Comparison of Active Remediation Rates and Natural Attenuation Rates for TCE In Groundwater

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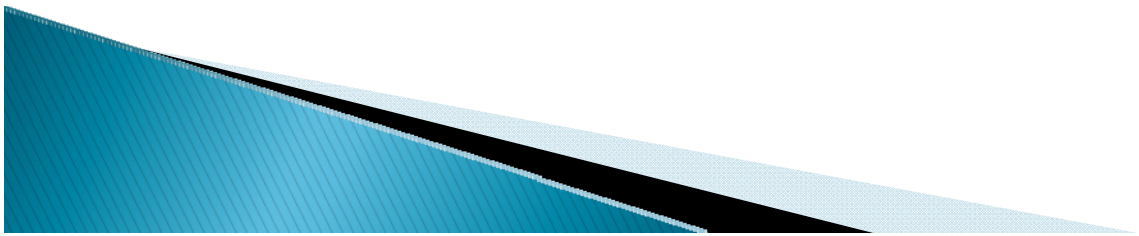
Introduction

- This Site represents a facility with over 30 years of investigation, soil/groundwater remediation and groundwater monitoring.
- Site conditions had improved substantially as a result of the site work and the question remained what is the appropriate course of action going forward.
- Groundwater quality monitoring data demonstrates that groundwater quality is improving as fast, if not faster, outside the capture area of the P&T system versus within the capture.

Background

- Site Setting/Geology/Hydrogeology
  - Overburden (weathered shale) to ~9-15 ft bgs
  - Bedrock below 9-15 ft composed of Triassic Newark Group (shales, siltstones, and argillites)
  - Shallow bedrock aquifer (to approx. 80 feet depth):
    - Numerous but small fractures/partings, low K and low yield
  - Deep bedrock aquifer below approx. 80 feet depth):
    - Few but large fractures, high K and high yield
  - Aquifer is anisotropic with higher K along strike, lower K perpendicular to strike



Background

- Contamination discovered in 1979
  - Small waste solvent tank
- Numerous wells installed to define area in 1980
  - 18 shallow over burden wells
  - 19 bedrock wells
- Highest groundwater contamination reported at ~60,000 ug/l TCE in bedrock groundwater in 1980

Background

- Source Removal
  - Waste solvent tank excavated in 1980 (tank tested tight, releases associated with over fills)
  - 225 cubic yards of soil excavated and treated (1981 and 1982)
  - Shallow groundwater extracted and treated on a batch basis (1982 to 1983)

Background

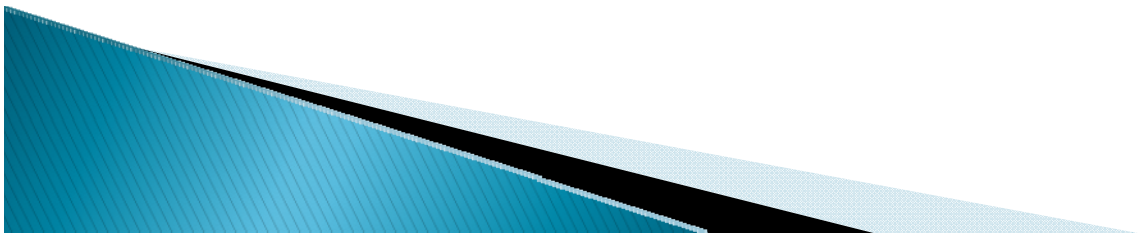
- Long Term Remedial Action
  - Groundwater P&T system began operation in 1986 in source area
  - Maximum TCE groundwater concentration when P&T system initiated was ~350 ug/l
  - System remained active until 2010

Background

- Site was listed as CERCLA site in 1989
- RI conducted in 1998
  - Investigation of source area soils revealed a maximum concentration of TCE in soil of ~5 ug/kg
  - One additional well (cluster) installed
  - Maximum TCE concentration in groundwater reported was 320 ug/l

Background

- ROD issued in 2004
  - Required implementation of a chemical oxidation remedy for “source control” and expansion of P&T system
- Independent of the ROD, the P&T System was expanded in 2004 to include two additional wells that reported TCE > 100 ug/l (but less than 300 ug/l)

