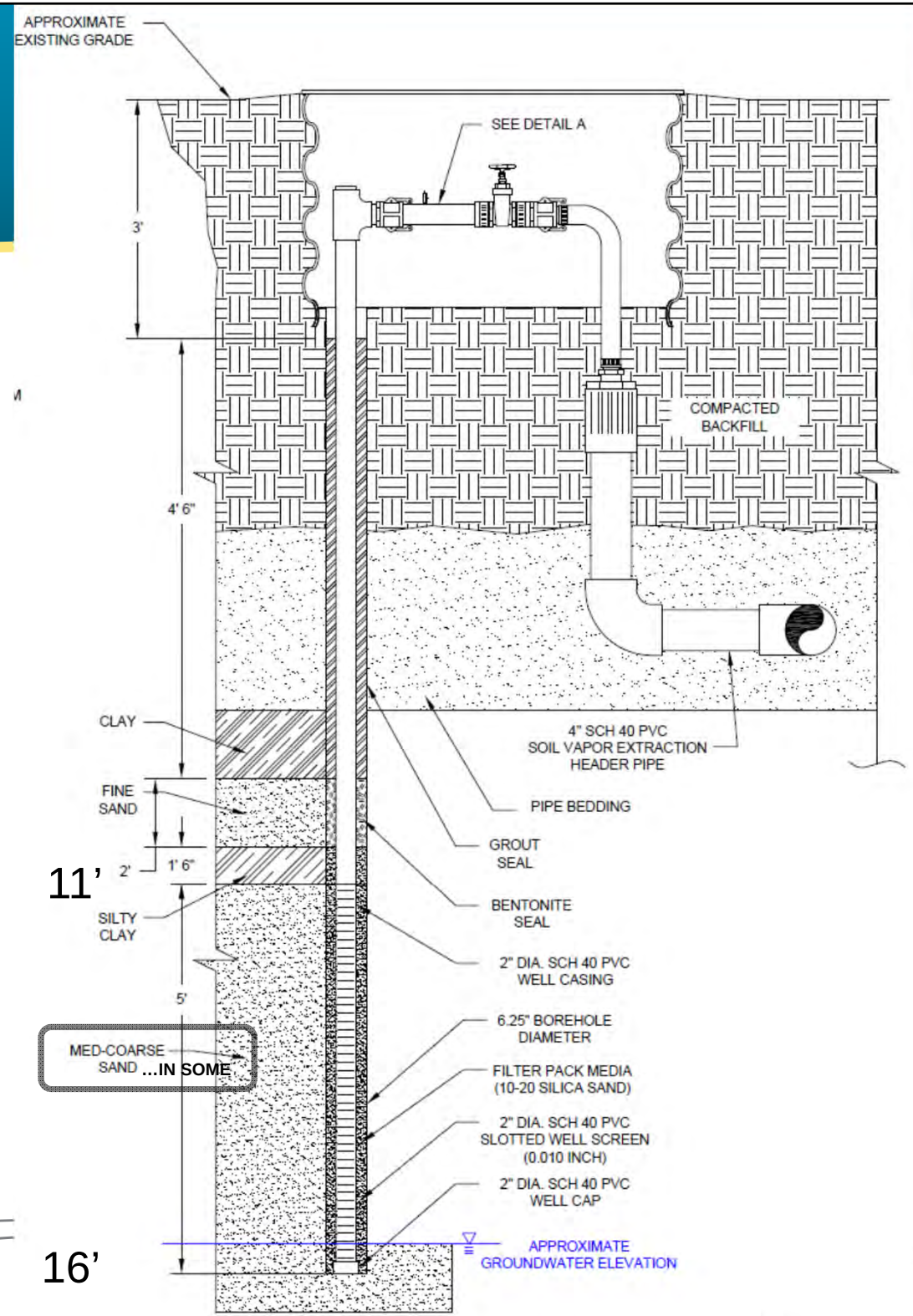
- East Side (System #1): 24 SVE and 22 AS Wells
  - SVE Blower: 3.5 hp Regenerative, 200-230 scfm actual
  - AS Compressor: 40 hp Rotary Screw, 130 scfm actual
- West Side (System #2): 7 SVE and 4 AS Wells
  - SVE Blower: 1.25 hp Regenerative, 60-100 scfm actual
  - AS Compressor: 7.5 hp Rotary Screw, 30 scfm
- No AS pulsing
  - East side: 130 scfm / 22 AS wells = 6 scfm/well
  - West side: 30 scfm / 4 AS wells = 7 scfm/well

SVE/AS Plan View



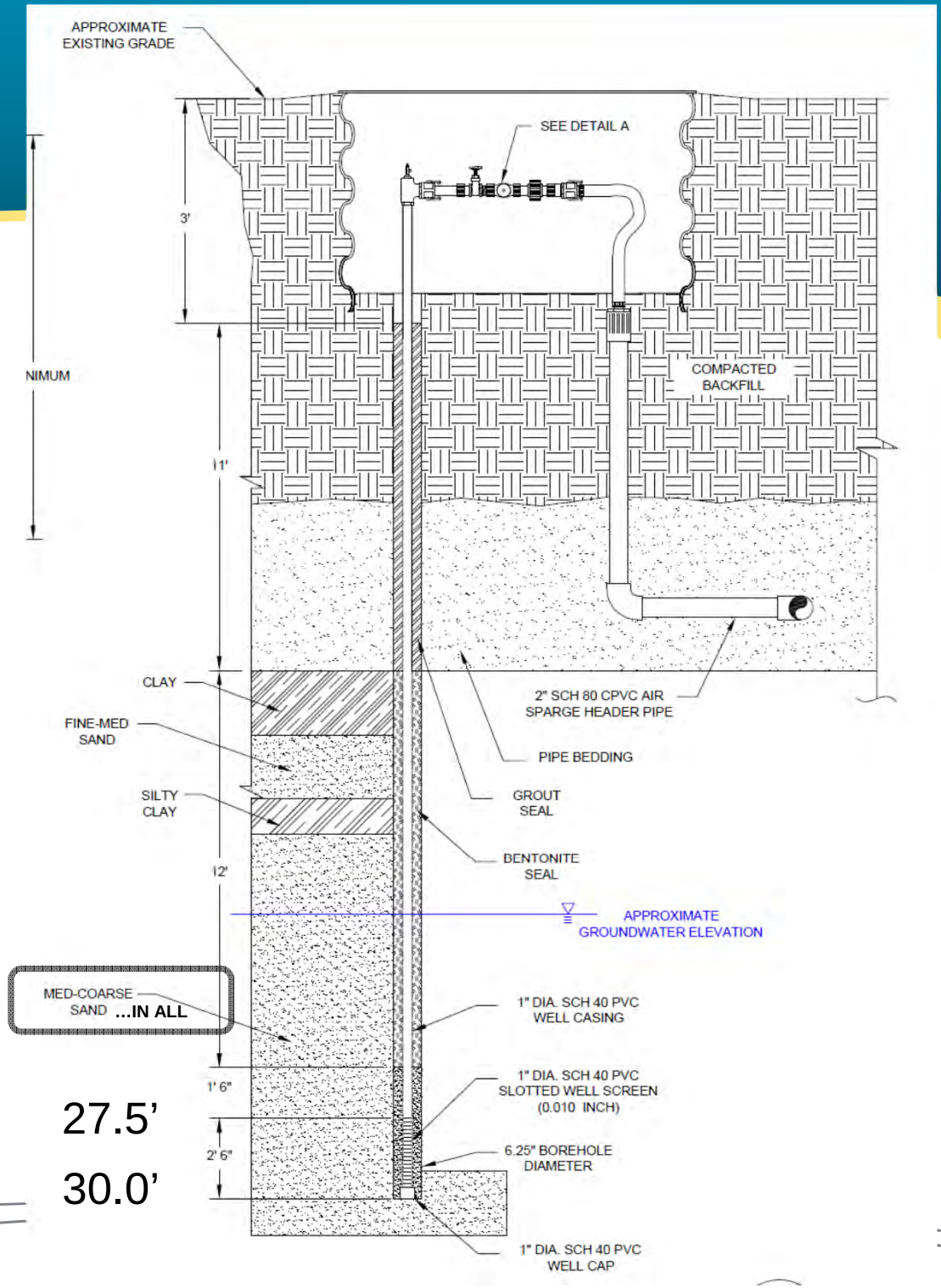
SVE Well Design

- Variable flow rates depending upon sand vs clay/silt interval
- Originally, no ability to monitoring individual well flow (added rotometers)

