Groundwater Modeling and Fate and Transport Analysis for the Hoff VC Site

Work Completed by Tetra Tech, Inc.

Scott R. Anderson, Hydrogeologist

Project Objectives – Summary of Scoped Work

Objective 1 - Tetra Tech understands that the DEP's main focus is being able to provide 30-year projections of plume migration under site-specific conditions for several different parameters (or contaminants of concern). Based on this, Tetra Tech will construct a numerical 3-D model (MODFLOW) that while not be calibrated but does accurately reflect the 3-D groundwater flow system for an "average" synoptic event. The 3-D numerical groundwater flow system will be controlled by observed site-specific conditions represented as boundary conditions. This essentially will be a numerical rendering of the 3-D flow field.

Objective 2 - Tetra Tech will then input the plume information and run MT3D within that flow-field, utilizing the parameter information already assumed in the 2014 Leidos Report. This will produce contaminant plume migration in full site-specific 3-D conditions for 30 years into the future under representative groundwater flow conditions. Simplified model output will be provided in figures (or series of figures to represent changes through time).

Model Overview and Package Information

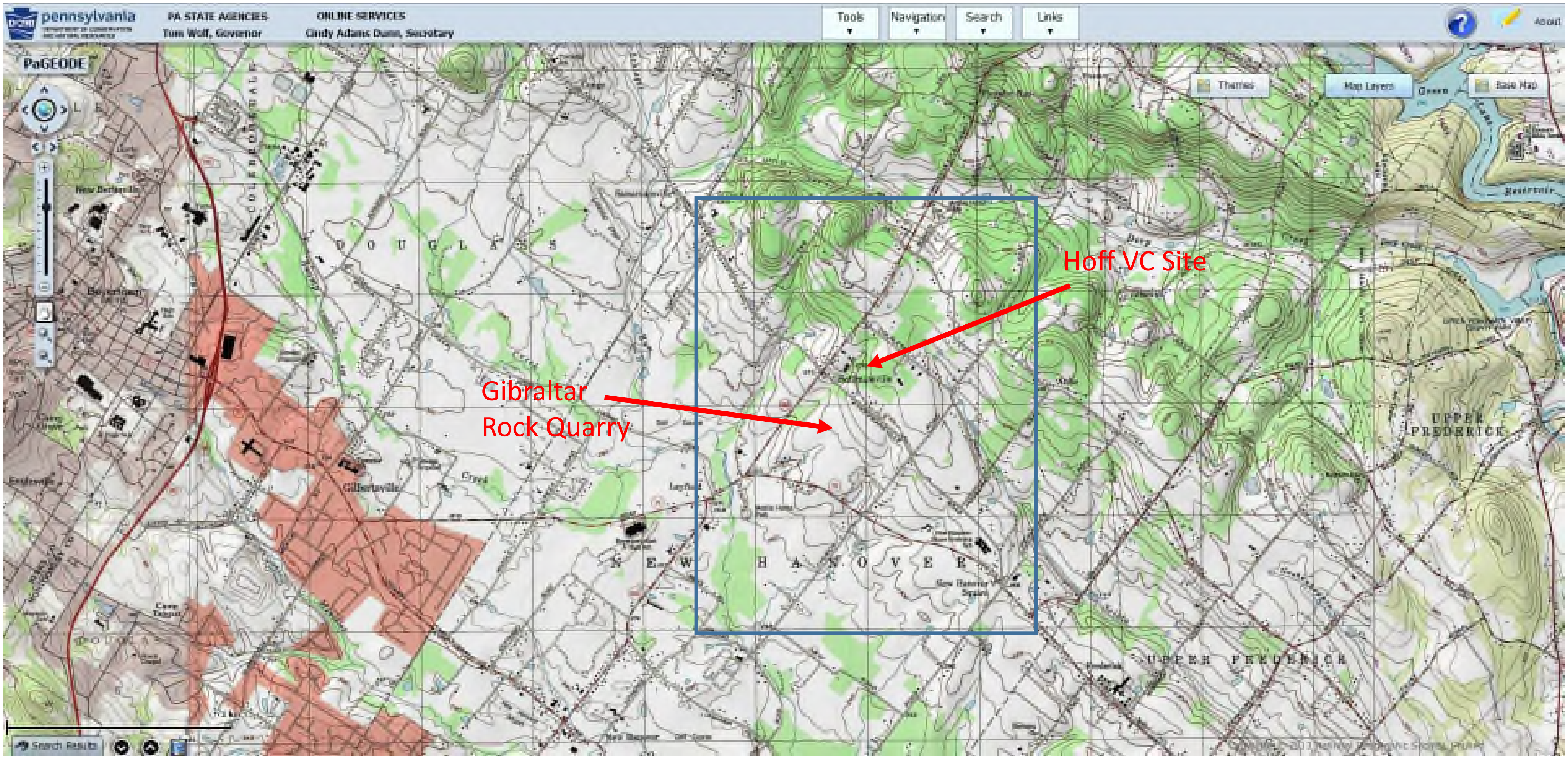
- MODFLOW groundwater model constructed for groundwater flow
  - Full 3-D based on site-specific information
  - Steady-state model utilized (time-independent)