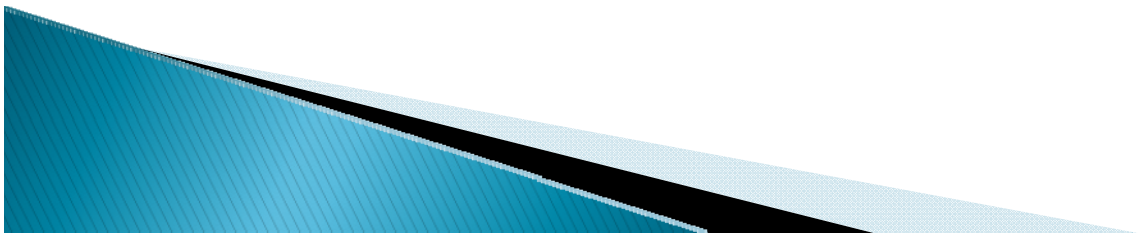


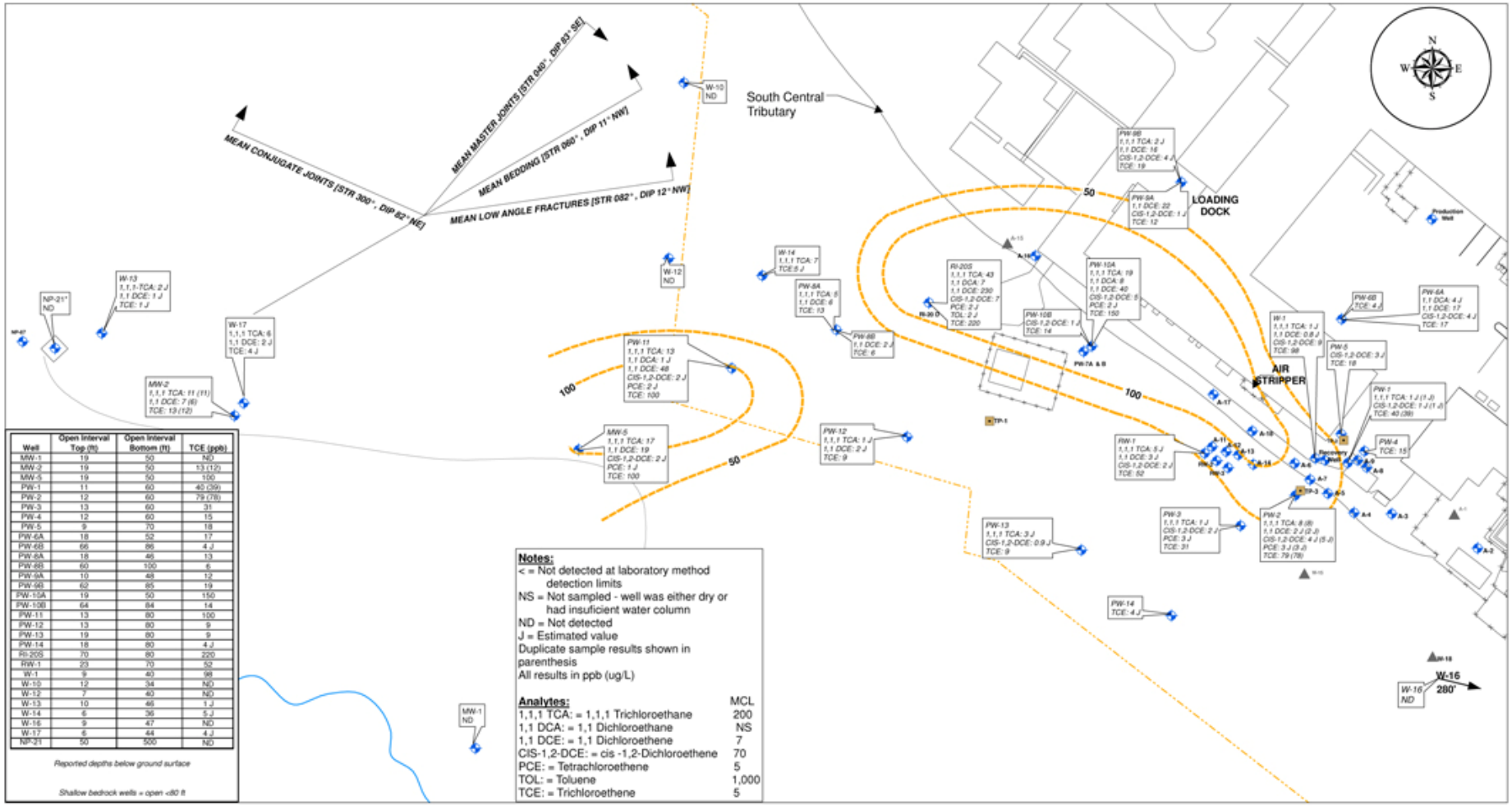
Background

- To address the requirements of the ROD, a Pre-Design Investigation (PDI) was completed in 2008 to evaluate how to implement the remedy
  - 19 additional bedrock wells installed
  - No residual source materials found
- PDI Concluded:
  - Chemical Oxidation not justified given the absence of any residual source materials
  - Continuing P&T not warranted
  - MNA recommended remedy

Background

- What you're left with:
  - A site that was investigated in ~1980
  - Source removal completed in 1982
  - Groundwater remediation began in 1982
  - Continuous P&T began in 1986
  - P&T expanded in 2004
  - No residual source materials or DNAPL
  - Dilute groundwater plume in bedrock (avg. TCE concentration of ~ 40 ug/l
  - 30 years of groundwater quality from a number of wells, both within and outside the influence of the pumping well(s)





Well	Open Interval Top (ft)	Open Interval Bottom (ft)	TCE (ppb)
MW-1	19	50	ND
MW-2	19	50	13 (12)
MW-5	19	50	100
PW-1	11	60	40 (39)
PW-2	12	60	79 (78)
PW-3	13	60	31
PW-4	12	60	15
PW-5	9	70	18
PW-6A	18	52	17
PW-6B	66	86	4 J
PW-8A	18	46	13
PW-8B	60	100	6
PW-9A	10	48	12
PW-9B	62	85	19
PW-10A	19	50	150
PW-10B	64	84	14
PW-11	13	80	100
PW-12	13	80	9
PW-13	19	80	9
PW-14	18	80	4 J
RI-20S	70	80	220
RW-1	23	70	52
W-1	9	40	98
W-10	12	34	ND
W-12	7	40	ND
W-13	10	46	1 J
W-14	6	36	5 J
W-16	9	47	ND
W-17	6	44	4 J
NP-21	50	500	ND

Reported depths below ground surface

Shallow bedrock wells = open <80 ft

Notes:
< = Not detected at laboratory method detection limits
NS = Not sampled - well was either dry or had insuficient water column
ND = Not detected
J = Estimated value
Duplicate sample results shown in parenthesis
All results in ppb (ug/L)

Analytes:	MCL
1,1,1 TCA: = 1,1,1 Trichloroethane	200
1,1 DCA: = 1,1 Dichloroethane	NS
1,1 DCE: = 1,1 Dichloroethene	7
CIS-1,2-DCE: = cis -1,2-Dichloroethene	70
PCE: = Tetrachloroethene	5
TOL: = Toluene	1,000
TCE: = Trichloroethene	5

MEAN BEDDING, LOW-ANGLE FRACTURE, & HIGH-ANGLE FRACTURE STRIKE & DIP FROM DOWNHOLE OTV SURVEY

AREA INSIDE CONTOUR LINES:
5 PPB CONTOUR = 325,596.3 SQFT

GROUNDWATER RECOVERY SYSTEM (PUMPING WELLS: RECOVERY WELL, RI-20S & RW-1) OFF DURING DATA COLLECTION AT ALL WELLS EXCEPT FOR NP-21

PW-11 THROUGH PW-14 AND MW-5 WERE SAMPLED IN AUGUST 2009. ALL OTHER WELLS WERE SAMPLED IN JUNE/JULY 2008.

Legend
- * TCE Plume
- Monitoring Well
- Unlocated Well
- Test Pit
- Stream/Tributary
- Site Road
- Property Line

Scale:
0 85 170 Feet
1:1,310

Sources:
Modified from PASDA Aerial Image

Environmental Alliance, Inc.
5341 Limestone Rd. - Wilmington, DE 19707
Phone: (302) 234-4400 - Fax: (302) 234-1535