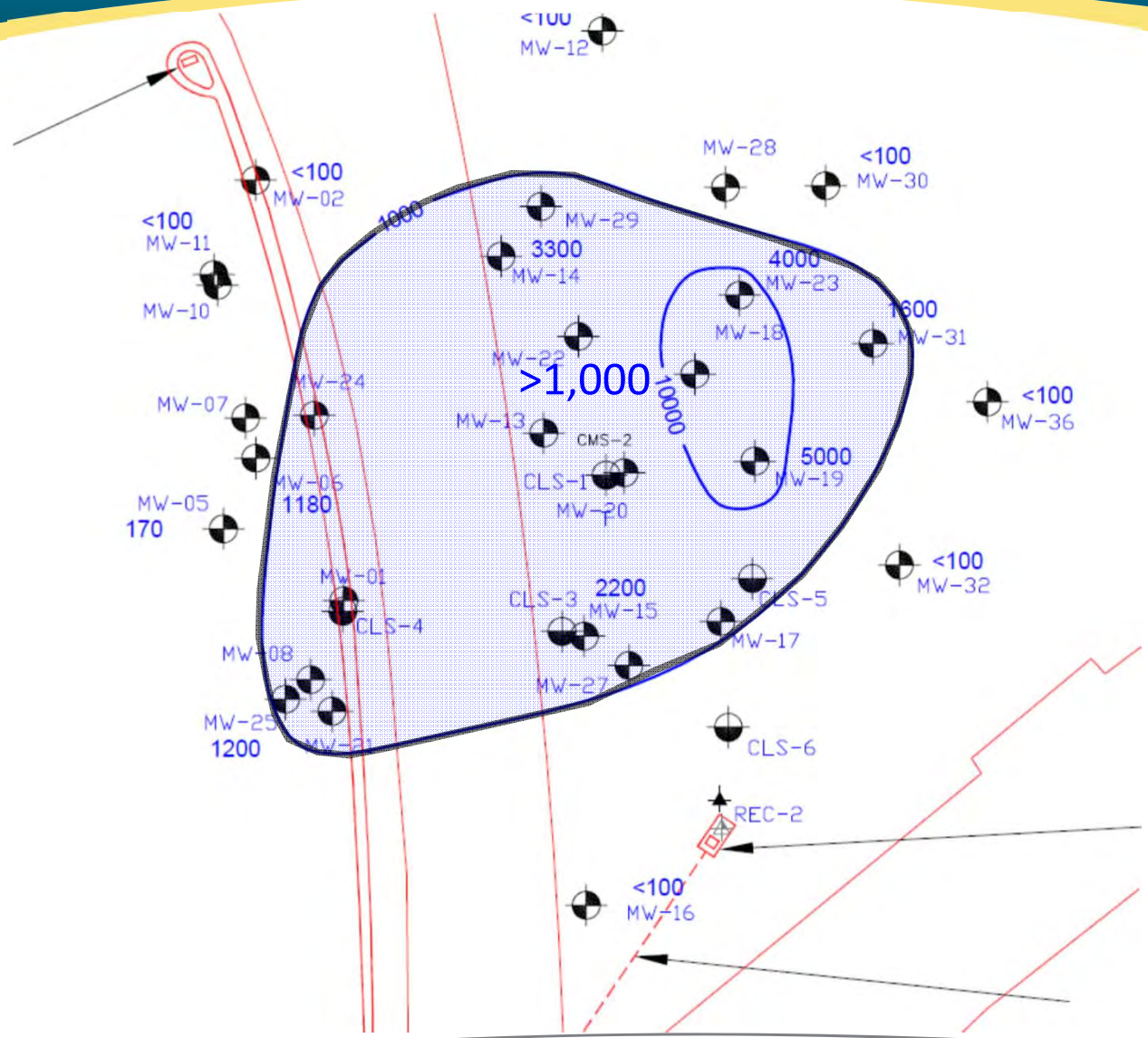


AS Well Design

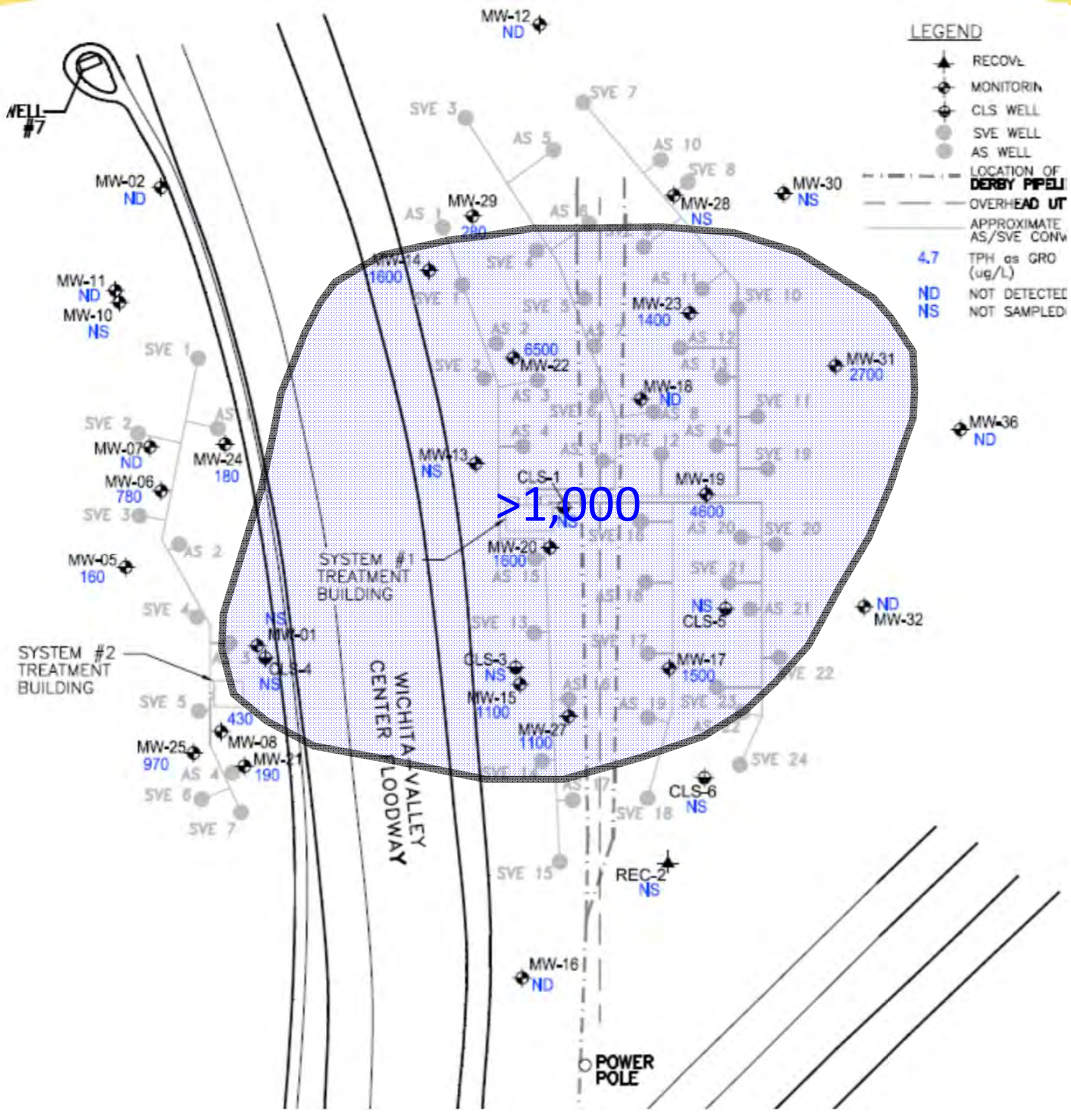
- Relatively uniform flow rates of greater than 20 scfm possible
- Originally, no ability to monitor individual well flow (added rotometers)



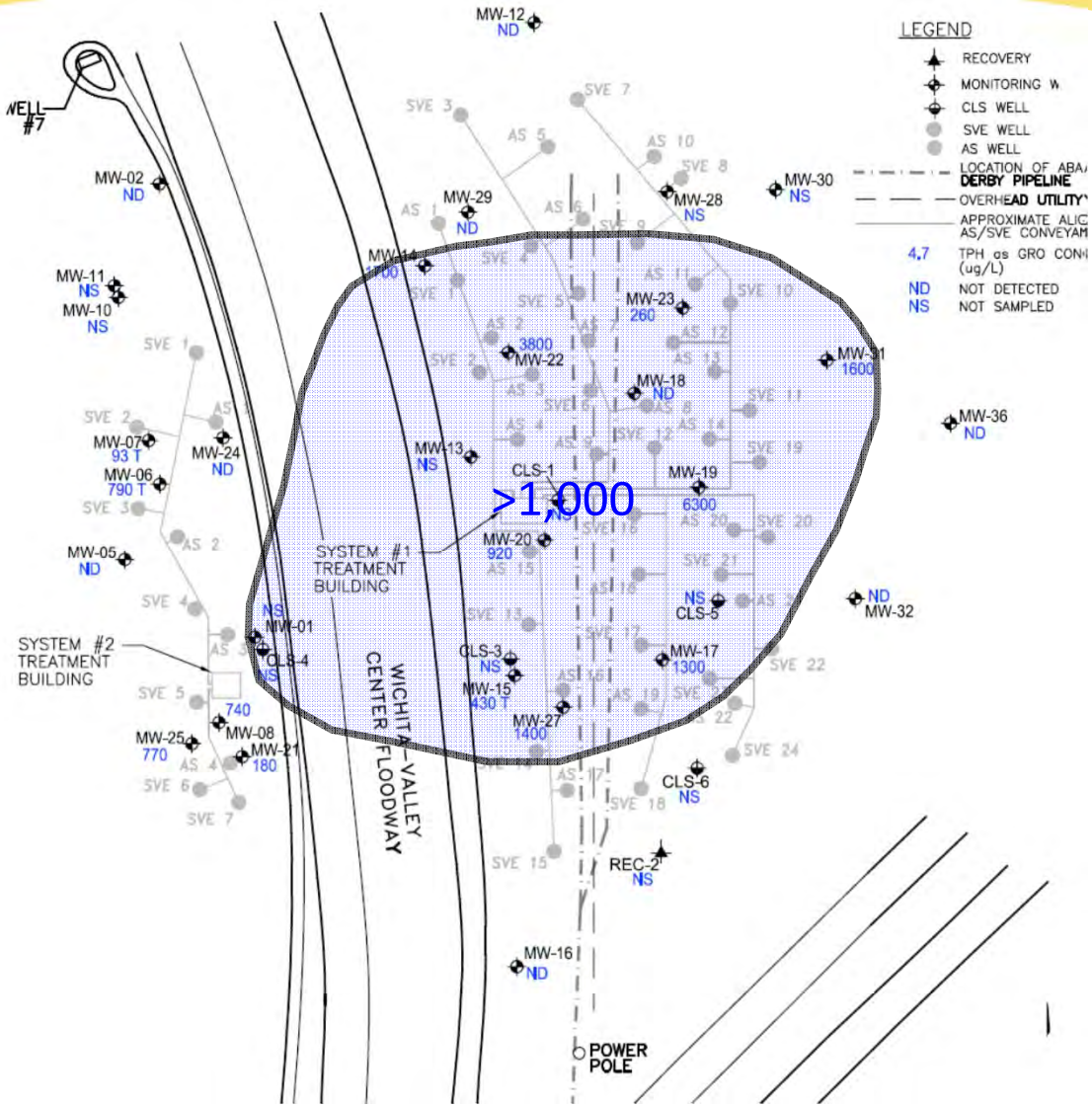
2004 TPH-GRO – Rebound Study (revisited)



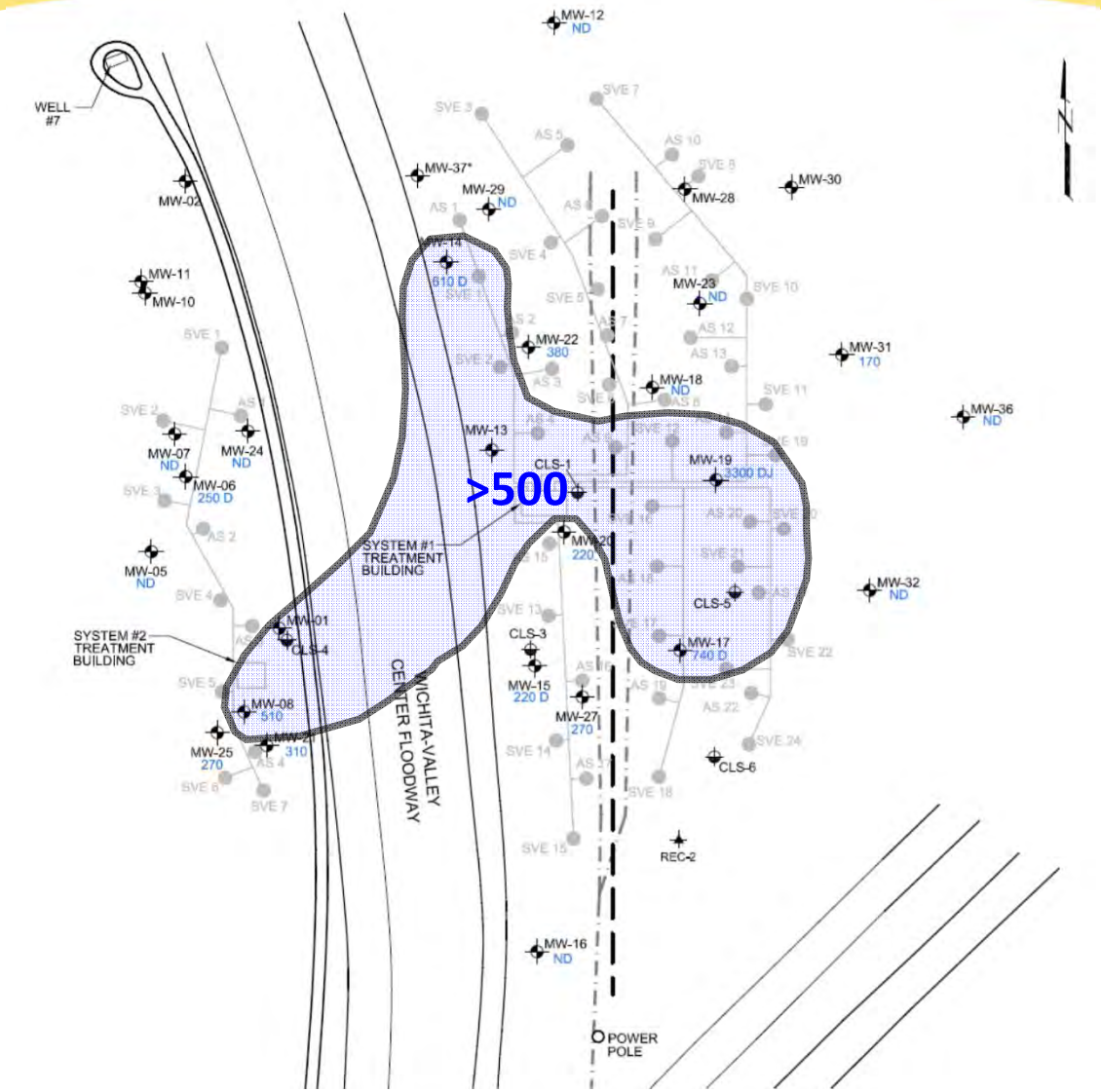
2005 TPH-GRO – SVE/AS – No Pulse



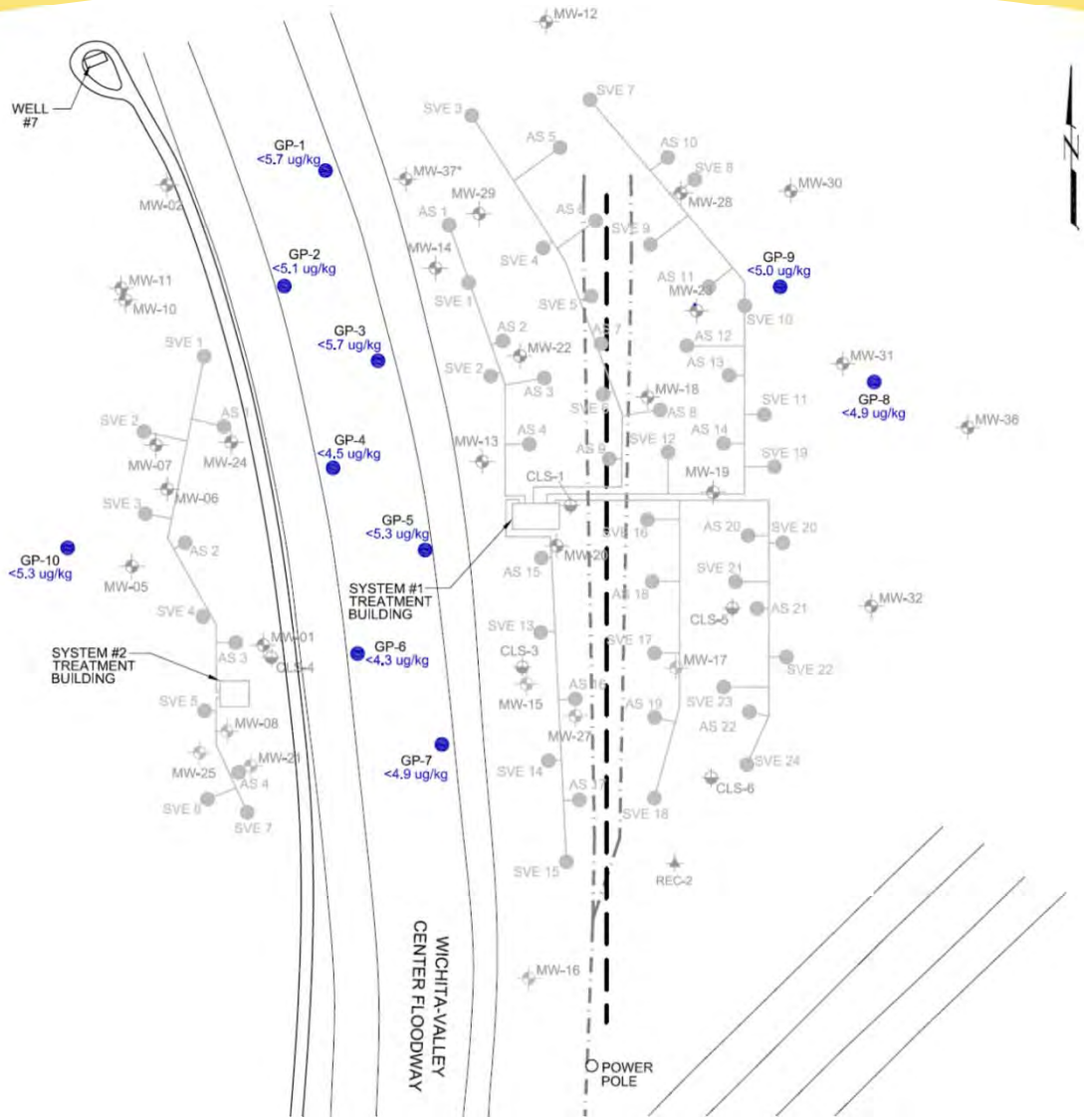
2006 TPH-GRO – SVE/AS, E Side 2 Zone Pulse