- MT3D Utilized for fate and transport analysis of groundwater contamination for four contaminants – TCE, 1,2-DCB, 1,4-Dioxane, MTBE

- Model constructed in Windows-based program Groundwater Vistas®

Model Domain (Physical Extents) and Grid Size

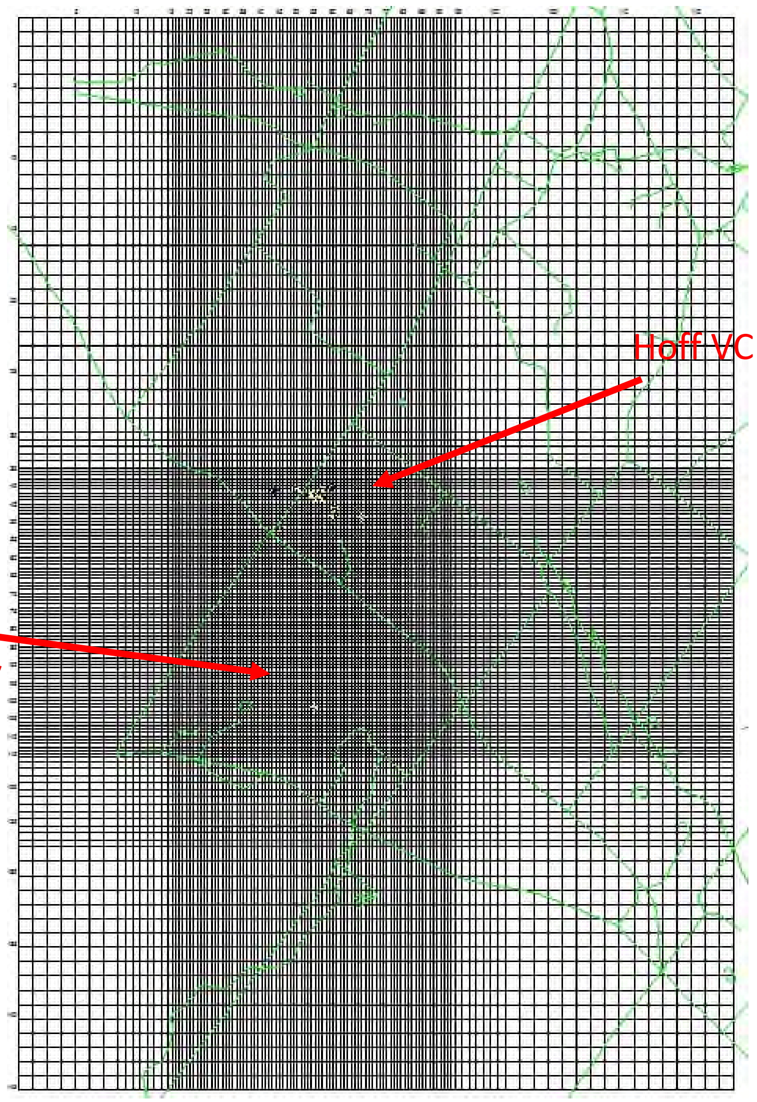
- Based on the Scoped Modeling Objectives, initially, a simplified model domain centered around the Hoff VC Site was envisioned.
  - Model would extend below Hoffmansville Road several hundred feet
- However, based on discussions with PADEP during the Project Kickoff Conference Call (April 4th), the model domain was expanded to fully incorporate the downgradient area of the Gibraltar Rock Quarry.
- Model domain was selected to center the Hoff VC Site and Gibraltar Rock Quarry and correspond to natural boundary conditions such as higher elevations, streams (though no hydraulic connection to system)
- Model Domain is approximately –
  - 10,000 feet east-west
  - 15,000 feet north-south
- Variable grid size employed –
  - 50 feet by 50 feet at Hoff VC Site and most of Gibraltar Rock Quarry
  - 200 feet by 200 feet at model edges