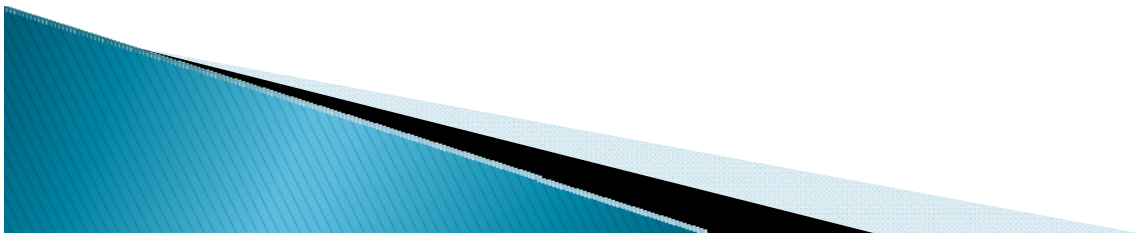
SUPERFUND SITE

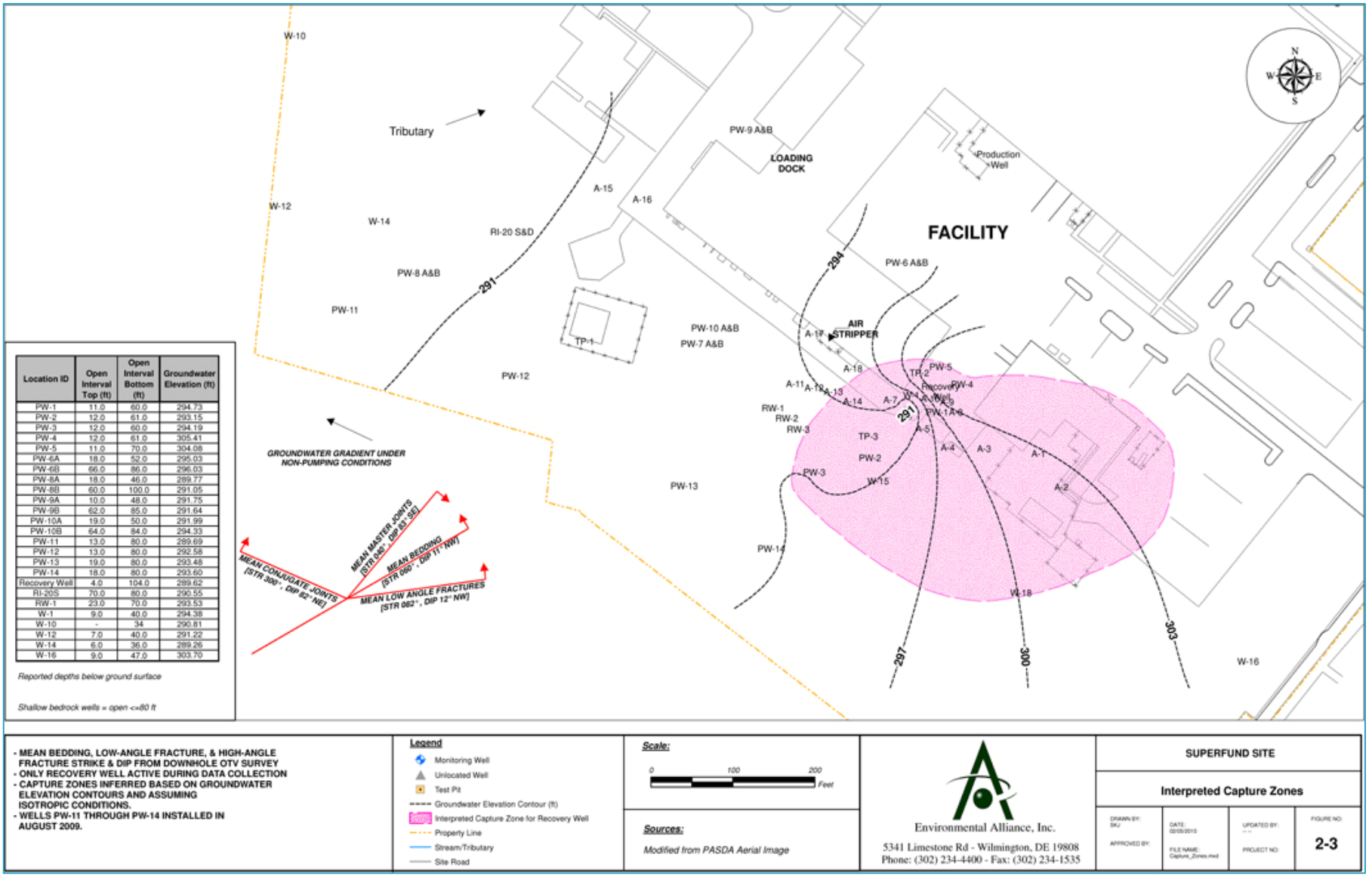
Inferred Extent of TCE in Shallow Bedrock Groundwater Groundwater Data

DRAWN BY: AGG	DATE: 08/31/2009	UPDATED BY: AGG	FIGURE NO: 3b
APPROVED BY:	FILE NAME: VOCs_S_GWM	PROJECT NO:	

Evaluation of the Effectiveness of P&T

- In order to evaluate the effectiveness of the P&T system going forward, the 30 years of groundwater quality data was evaluated.
  - Linear interpolation using Microsoft Excel.
  - Statistical analysis via the Mann-Kendall trend analysis (via ChemStat).
- Slope and trend of the data for groundwater within the capture zone of the pumping wells were compared to slope and trend for groundwater outside the capture zone of the pumping wells.





Location ID	Open Interval Top (ft)	Open Interval Bottom (ft)	Groundwater Elevation (ft)
PW-1	11.0	60.0	294.73
PW-2	12.0	61.0	293.15
PW-3	12.0	60.0	294.19
PW-4	12.0	61.0	305.41
PW-5	11.0	70.0	304.08
PW-6A	18.0	52.0	295.03
PW-6B	66.0	86.0	296.03
PW-8A	18.0	46.0	289.77
PW-8B	60.0	100.0	291.05
PW-9A	10.0	48.0	291.75
PW-9B	62.0	85.0	291.64
PW-10A	19.0	50.0	291.99
PW-10B	64.0	84.0	294.33
PW-11	13.0	80.0	289.69
PW-12	13.0	80.0	292.58
PW-13	19.0	80.0	293.48
PW-14	18.0	80.0	293.60
Recovery Well	4.0	104.0	289.62
RI-20S	70.0	80.0	290.55
RW-1	23.0	70.0	293.53
W-1	9.0	40.0	294.38
W-10	-	34	290.81
W-12	7.0	40.0	291.22
W-14	6.0	36.0	289.26
W-16	9.0	47.0	303.70

Reported depths below ground surface

Shallow bedrock wells = open <=80 ft

- MEAN BEDDING, LOW-ANGLE FRACTURE, & HIGH-ANGLE FRACTURE STRIKE & DIP FROM DOWNHOLE OTV SURVEY
- ONLY RECOVERY WELL ACTIVE DURING DATA COLLECTION
- CAPTURE ZONES INFERRED BASED ON GROUNDWATER ELEVATION CONTOURS AND ASSUMING ISOTROPIC CONDITIONS.
- WELLS PW-11 THROUGH PW-14 INSTALLED IN AUGUST 2009.

Legend

- Monitoring Well
- Unlocated Well
- Test Pit
- Groundwater Elevation Contour (ft)
- Interpreted Capture Zone for Recovery Well
- Property Line
- Stream/Tributary
- Site Road

Scale:

0 100 200 Feet

Sources:

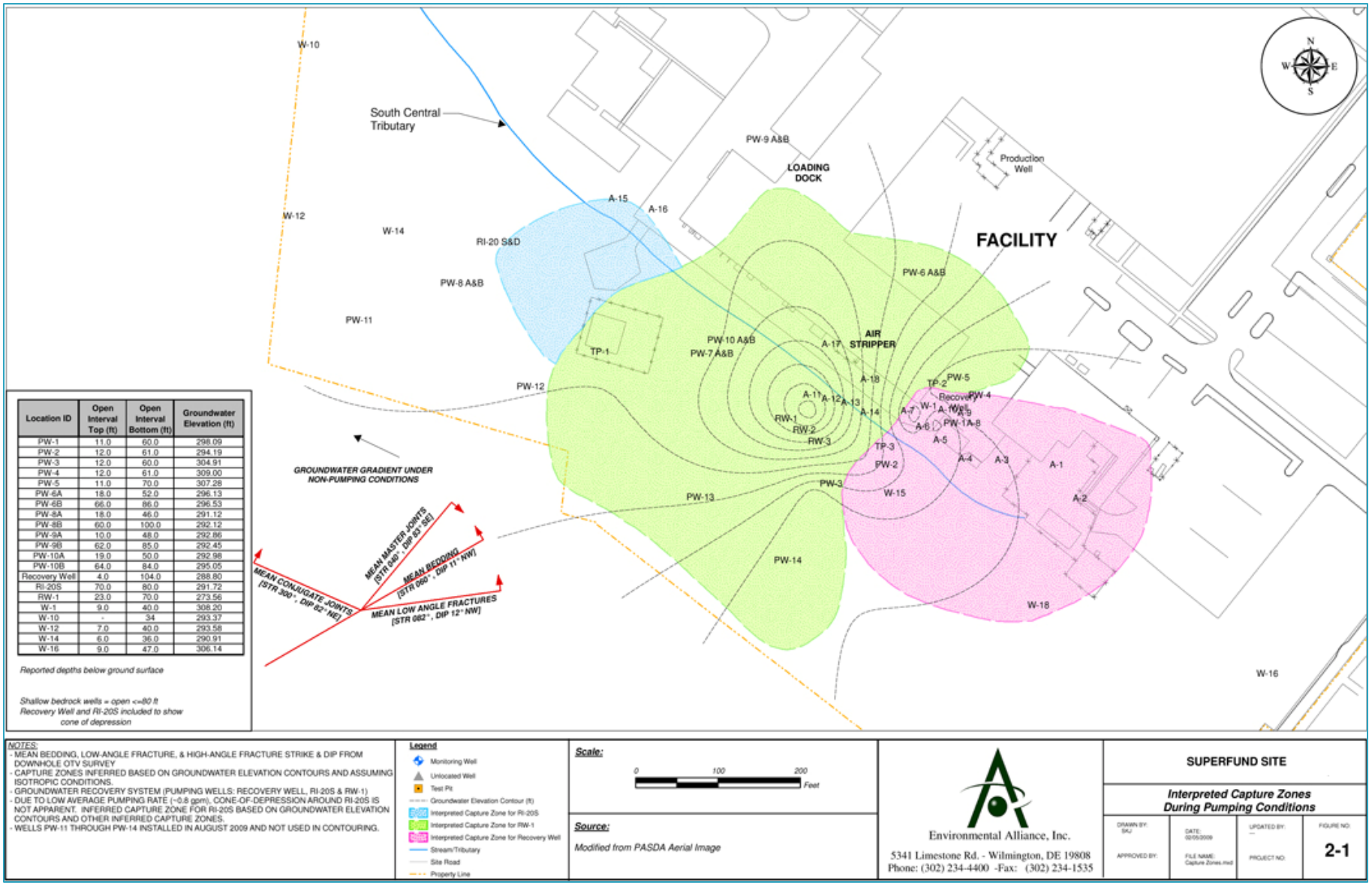
Modified from PASDA Aerial Image

Environmental Alliance, Inc.
5341 Limestone Rd - Wilmington, DE 19808
Phone: (302) 234-4400 - Fax: (302) 234-1535

SUPERFUND SITE

Interpreted Capture Zones

DRAWN BY: SKJ	DATE: 02/05/2010	UPDATED BY: --	FIGURE NO: 2-3
APPROVED BY:	FILE NAME: Capture_Zones.mxd	PROJECT NO:	



Location ID	Open Interval Top (ft)	Open Interval Bottom (ft)	Groundwater Elevation (ft)
PW-1	11.0	60.0	298.09
PW-2	12.0	61.0	294.19
PW-3	12.0	60.0	304.91
PW-4	12.0	61.0	309.00
PW-5	11.0	70.0	307.28
PW-6A	18.0	52.0	296.13
PW-6B	66.0	86.0	296.53
PW-8A	18.0	46.0	291.12
PW-8B	60.0	100.0	292.12
PW-9A	10.0	48.0	292.86
PW-9B	62.0	85.0	292.45
PW-10A	19.0	50.0	292.98
PW-10B	64.0	84.0	295.05
Recovery Well	4.0	104.0	288.80
RI-20S	70.0	80.0	291.72
RW-1	23.0	70.0	273.56
W-1	9.0	40.0	308.20
W-10	-	34	293.37
W-12	7.0	40.0	293.58
W-14	6.0	36.0	290.91
W-16	9.0	47.0	306.14

Reported depths below ground surface

Shallow bedrock wells = open <=80 ft
Recovery Well and RI-20S included to show cone of depression

NOTES:
- MEAN BEDDING, LOW-ANGLE FRACTURE, & HIGH-ANGLE FRACTURE STRIKE & DIP FROM DOWNHOLE OTV SURVEY
- CAPTURE ZONES INFERRED BASED ON GROUNDWATER ELEVATION CONTOURS AND ASSUMING ISOTROPIC CONDITIONS.
- GROUNDWATER RECOVERY SYSTEM (PUMPING WELLS: RECOVERY WELL, RI-20S & RW-1)
- DUE TO LOW AVERAGE PUMPING RATE (~0.8 gpm), CONE-OF-DEPRESSION AROUND RI-20S IS NOT APPARENT. INFERRED CAPTURE ZONE FOR RI-20S BASED ON GROUNDWATER ELEVATION CONTOURS AND OTHER INFERRED CAPTURE ZONES.
- WELLS PW-11 THROUGH PW-14 INSTALLED IN AUGUST 2009 AND NOT USED IN CONTOURING.

Legend
- Monitoring Well
- Unlocated Well
- Test Pit
- Groundwater Elevation Contour (ft)
- Interpreted Capture Zone for RI-20S
- Interpreted Capture Zone for RW-1
- Interpreted Capture Zone for Recovery Well
- Stream/Tributary
- Site Road
- Property Line

Scale: 0 100 200 Feet

Source: *Modified from PASDA Aerial Image*

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SUPERFUND SITE

Interpreted Capture Zones During Pumping Conditions

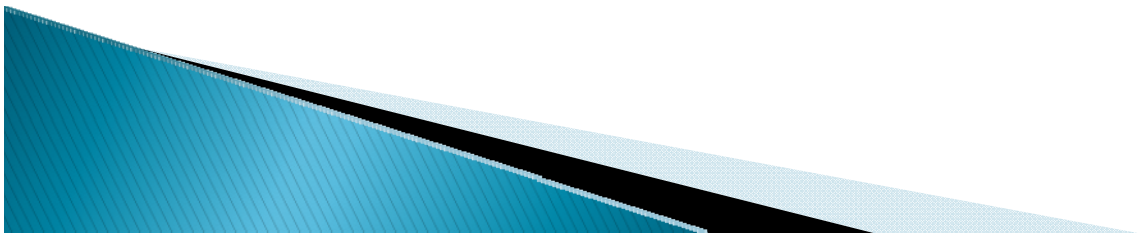
DRAWN BY: SKJ	DATE: 02/05/2009	UPDATED BY: --	FIGURE NO: 2-1
APPROVED BY:	FILE NAME: Capture Zones.mxd	PROJECT NO:	