2007 TPH-GRO – SVE/AS

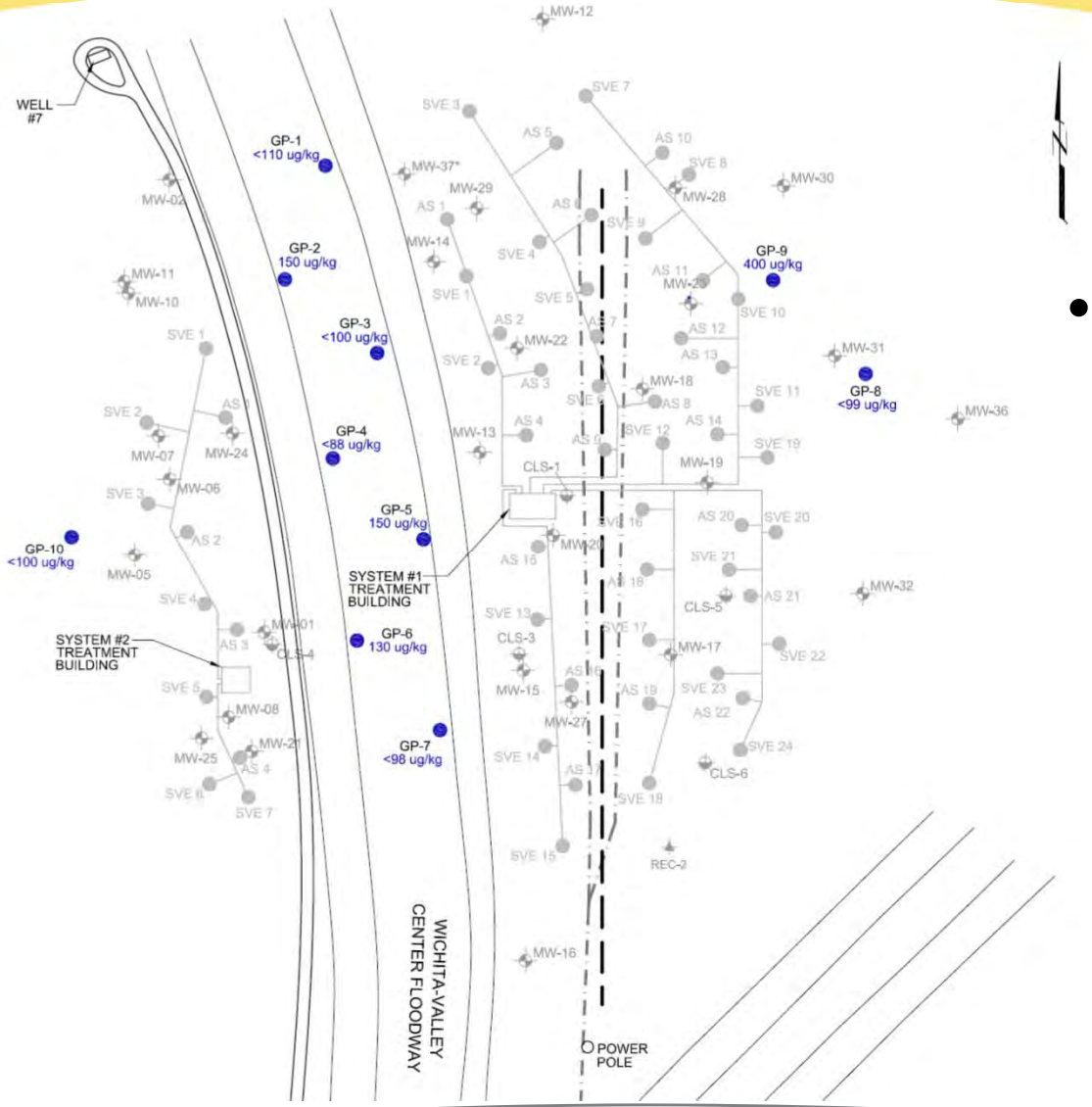


2008 Floodway+ Investigation – Soil Benzene



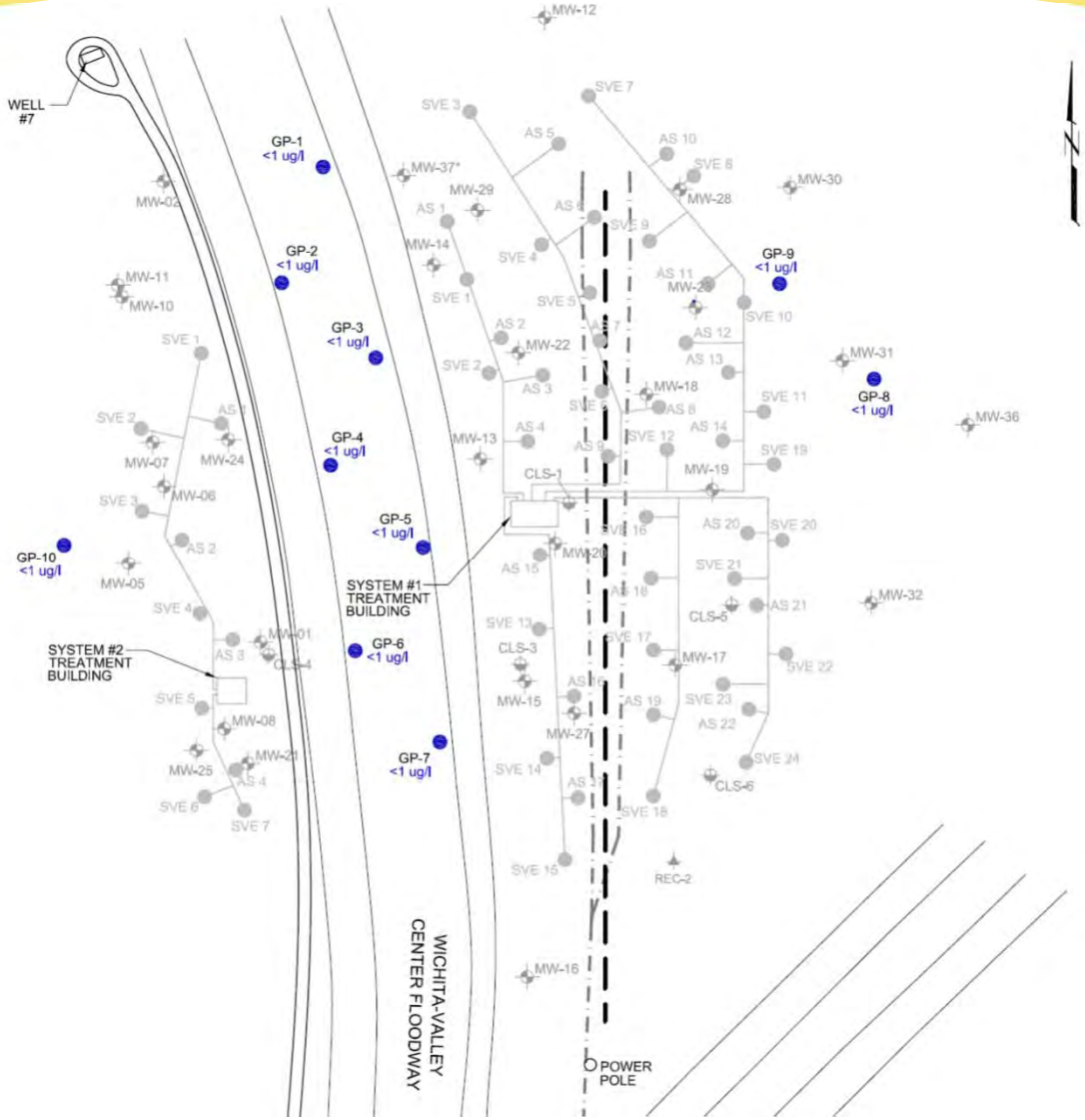
- All <15.9 mg/kg (all non-detect)

2008 Floodway+ Investigation – Soil TPH-GRO



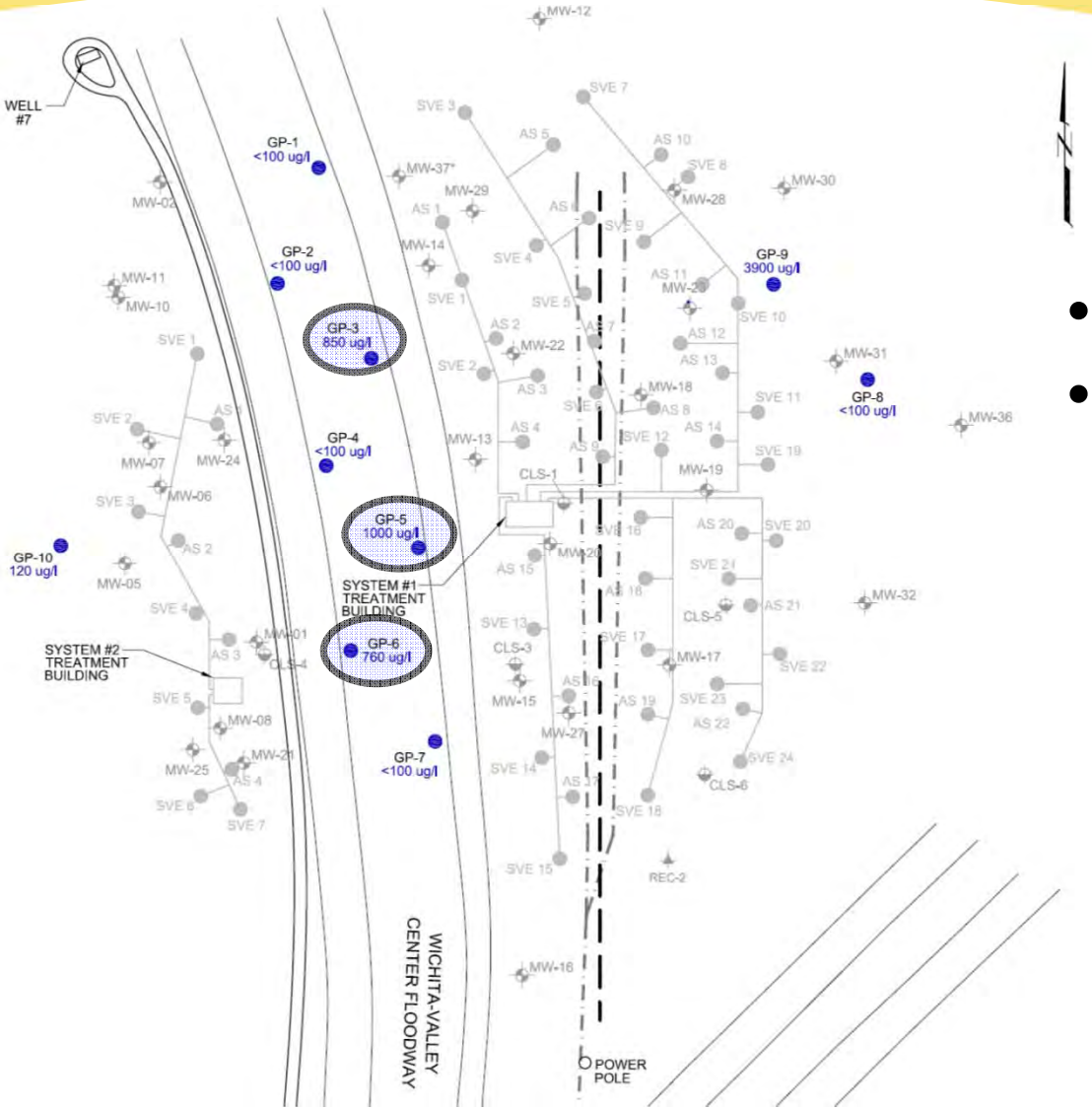
- All < 220 mg/kg (in the floodway)