Model Domain – Area – USGS Topo Background

Variable Grid Spacing –

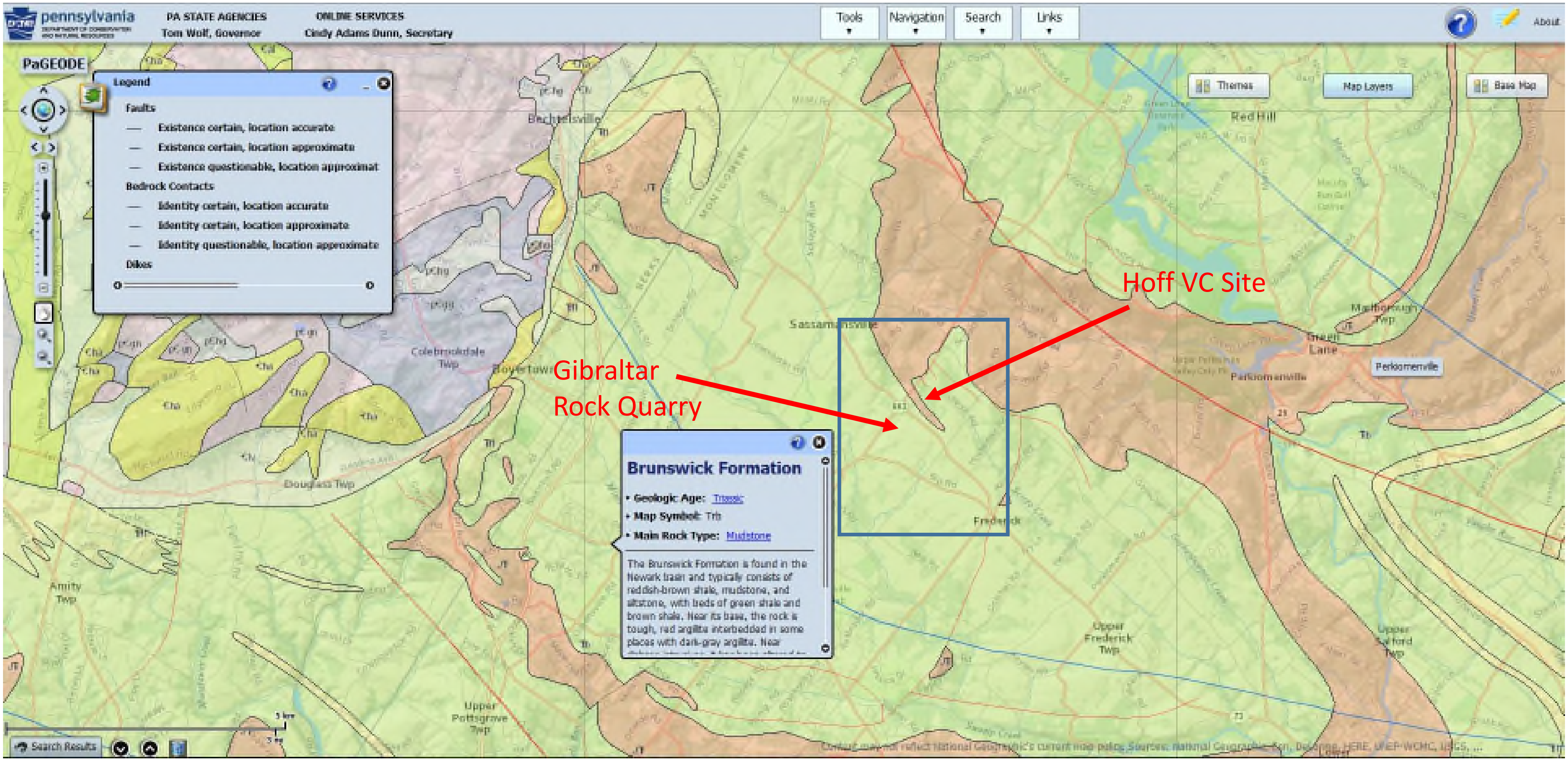
50 feet by 50 feet centered on Hoff Site and Quarry to 200 feet by 200 feet near Model edges