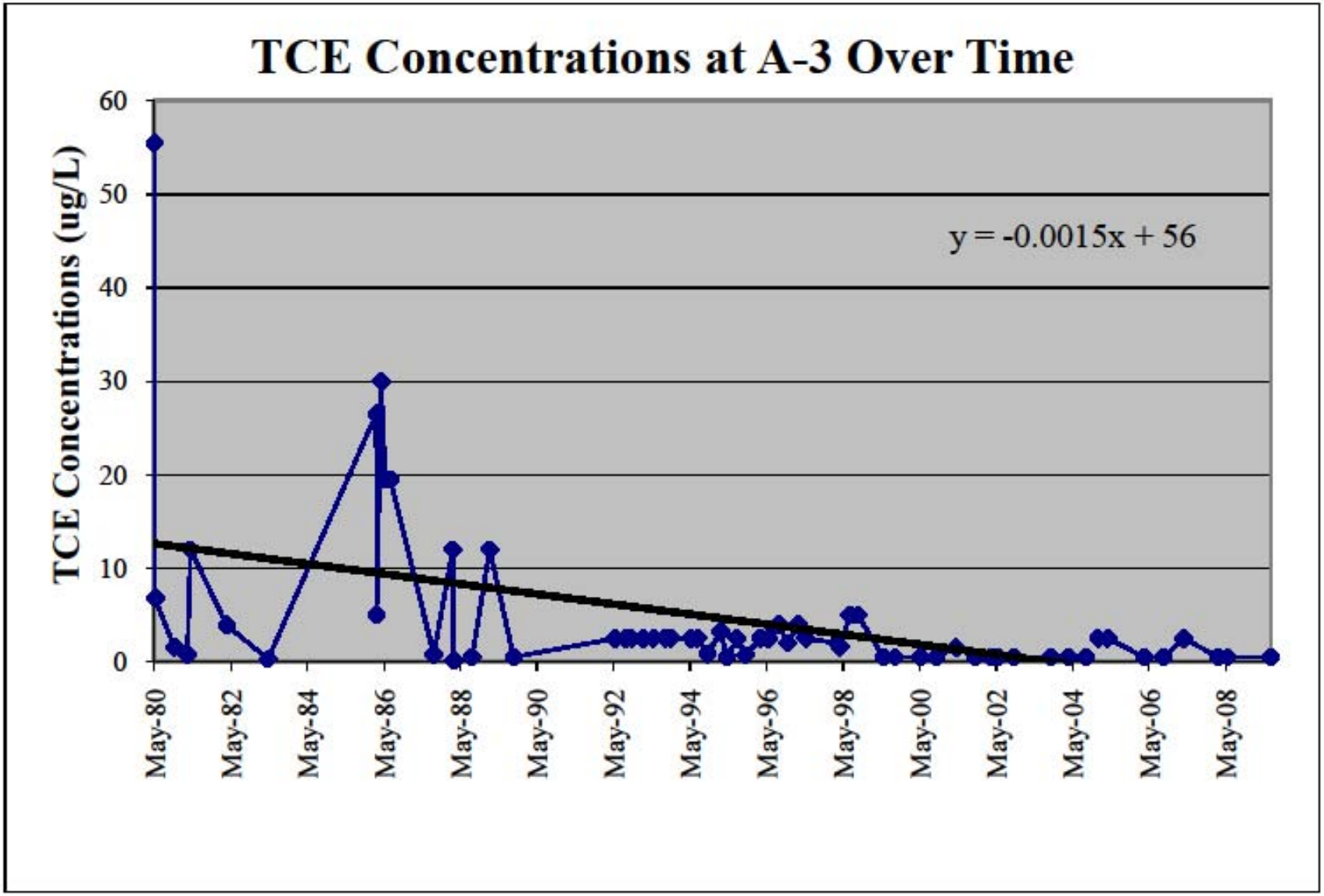
Slope and Trend Analysis

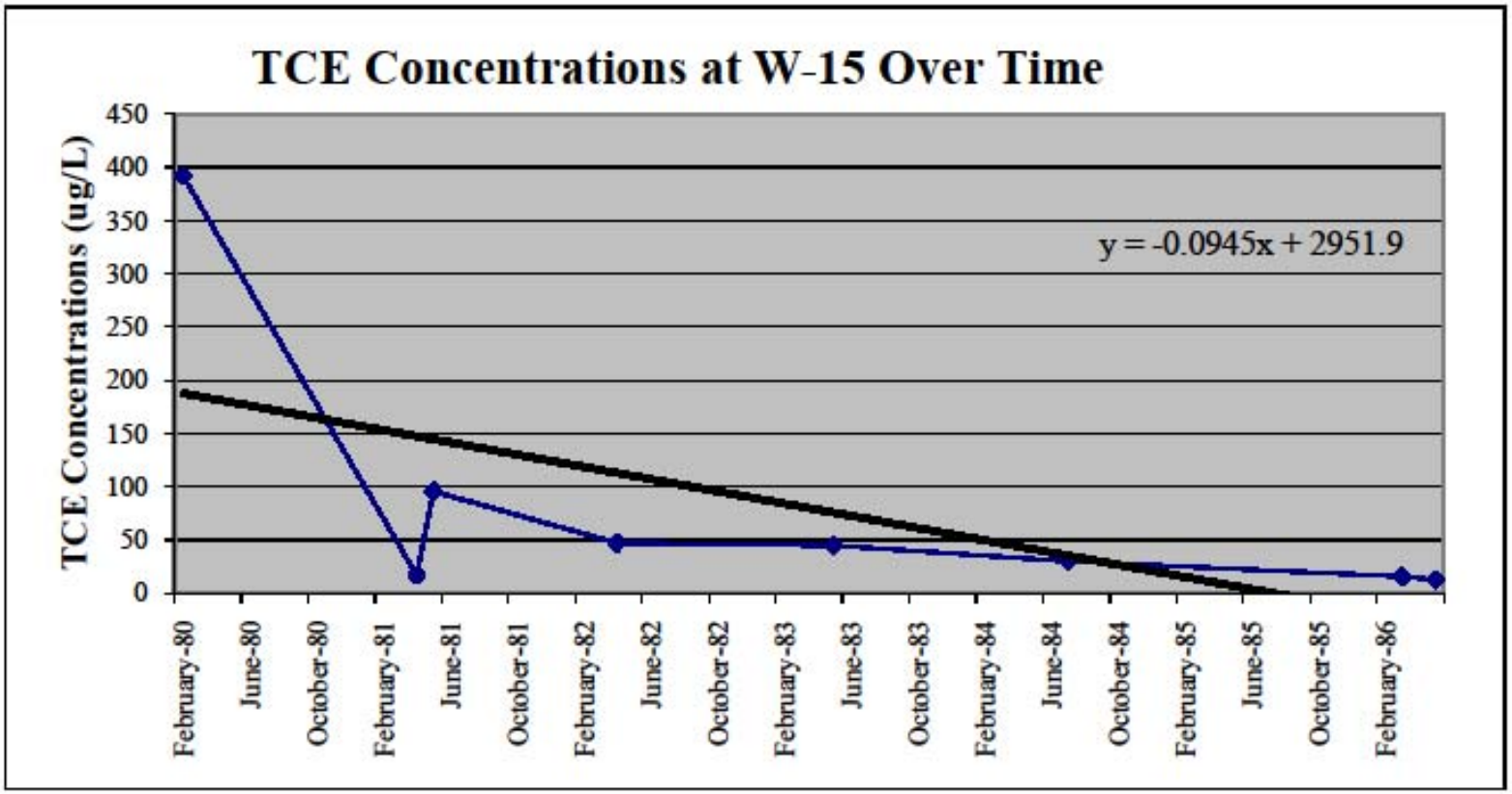
- For wells that were in close proximity to the source area, only the data collected after the source removal work was completed was evaluated to reduce the bias in the data.
  - The data used included data from the initiation of the full time P&T system in 1986.
- For the wells that were not in close proximity of the source area, all data was used.

Slope Analysis (Linear Interpolation)

- 27 wells were determined to have sufficient data for analysis.
  - Up to 62 data points were available over almost a 30 year period.
- Results of the Linear Interpolation:
  - 25 of the 27 wells indicated a negative slope in the linear interpolation.
  - 17 of the 25 wells with negative slopes were wells that were not in the capture zone of the pumping wells over the time frames evaluated.

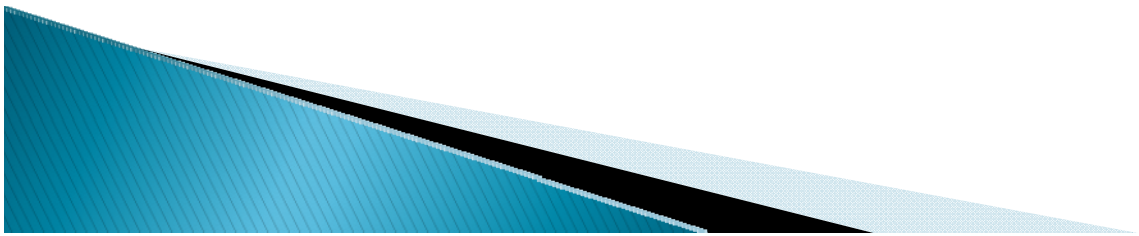



TCE Concentrations at A-3 Over Time
TCE Concentrations (ug/L)
60
50
40
30
20
10
0
y = -0.0015x + 56
May-80
May-82
May-84
May-86
May-88
May-90
May-92
May-94
May-96
May-98
May-00
May-02
May-04
May-06
May-08