2008 Floodway+ Investigation – GW Benzene



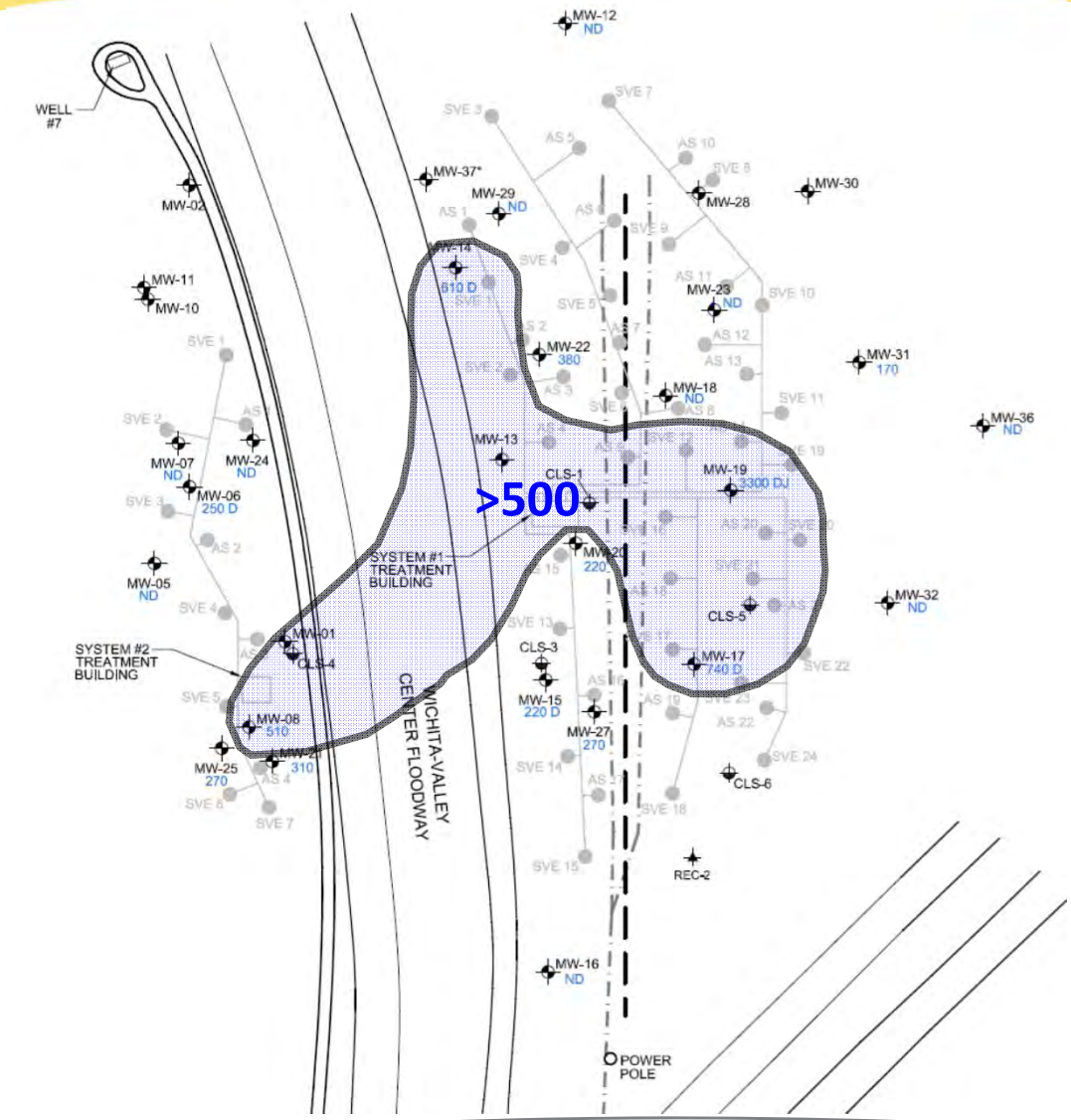
- All < 5 ppb (all non-detect)

2008 Floodway+ Investigation – GW TPH-GRO

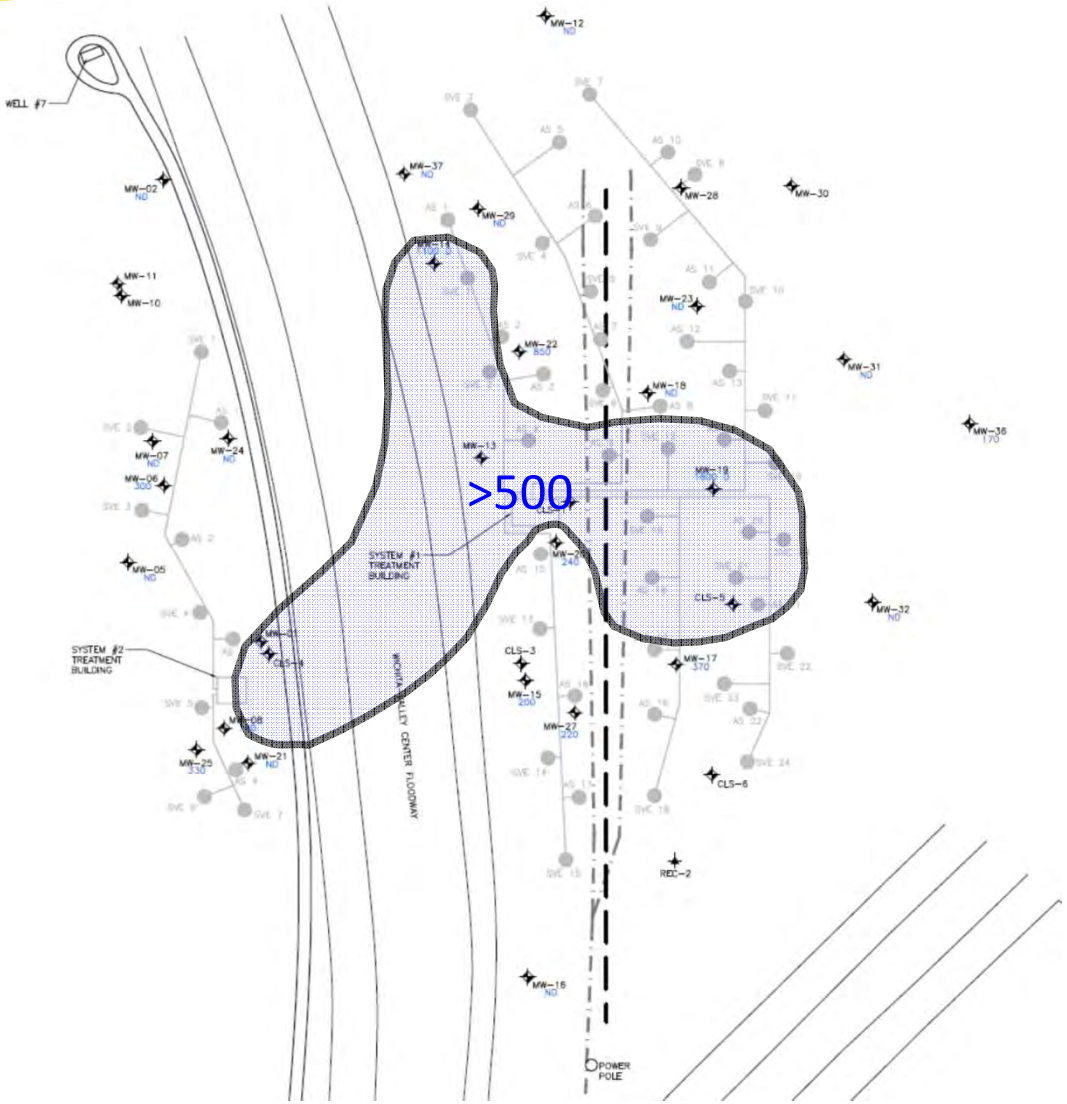


- A few > 500 µg/L
- Similar to nearby MWs

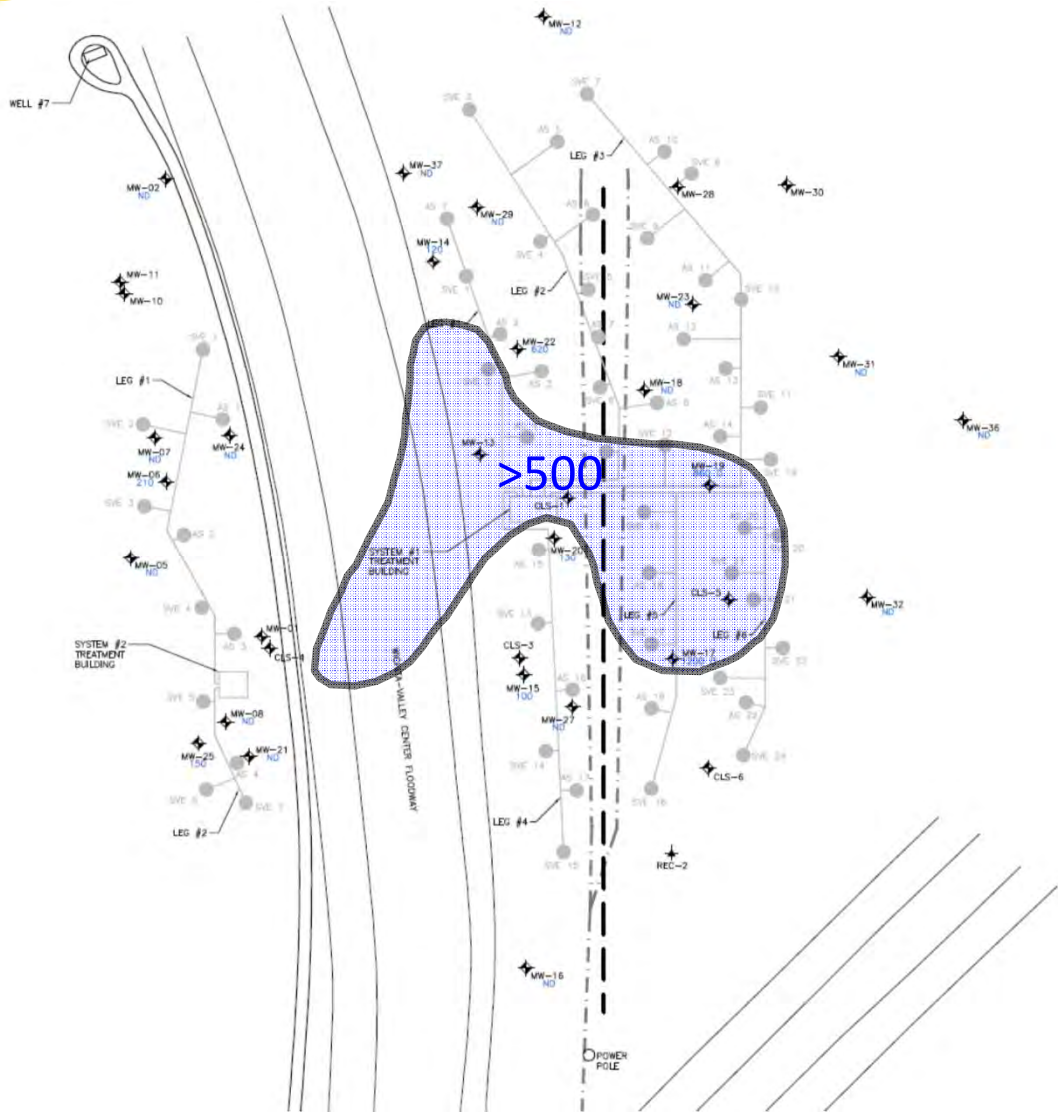
2007 TPH-GRO – SVE/AS (repeat)