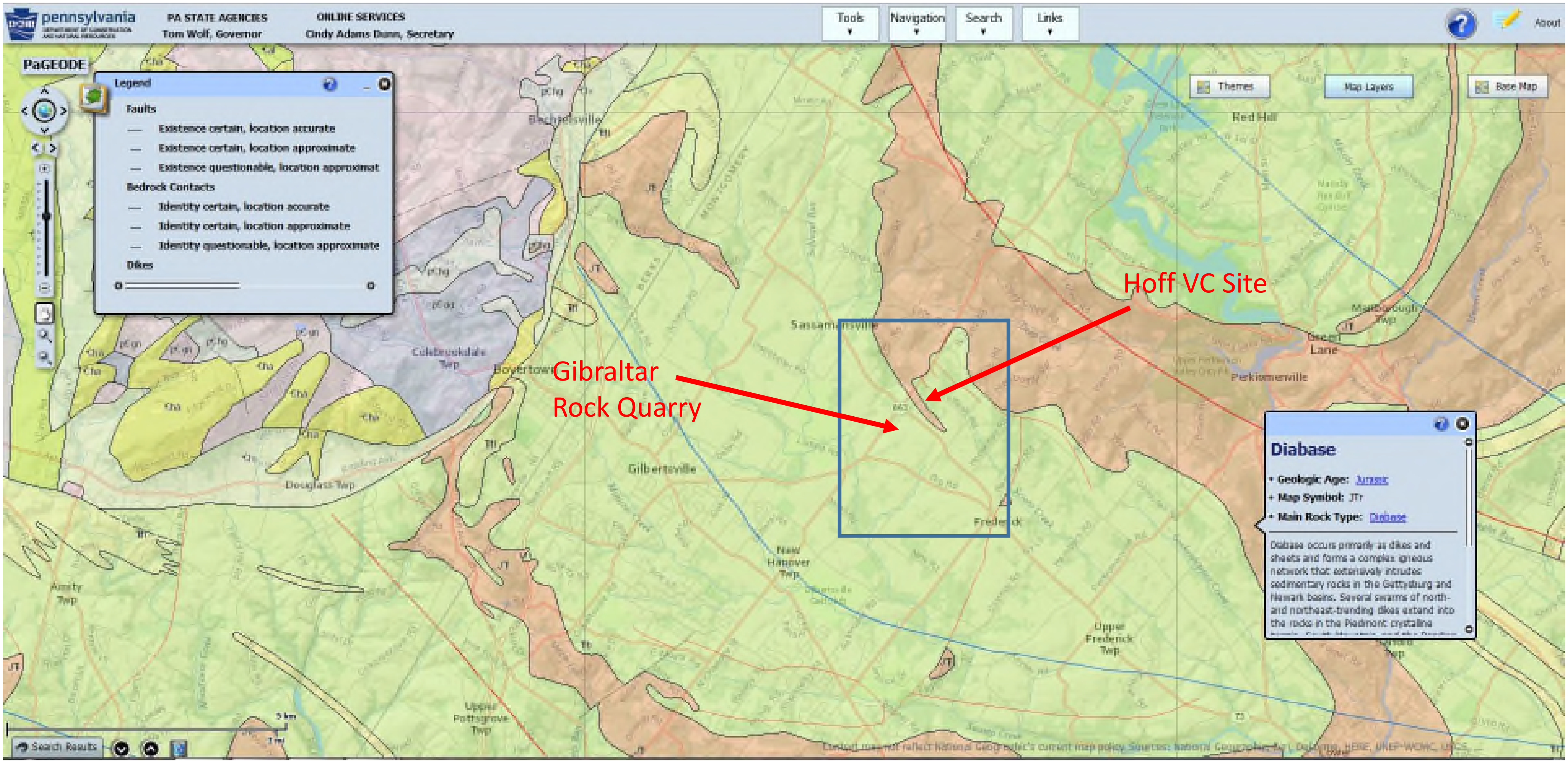
Final Model Domain & Grid – Variable Spacing Centered on Hoff Site and Quarry