TCE Concentrations at W-15 Over Time
TCE Concentrations (ug/L)
450
400
350
300
250
200
150
100
50
0
y = -0.0945x + 2951.9
February-80
June-80
October-80
February-81
June-81
October-81
February-82
June-82
October-82
February-83
June-83
October-83
February-84
June-84
October-84
February-85
June-85
October-85
February-86

Trend Analysis

- Results of the Mann-Kendall trend analysis:
  - 27 wells were evaluated for trend
  - 20 wells reported a negative “S” statistic, which indicates a downward trend
  - 6 wells reported a positive “S” statistic
  - 1 well reported an “S” Statistic of 0



Well ID	Data Evaluation Time Period	TCE Concentration Range (ug/L)	Number of Samples	Graphical Slope (ug/L)	Graphical Slope Trend	Calculated Mann-Kendall "S" Statistic	Probability of "S" Statistic or Calculated Z-Statistic	Comparison Probability or Z-Value (95% Confidence)	Evidence of Statistically Significant Trend?	Within Inferred "Recovery Well" Capture Area?	Comment
A-2	05/27/1980 - 03/24/2008	ND - 1,290	8	-0.0468	Downward	-10	0.138	0.05	No	Yes	Elevated result 04/20/82 likely caused result to not support downward trend
A-3	05/27/1980 - 08/04/2009	ND - 55.5	62	-0.00015	Downward	-687	-4.272	1.65	Yes Downward	Yes	
A-4	09/17/1992 - 06/17/2008	ND - 2 B	10	-0.00037	Downward	-31	0.002	0.05	Yes Downward	Yes	
A-5	06/09/1992 - 06/17/2008	ND - 5 B	6	-0.00047	Downward	-8	0.102	0.05	No	Yes	
A-6	03/31/1994 - 06/17/2008	ND - 15	6	-0.00095	Downward	-3	0.360	0.05	No	Yes	
A-7	11/17/1992 - 06/17/2008	ND - 53	8	0.0035	Upward	5	0.317	0.05	No	Yes	
A-8	03/11/1993 - 03/20/2008	ND - 12	5	-0.0095	Downward	-4	0.242	0.05	No	Yes	
A-9	06/10/1986 - 03/20/2008	1 J - 433.5	6	-0.0463	Downward	-15	0.001	0.05	Yes Downward	Yes	
A-11	05/01/1986 - 06/17/2008	ND - 288	41	-0.0267	Downward	-282	-3.157	1.65	Yes Downward	No	
A-12	03/31/1994 - 08/04/2009	ND - 120	38	-0.00995	Downward	-284	-3.559	1.65	Yes Downward	No	
A-13	03/31/1994 - 08/04/2009	ND - 75	39	-0.0062	Downward	-355	-4.285	1.65	Yes Downward	No	
A-14	05/01/1986 - 08/04/2009	ND - 264	39	-0.0199	Downward	-477	-5.761	1.65	Yes Downward	Yes	

Well ID	Data Evaluation Time Period	TCE Concentration Range (ug/L)	Number of Samples	Graphical Slope (ug/L)	Graphical Slope Trend	Calculated Mann-Kendall "S" Statistic	Probability of "S" Statistic or Calculated Z-Statistic	Comparison Probability or Z-Value (95% Confidence)	Evidence of Statistically Significant Trend?	Within Inferred "Recovery Well" Capture Area?	Comment
A-16	04/07/1981 - 03/17/2008	ND - 70	7	-0.0037	Downward	-6	0.236	0.05	No	No	Consider data from max concentration to present?
A-17	04/07/1981 - 03/17/2008	3 J - 6,000	3	-0.3955	Downward	1	N/A	0.05		No	Insufficient Data to Test
A-18	05/01/1986 - 03/17/2008	ND - 201	5	-0.0142	Downward	-3	0.325	0.05	No	No	Consider data from max concentration to present?
FOXMW-2	04/11/2002 - 06/19/2008	12 - 23	6	-0.0016	Downward	-3	0.360	0.05	No	No	
FOXMW-5	04/11/2002 - 08/24/2009	56 - 120	7	0.0112	Upward	10	0.094	0.05	No	No	
RI-20S	09/01/1998 - 09/29/2004	ND - 320 L	8	-0.0273	Downward	-6	0.274	0.05	No	No	
RW-1	05/02/1986 - 09/28/2004	100 - 392	48	-0.0095	Downward	-222	-1.968	1.65	Yes Downward	No	
W-1	05/01/1986 - 08/04/2009	ND - 180	57	-0.0055	Downward	-55	-0.372	1.65	No	Yes	
W-10	02/04/1980 - 06/16/2008	ND - 23	25	-0.0003	Downward	35	0.883	1.65	No	No	May show negative trend if non-detects assigned same value
W-12	02/04/1980 - 06/16/2008	ND - 437	25	-0.0066	Downward	5	0.106	1.65	No	No	May show negative trend if non-detects assigned same value
W-13	02/04/1980 - 06/19/2008	ND - 30.7	20	-0.0009	Downward	-43	-1.370	1.65	No	No	

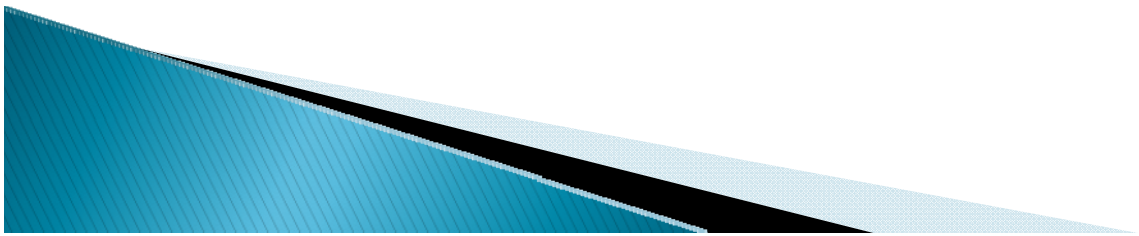
Well ID	Data Evaluation Time Period	TCE Concentration Range (ug/L)	Number of Samples	Graphical Slope (ug/L)	Graphical Slope Trend	Calculated Mann-Kendall "S" Statistic	Probability of "S" Statistic or Calculated Z-Statistic	Comparison Probability or Z-Value (95% Confidence)	Evidence of Statistically Significant Trend?	Within Inferred "Recovery Well" Capture Area?	Comment
W-14	02/04/1980 - 06/16/2008	ND - 325	14	-0.0077	Downward	12	0.614	1.65	No	No	May show negative trend if non-detects assigned same value
W-15	02/04/1980 - 05/01/1986	12.6 - 392	8	-0.0946	Downward	-20	0.007	0.05	Yes Downward	No	
W-16	02/04/1980 - 06/18/2008	ND - 29	12	-0.0012	Downward	-23	-1.696	1.65	Yes Downward	No	Consider data from max concentration to present? May show stronger negative trend if non-detects assigned
W-17	02/04/1980 - 06/19/2008	ND - 21.4	15	-0.0002	Downward	0	0.000	1.65	No	No	

ND = Non-detect
J = estimated value
L = Analyte present. Reported value may be biased low
B = detected analyte in blank sample

(white) All data used
Data from April 1986-November 2004
Data from April 1986-present

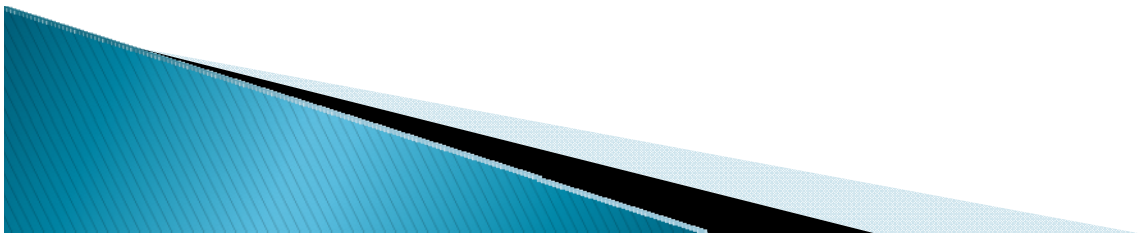
Trend Analysis

- For the wells that reported a negative S statistic, 10 wells were determined to have “statistically significant” downward trends.
  - Statistically significant at 95% confidence.
- Of these 10 wells with statistically significant trends:
  - The slope of the trend ranged from 0.00015 ug/l/day to 0.0946 ug/l/day (i.e., rate of decrease of TCE).
  - Four of these 10 wells were within the capture zone of the pumping wells, and 6 were outside the capture zone.