2008 TPH-GRO – SVE/AS

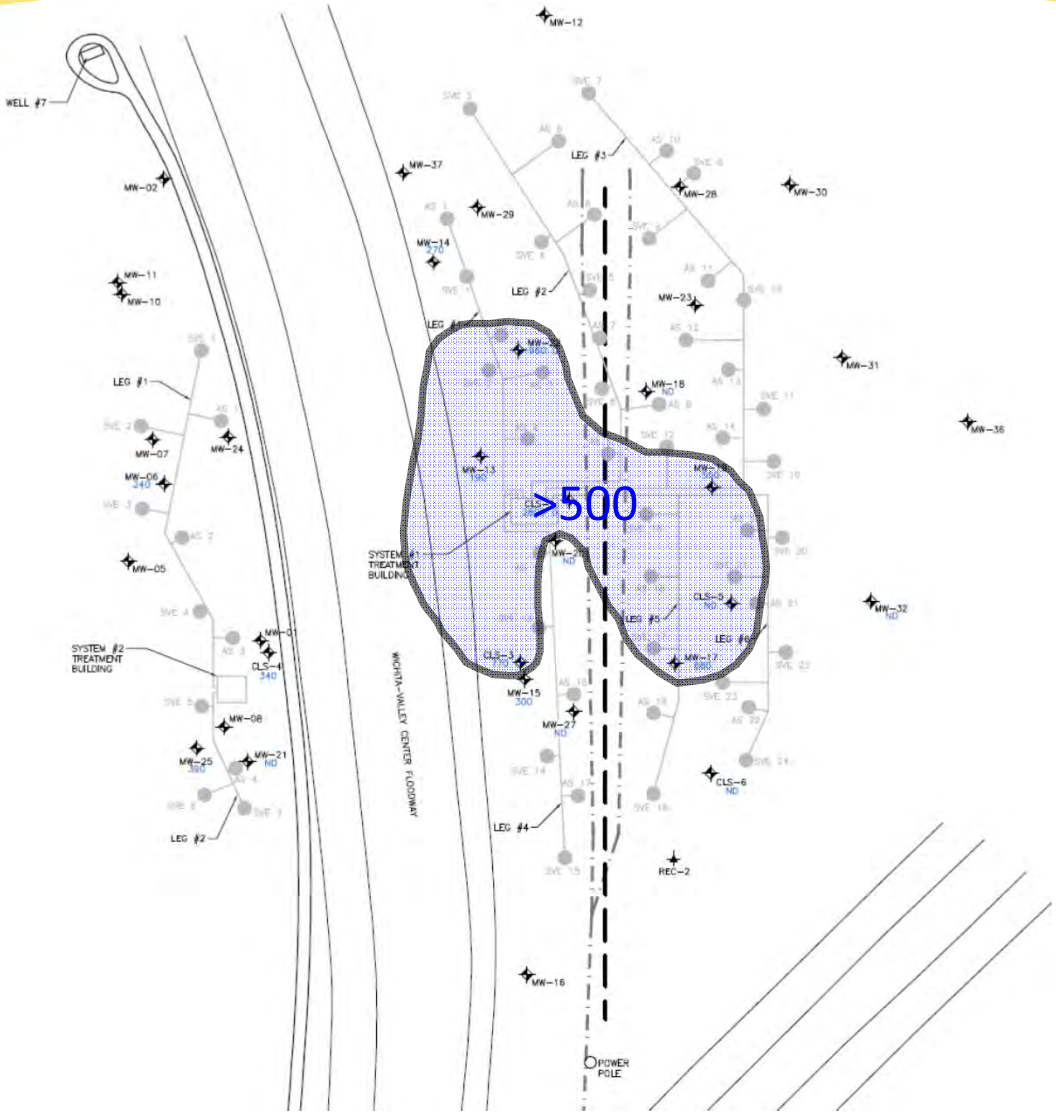


2009 TPH

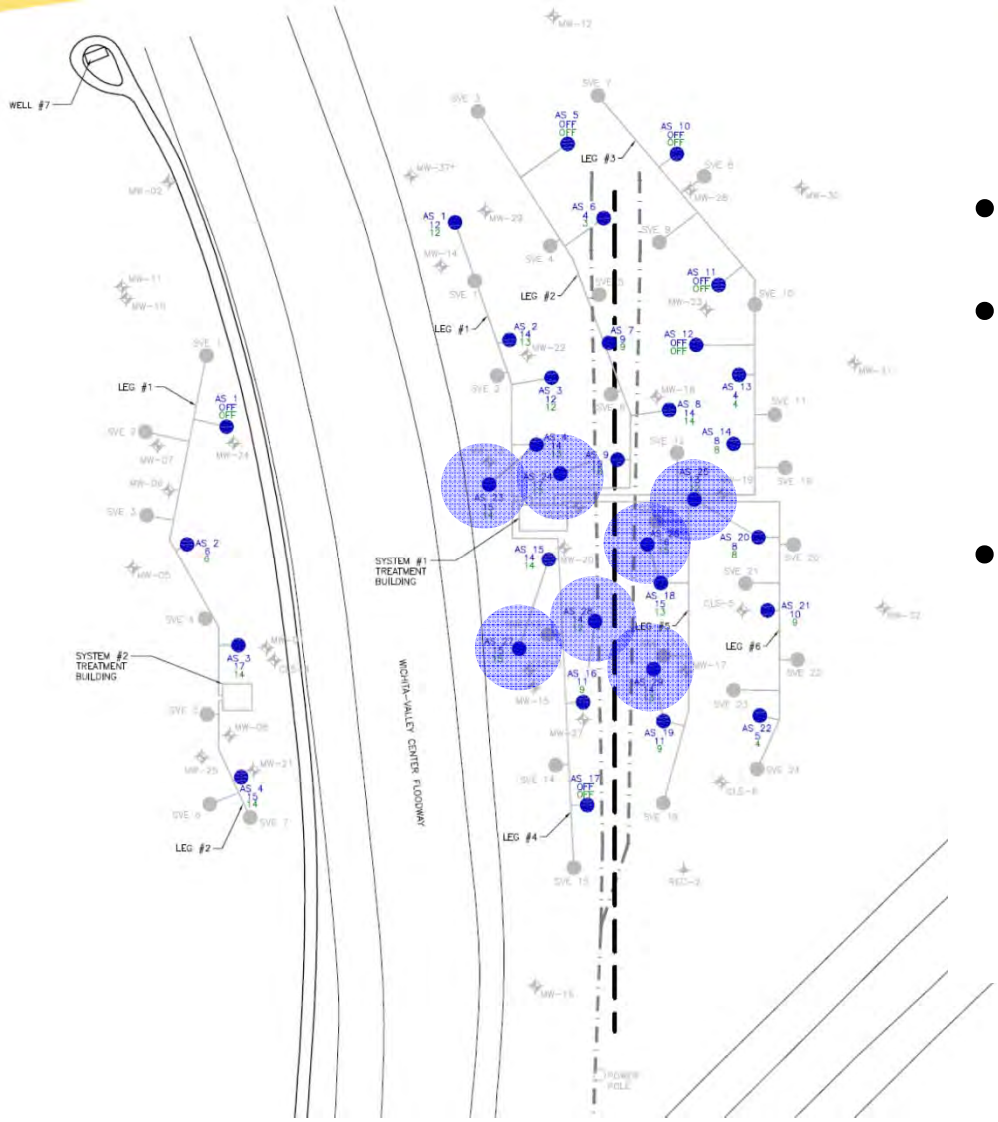


>500
WELL #7
LEG #1
LEG #2
LEG #3
LEG #4
LEG #5
LEG #6
SYSTEM #1 TREATMENT BUILDING
SYSTEM #2 TREATMENT BUILDING
VALLEY CENTER FLOODWAY
POWER POLE
MW-12
MW-37
MW-02
MW-29
MW-28
MW-30
MW-14
MW-11
MW-10
MW-23
MW-22
MW-31
MW-18
MW-36
MW-07
MW-24
MW-06
MW-13
MW-19
MW-05
MW-20
MW-32
MW-01
CLS-4
CLS-3
MW-15
MW-17
MW-08
MW-27
MW-25
MW-21
CLS-6
REC-2
MW-16

2010 TPH-GRO – SVE/AS

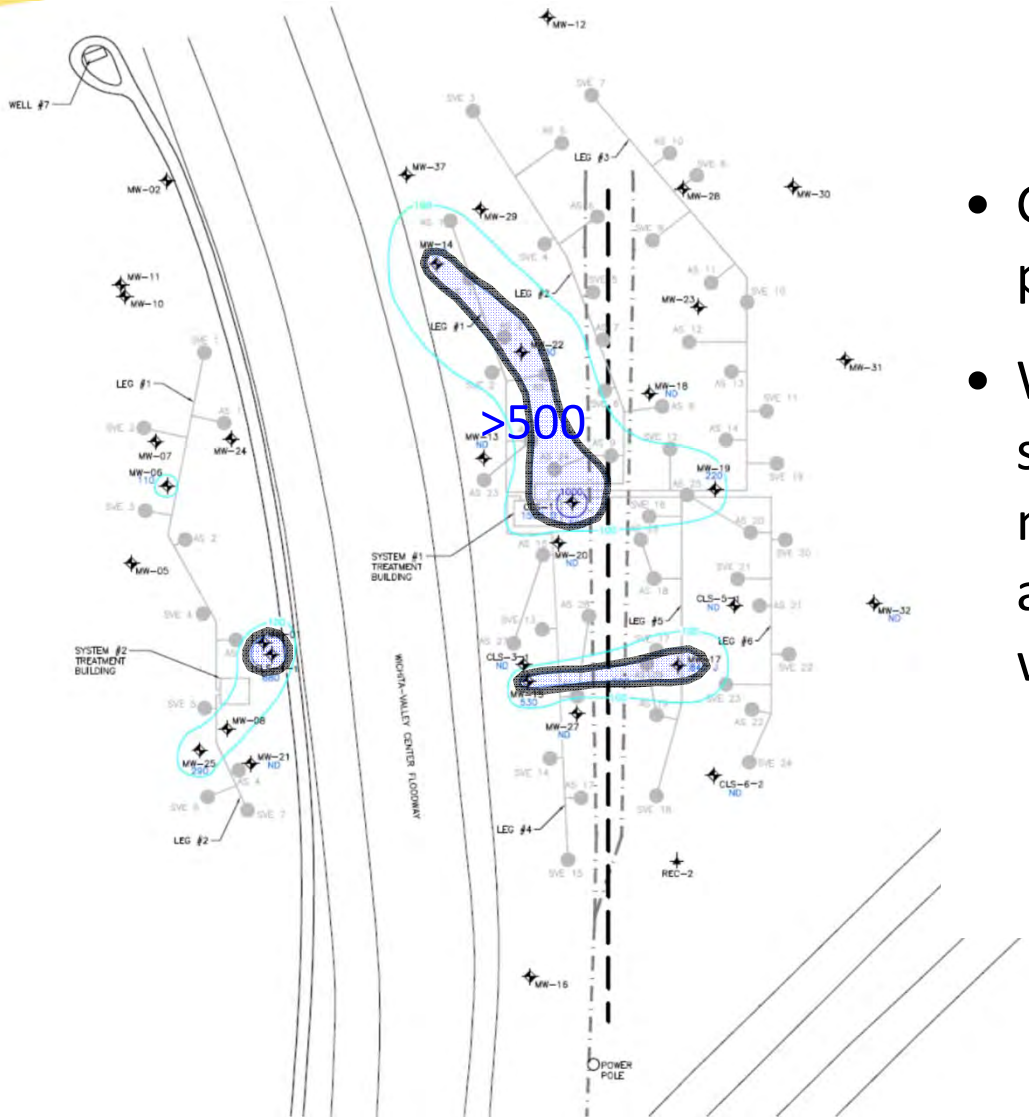


2011 March - Additional AS Wells



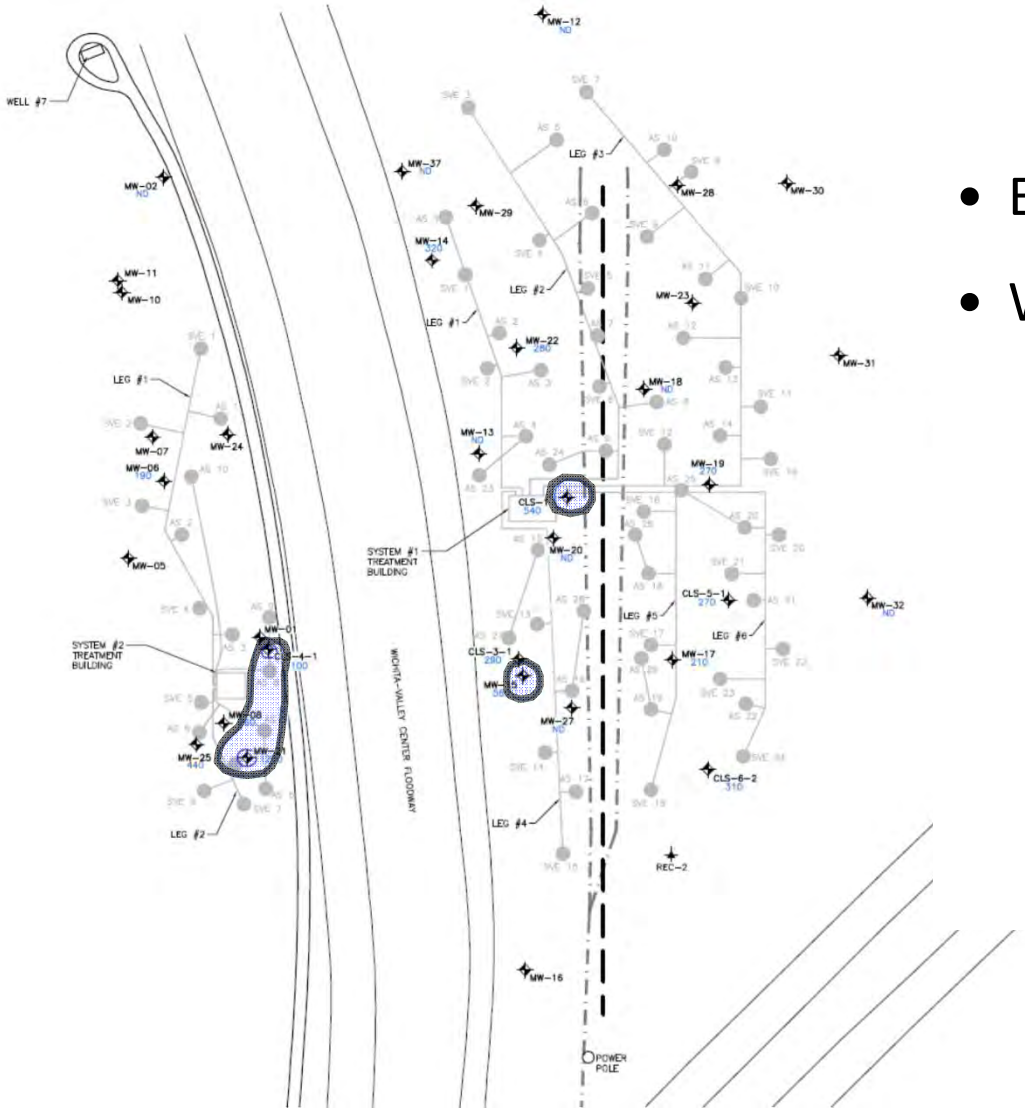
- 7 additional AS wells
- Outer AS wells shut-off & others turned down in clean areas
- West side sparge compressor failed in August 2011