General Geology and Hydrogeology

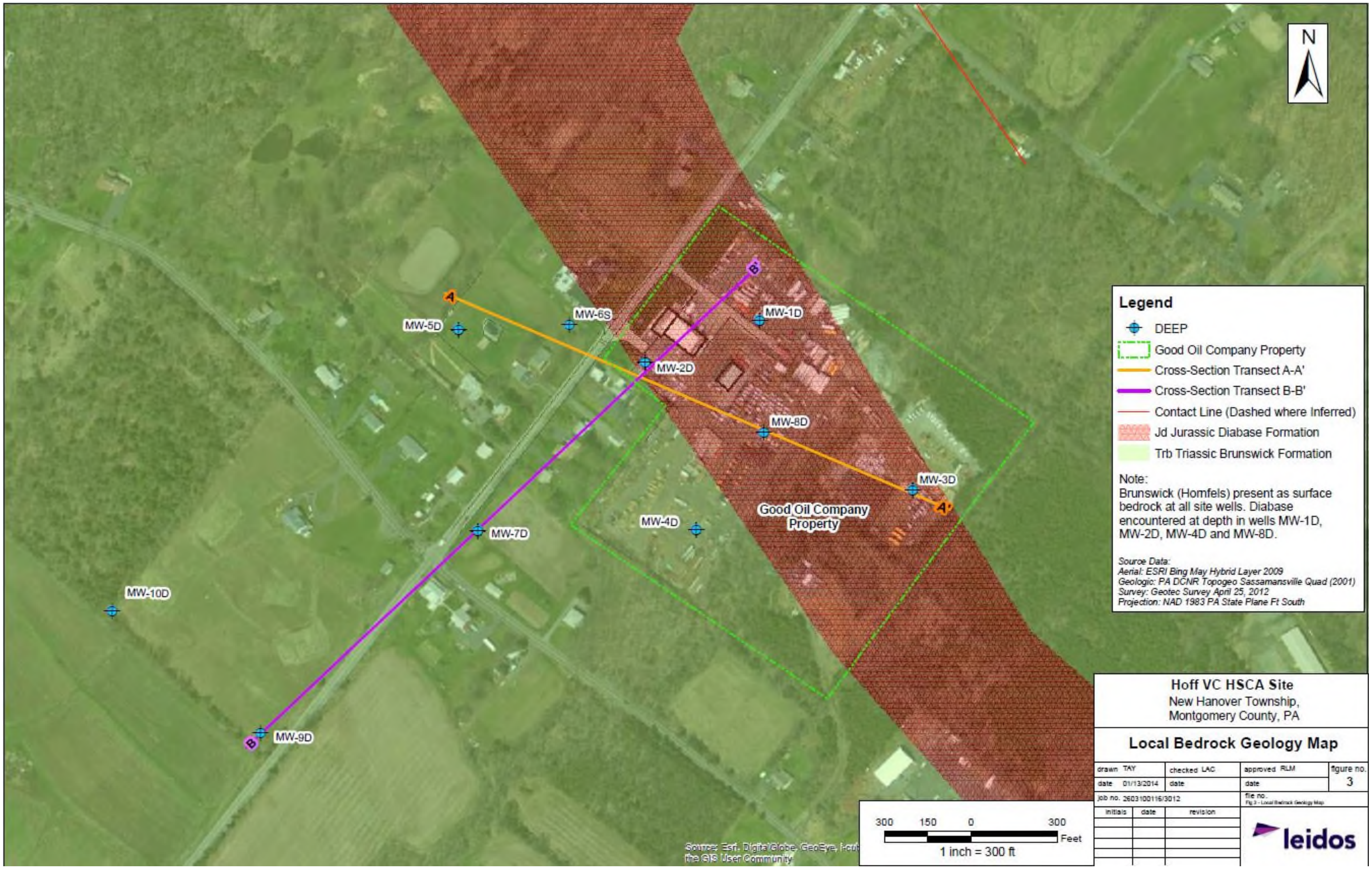
- Geology of the Hoff VC Site and Gibraltar Rock Quarry consists of clayey silt (likely residuum) overlying siltstones, hornfels and diabase.
- Based on Leidos Report (August 2014) and Gibraltar Rock Quarry reports (Appendix D of Leidos Report), groundwater flow is –
  - Within secondary openings - fractures and joints
  - Most groundwater occurs through vertically intersecting joints
- Surface water (streams) are not hydraulically connected to groundwater
- Permeability is generally low in all units and not distinct within any unit
  - Geology does not control groundwater flow – fractures and interconnectedness of the fractures controls groundwater flow
- Wells are generally in three zones at the Hoff VC Site –
  - Surface wells – Approximately 30 feet bgs (soil and uppermost rock)
  - Shallow bedrock wells – between 50 to 100 feet bgs
  - Deep bedrock wells – between 100 to 200 feet bgs
- Wells at Gibraltar Rock Quarry are open borehole wells to approximately 400 feet bgs