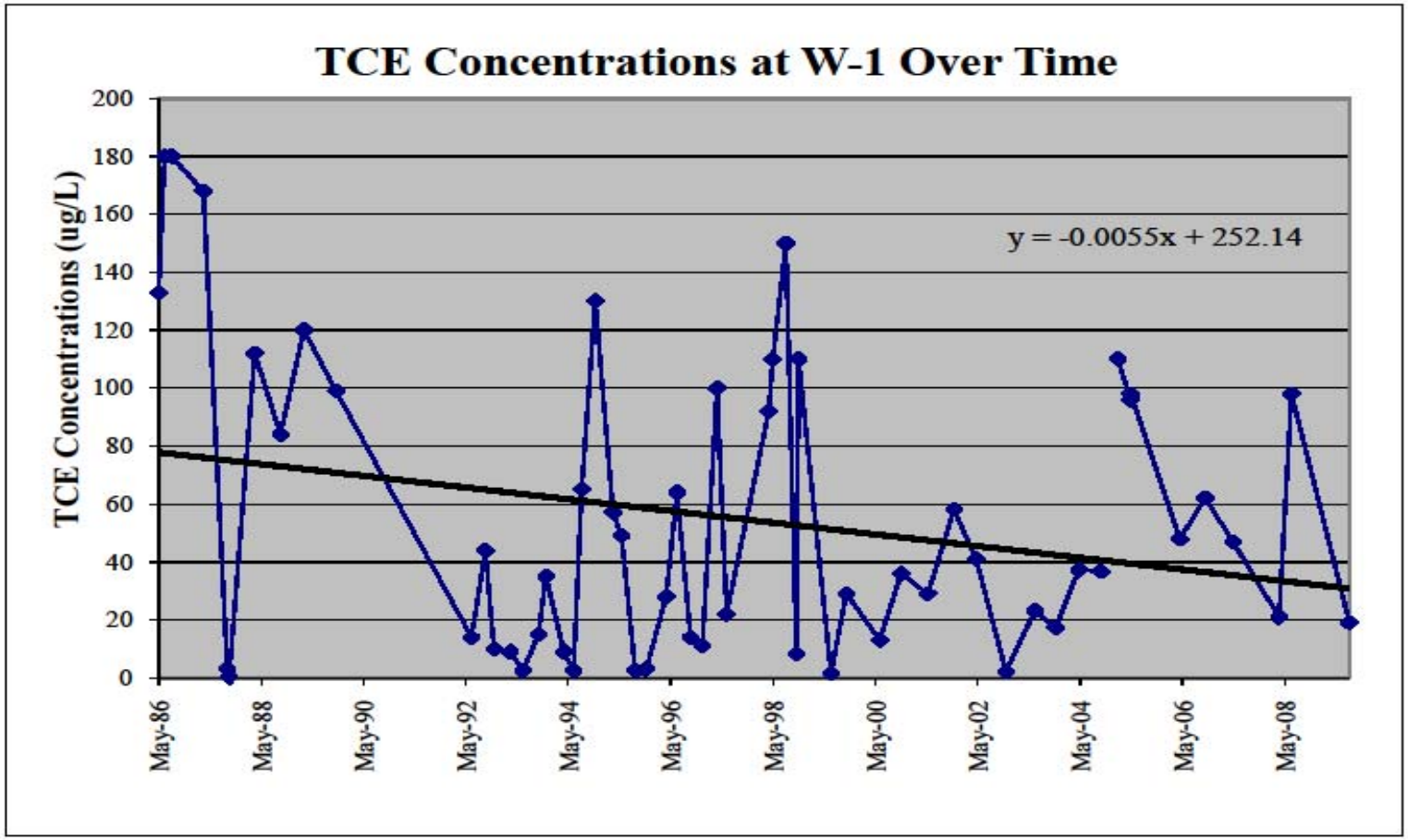


Slope and Trend Analysis

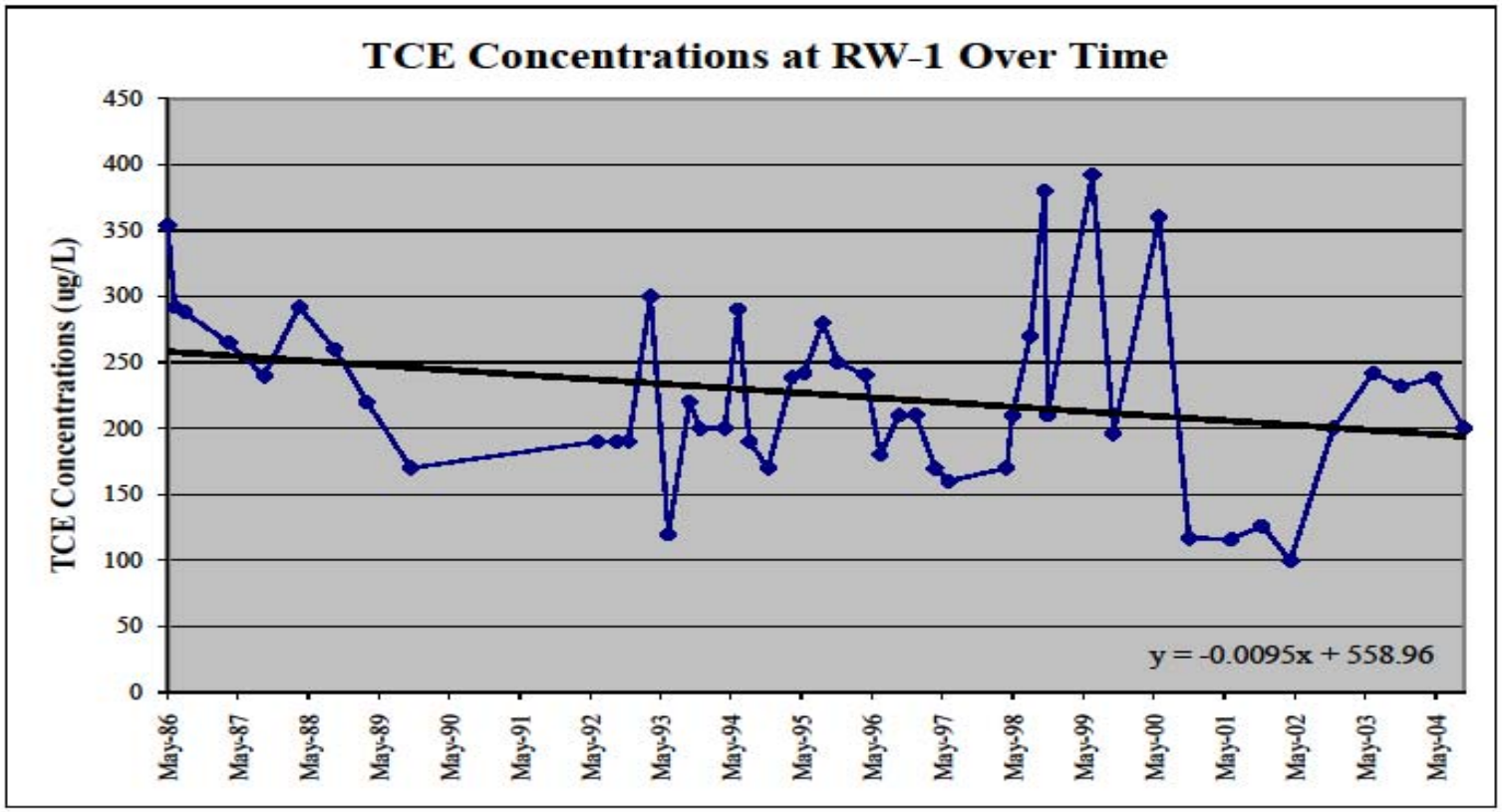
- For wells that reported a positive S statistic, none of the trends were observed to be statistically significant.
- In general, wells with a limited amount of data did not show statistically significant trends, but wells with extensive data did show statistically significant trends.