2011 TPH-GRO – SVE/AS – West Side Off



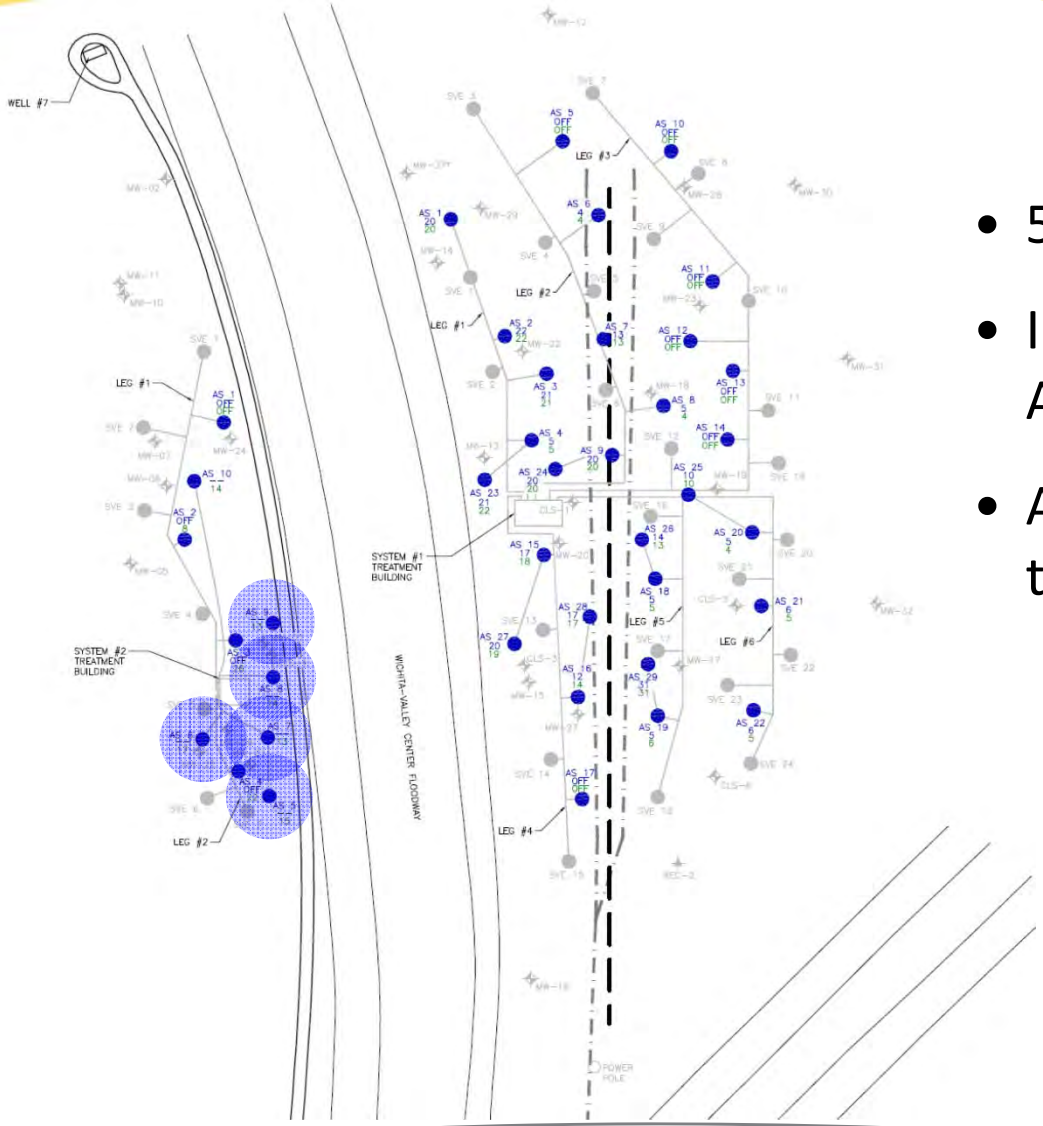
- Good East Side progress
- West Side rebound study to assess if a new compressor and/or wells were warranted

2012 TPH-GRO – SVE/AS – West Side Off



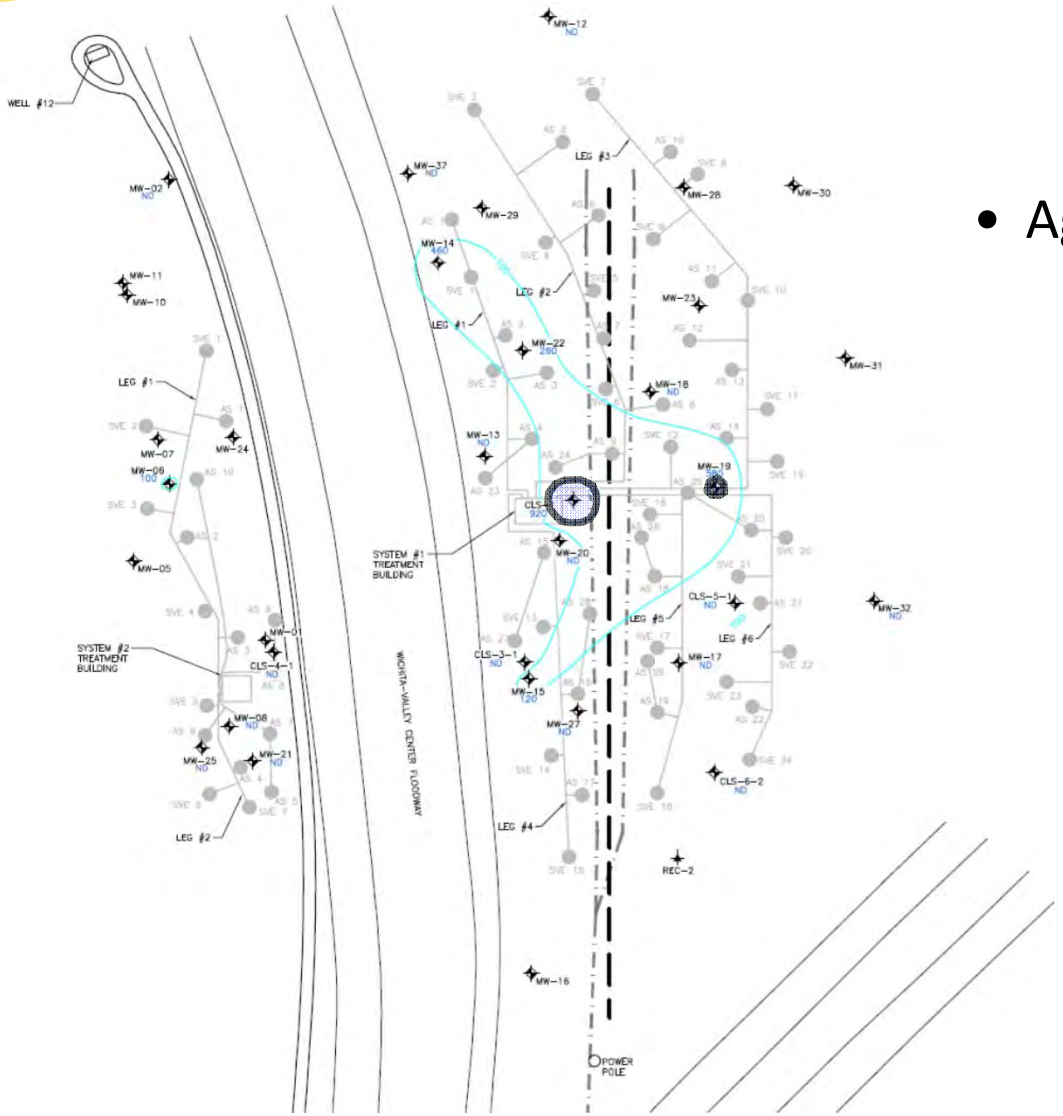
- East Side: Good news
- West Side: Hmm

2012 Dec - West Side AS Enhanced



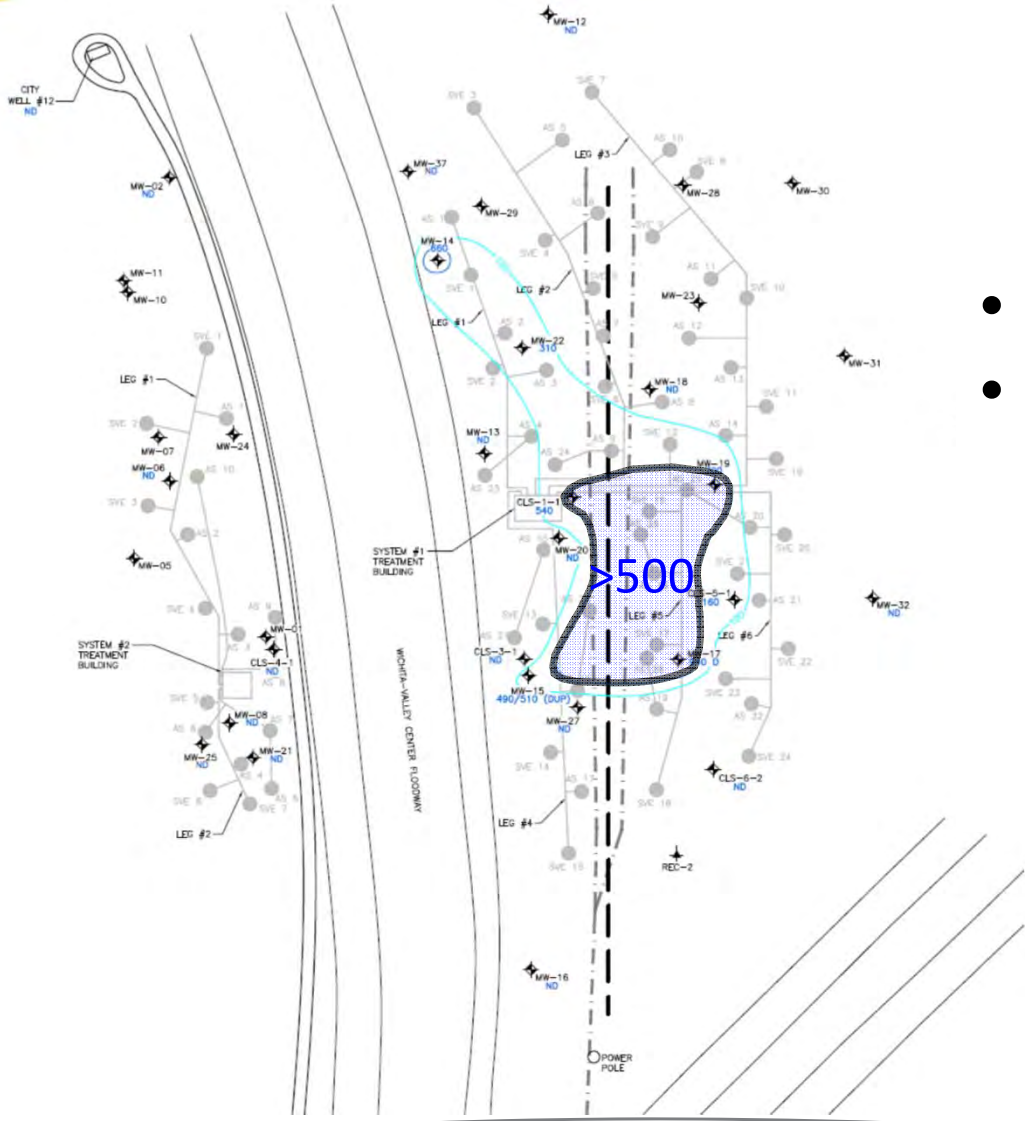
- 5 AS wells added
- Installed new larger AS compressor
- Added 2 zone pulsing to West Side