Result for Well within Capture Zone

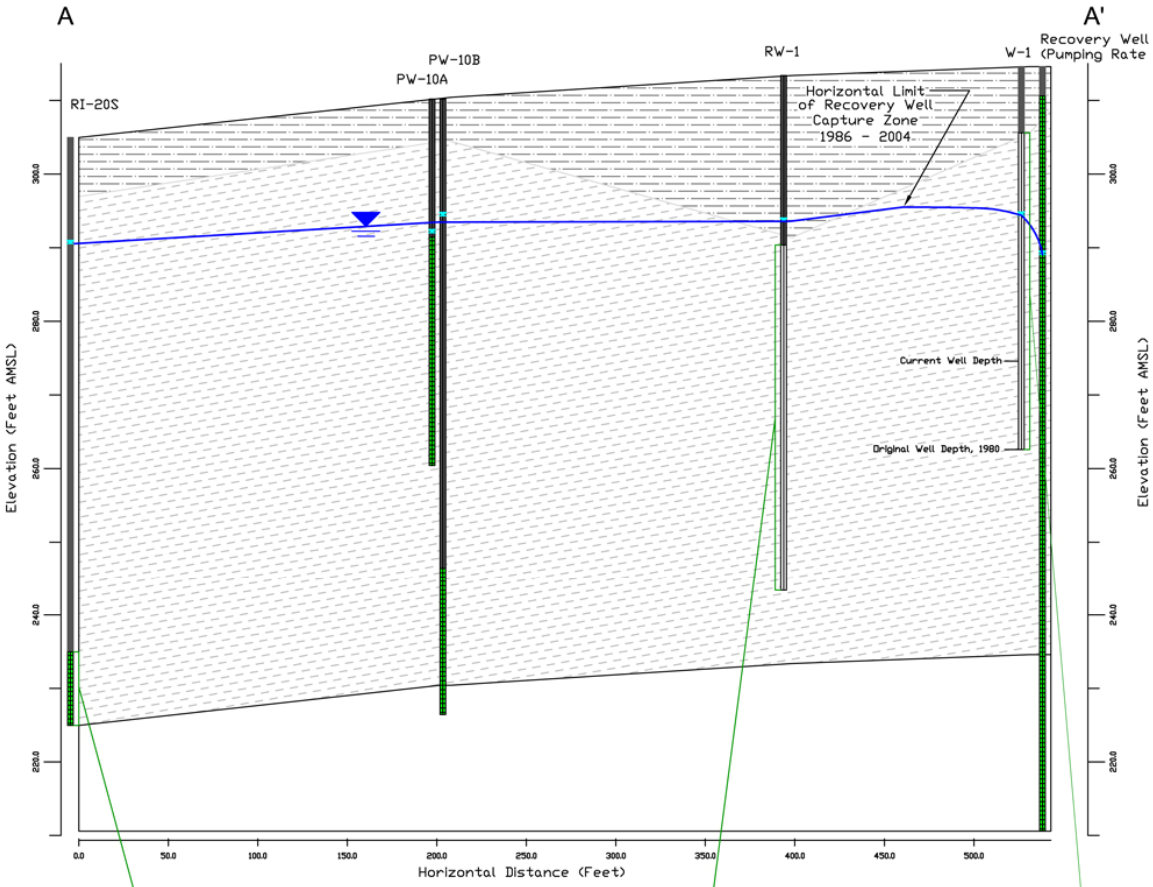


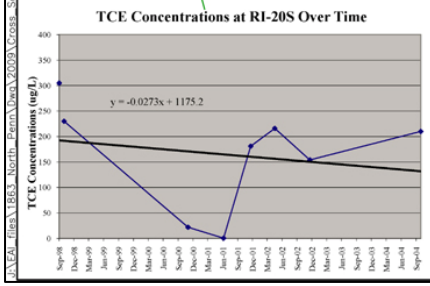
Result for Well outside Capture Zone

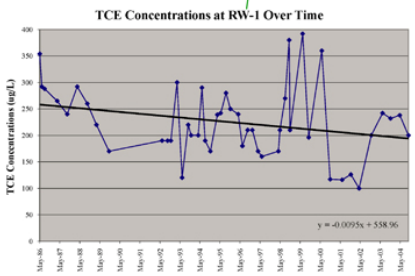


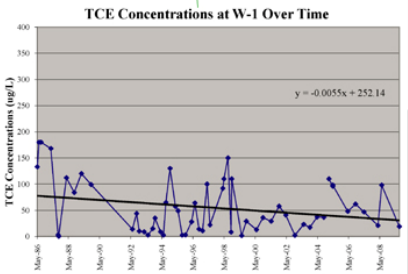
Comparison of slopes

- The rate of decrease of TCE concentration for a well within the capture zone of the P&T system was ~0.0055 ug/l/day.
- The rate of decrease of TCE concentration for a well outside the capture zone of the P&T system was ~0.0095 ug/l/day.









Legend:

- Open Borehole
- Screen
- Casing
- Regolith
- Shallow Bedrock (<=80 ft. BGS)
- Deep Bedrock (>80 ft. BGS)
- Potentiometric Surface 12-01-09
- Water Level Measured 12-01-09

Notes:

-Only Recovery Well active during data collection
-Horizontal limit of Recovery Well capture zone from 1986-2004 based on 12-01-09 GW evelation data (only Recovery Well pumping)

Scale: 10′ / 50′

Source: Rockworks, 2006

Environmental Alliance, Inc.
660 Yorklyn Road - Hockessin, DE 19707
Phone: (302) 234-4400 -Fax: (302) 234-1535

Superfund Site

Cross Section A-A'

DESIGNED BY:	DRAWN BY:	UPDATED BY:	FIGURE NO:
JE	KMB	AGG	4-1
APPROVED BY:	PROJECT NO.	DATE:	

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Conclusion

- The rate of decrease of TCE concentration in groundwater was as great, if not greater, in areas outside the capture zone of the P&T system as within the capture zone of the P&T system.
- Based on this information, the P&T system was shut off in late 2010 to begin a MNA study.
- The results from two quarters of groundwater monitoring have demonstrated no rebound in groundwater quality in the monitoring wells.