2013 TPH-GRO – SVE/AS



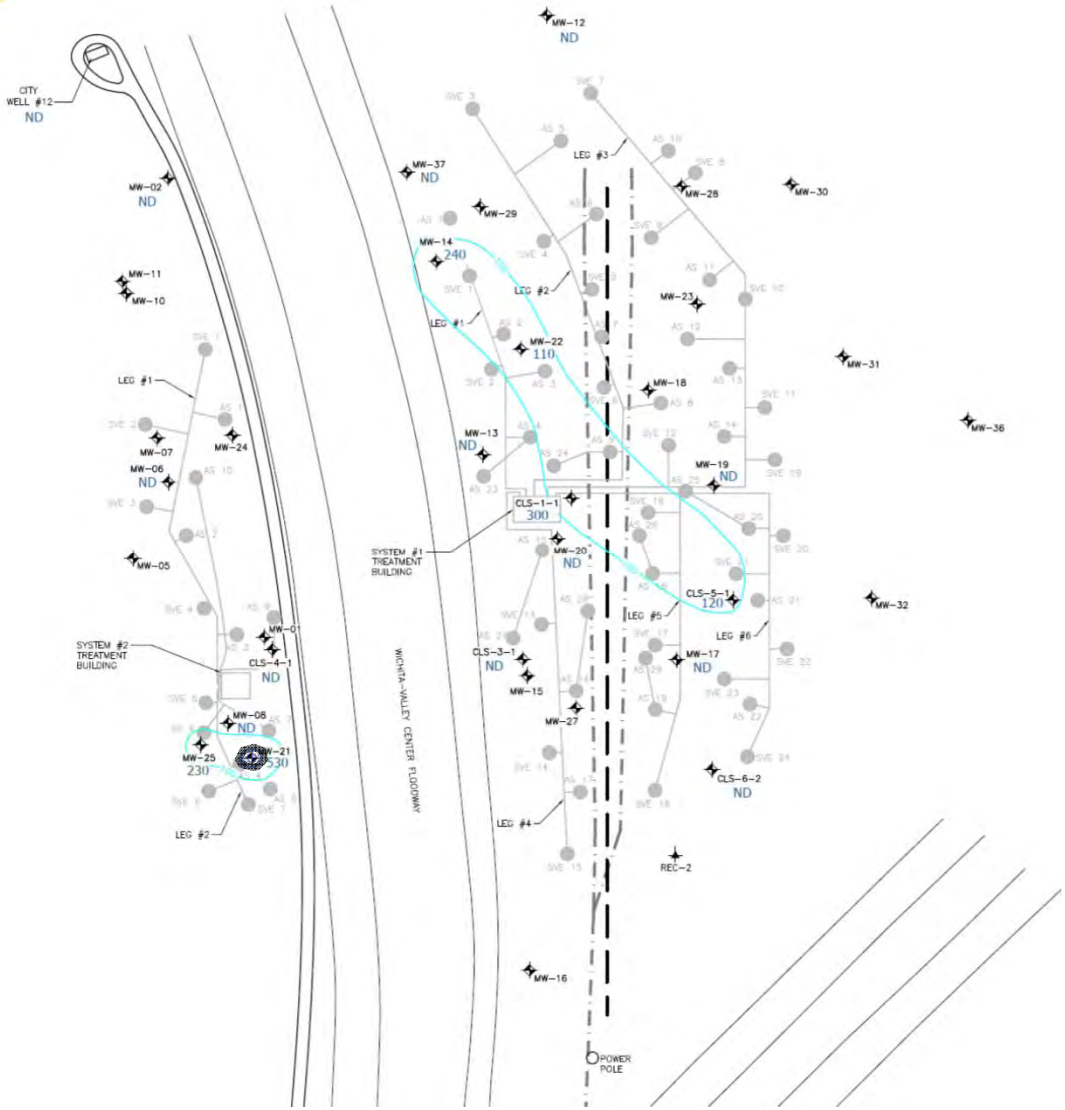
- Aggressive works

2014 TPH-GRO – SVE/AS

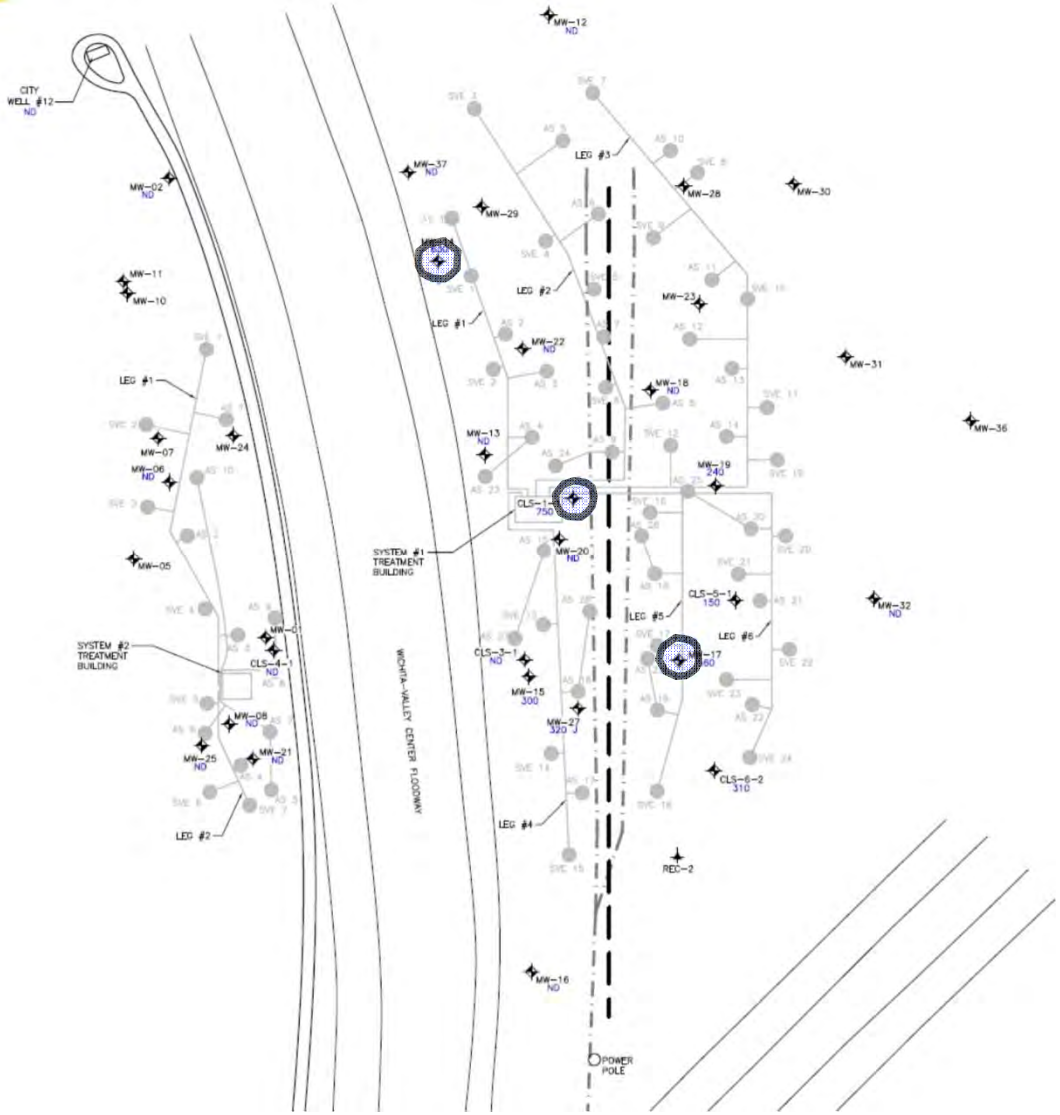


- Rebound when…
- Buried AS PVC Pipe breakage during winter – 2 of 6 legs off for a few months

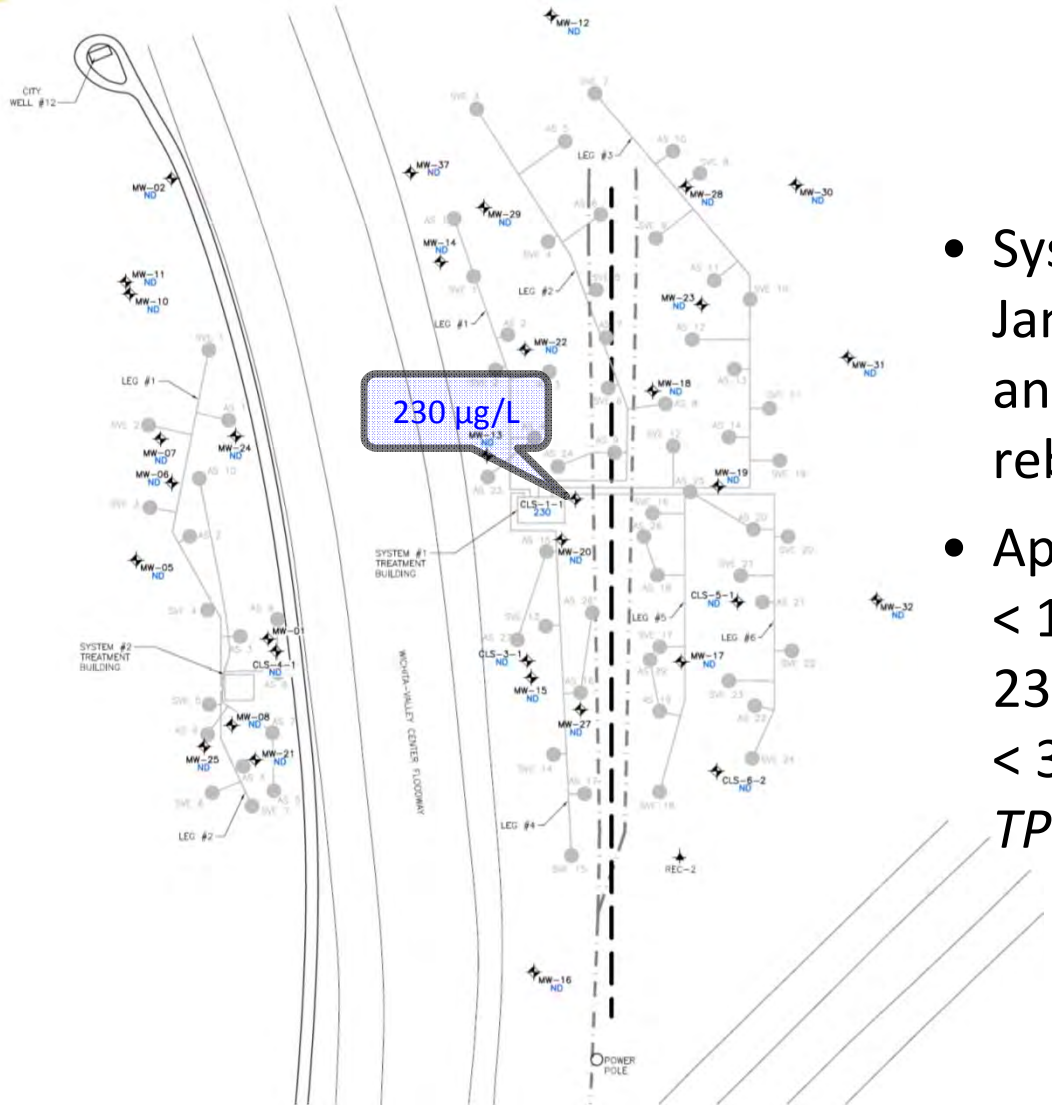
2015 Spring TPH-GRO – SVE/AS



2015 Fall TPH-GRO – SVE/AS

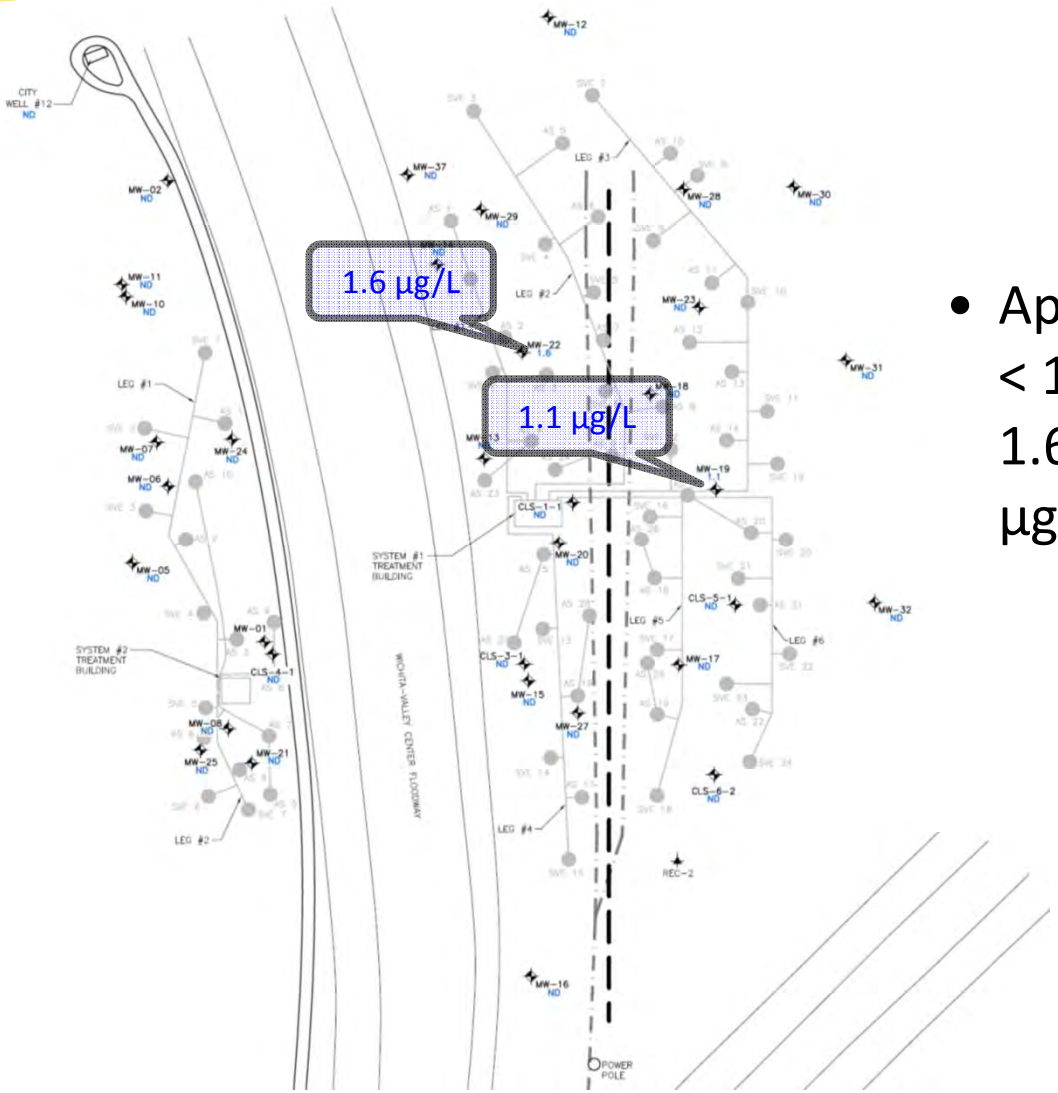


2016 Spring TPH-LRH – Rebound Study



- Systems turned off Jan 3 2016 for a 4 semi-annual event (2 year) rebound study
- April samples were all < 100 µg/L *RL* except 230 µg/L which is < 350 µg/L residential *TPH-LRH RSK RBSL*

2016 Spring Benzene – Rebound Study

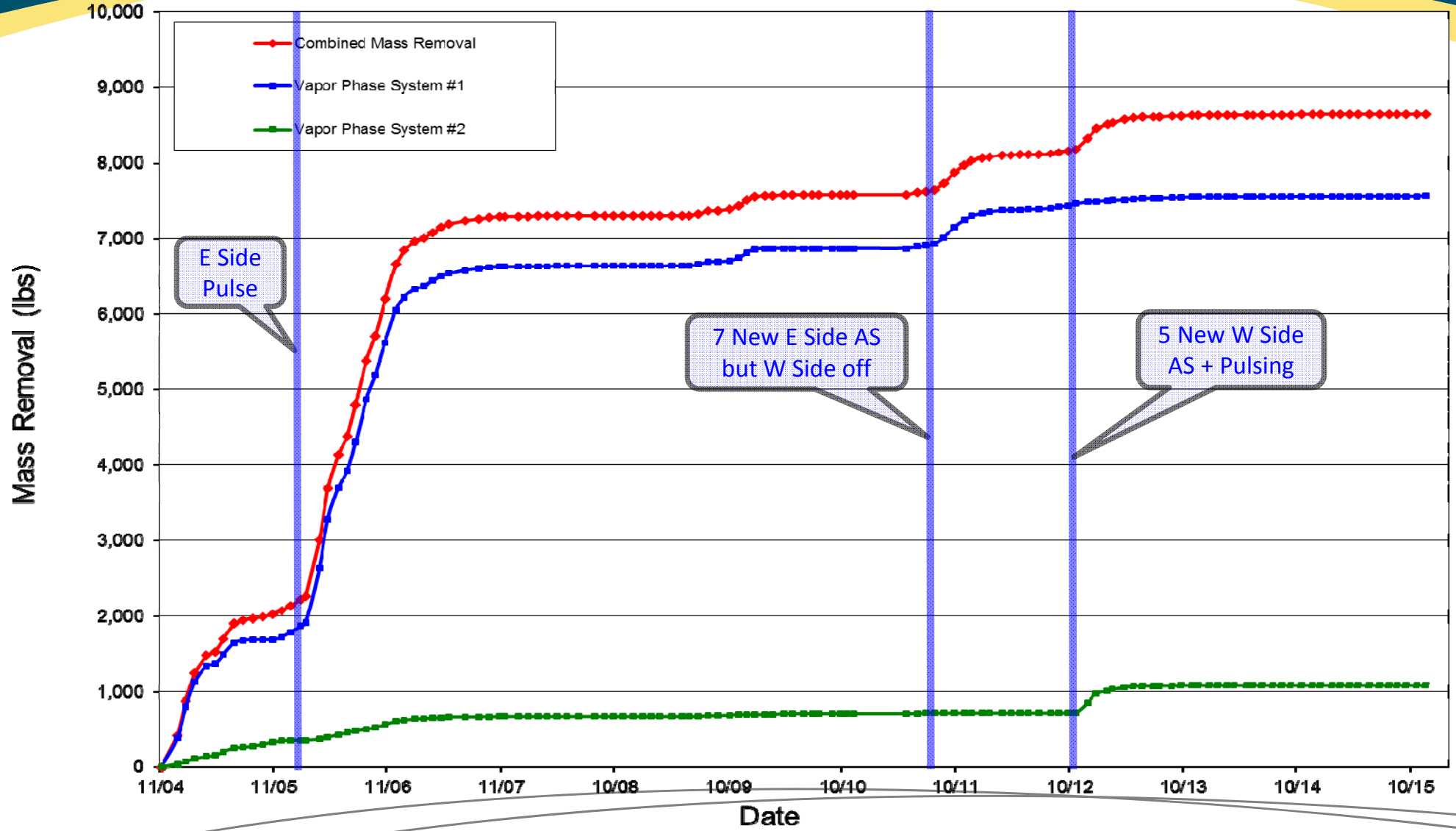


- April samples were all < 1 µg/L RL except 1.1 & 1.6 µg/L which are < 5 µg/L benzene RSK RBSL

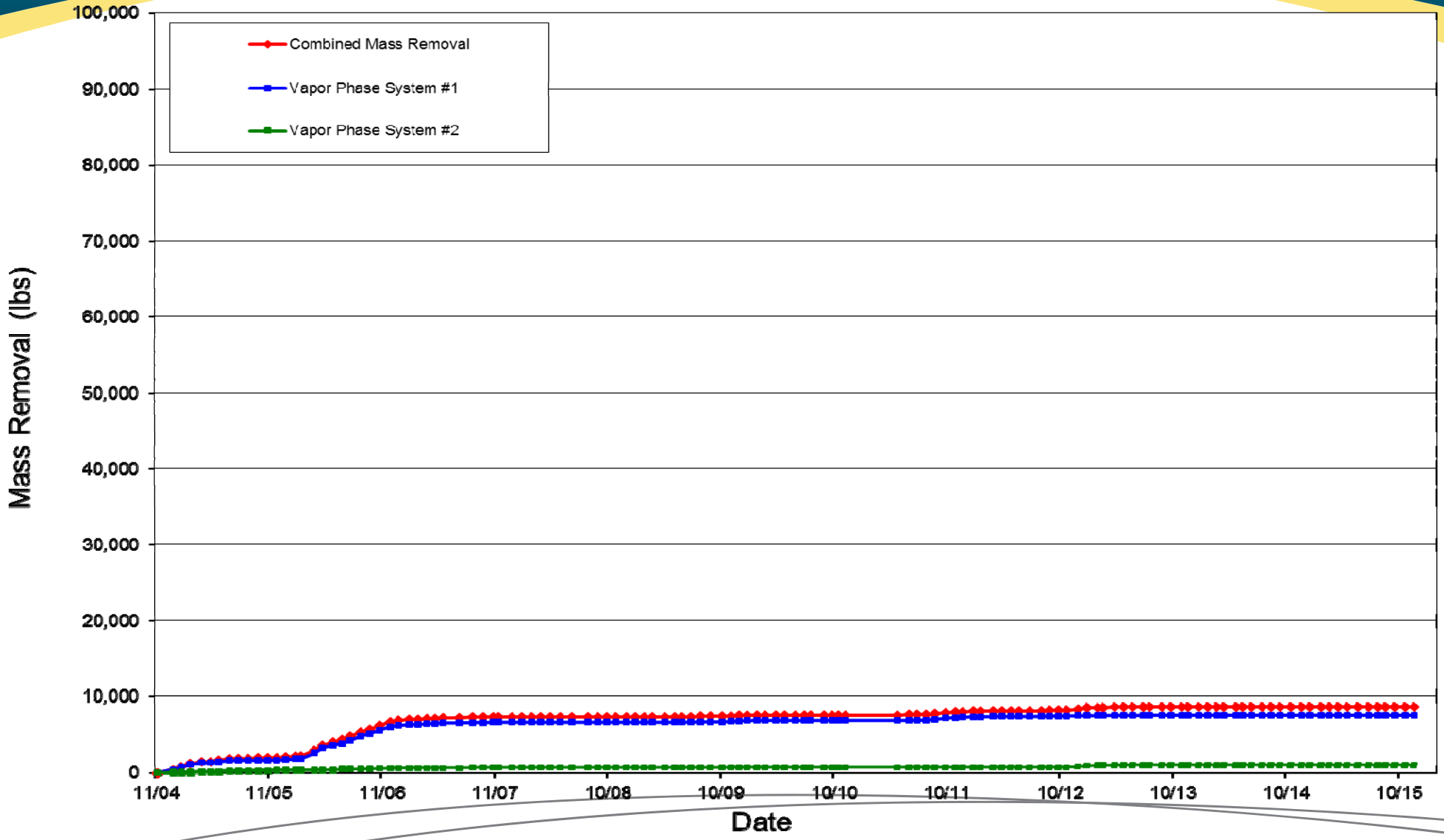
Future Plans

- Near-Term: Continue Rebound Study
- Complete soil confirmation sampling
  - Groundwater monitoring will tells us of any leaching concerns
  - If isolated soils exceed, EUCs may be warranted
- Hopefully close the site in 2 years

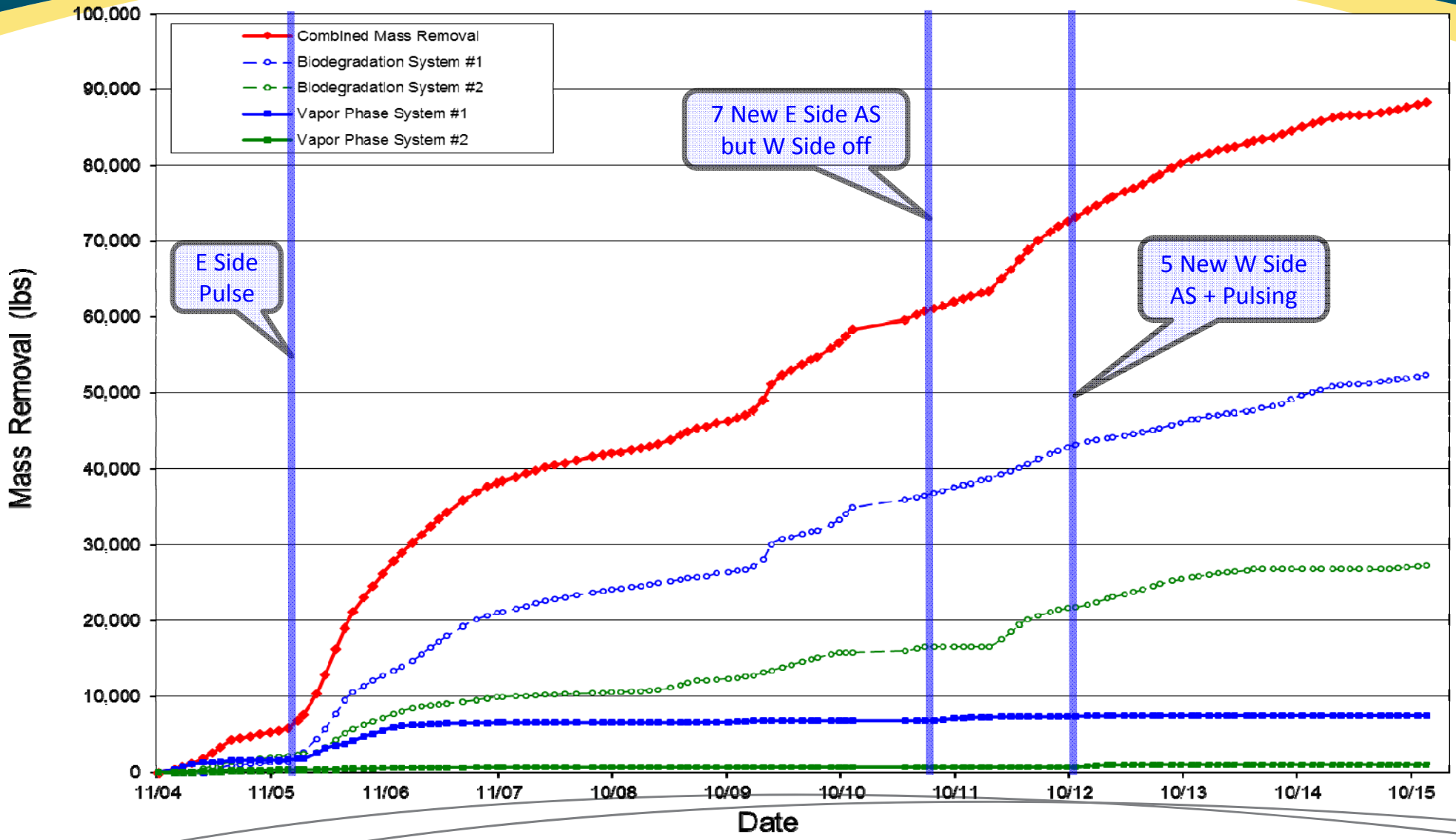
SVE Vapor Phase Mass Removal



SVE Vapor Phase Mass Removal



SVE/AS is also a Biovent/Biosparge System



Lessons Learned – Hydraulic Flushing

- Hydraulic flushing can rapidly (but temporarily) reduce dissolved phase concentrations
- High volume *oxygenated* water flushing can degrade notable contaminant mass…slowly and is
- Susceptible to mineral and biological fouling
- Neither address the vadose zone mass
- Significant rebound can result when ceased

Lessons Learned – SVE/AS

- Use HDPE vs. PVC for buried pipe
- Use conservative ROIs
  - Increased years of O&M are not worth savings of fewer wells
- 2” (and smaller) HDPE pipe is cheap
  - ½” piping often acceptable for AS
  - Run individual lines back to equipment building with flow meters on each well to save $$$ on O&M (balancing time)
- Do not undersize blowers
  - You can always bleed off or deliver less air if you don’t need it, but not vice-versa

Lessons Learned – SVE/AS

- Always pulse AS
  - Sloshing of oxygenated water
  - Higher well flows for same compressor size
- Consider bioremediation (CO_2) emissions when assessing the value of continued SVE and/or AS
  - Biological processes are likely a much larger mass removal mechanism than volatilization for both SVE and AS (more so if heavier/higher end LNAPLs)

THE END

Jeffrey.d.tegrotenhuis@mwhglobal.com
MWH, now part of Stantec

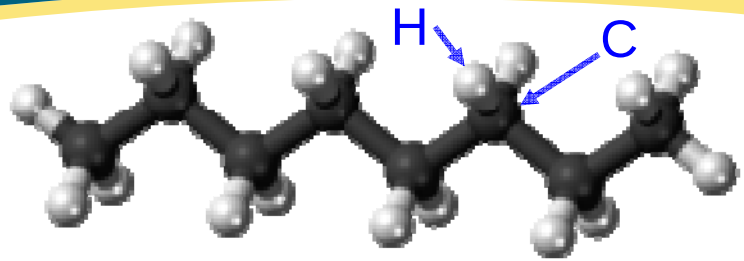
KINDER MORGAN

MWH now part of Stantec

Basis of CO_2-Based Biodegradation Calculation

- Similar to P&T groundwater preferential flow paths, preferential *air* flow paths rapidly volatilize/remediate
- 90% of SVE/AS operational life is diffusion-limited
  - SVE and AS add a LOT of oxygen to the subsurface
  - O2 diffuses into soil matrix more rapidly than VOCs diffuse out
  - Many VOCs degrade before they get out into the vapor stream
  - Near end of remediation, almost no VOCs make it out

Basis of CO_2 Biodegradation Calculation



- For Alkanes (decent approximation for all HCs)
  - Each C has 2 Hs attached = 12+1+1 = **14** grams/mole (approx.)
  - Each C takes 2 Os to oxidize to CO_2 = 12+16+16 = **44** grams/mole
- (CO_2 (ppmv) in off-gas – CO_2 in air) x air flow (scfm) x time
  - X necessary units conversions….
  - = CO_2 mass extracted over a time period (e.g. 1 month)
  - For every 44 grams of CO_2 removed, 14 grams of hydrocarbon have been biologically oxidized (roughly 1/3 of CO_2 mass) *<u>IF</u> all CO_2 is from hydrocarbons*

Basis of CO_2-Based Biodegradation Calculation

- In a desert that may be true, but in the Midwest…
- Must include a correction for natural soil organics, which also degrade and emit CO_2
  - Estimate (e.g. I subtracted 0.4% from all for Park City)
  - Clean area SVE well
  - Near end of treatment, the CO_2 concentrations will decline and all wells should approach a similar "background" value
  - E-flux® (NSZD firm) uses carbon isotopes to determine new vs. old carbon using a solid peer-reviewed calculation.