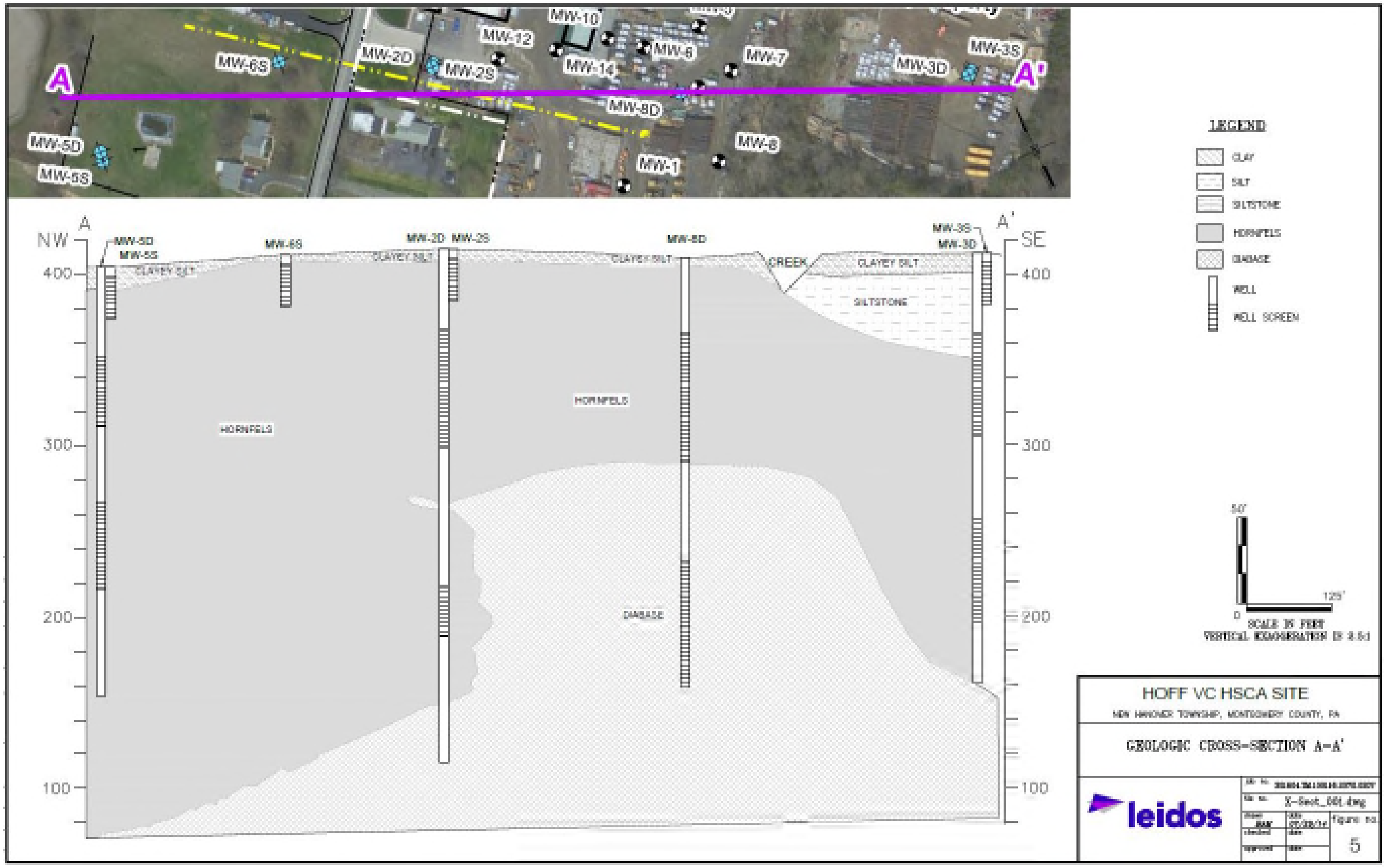
Model Domain – Geology – Brunswick Formation



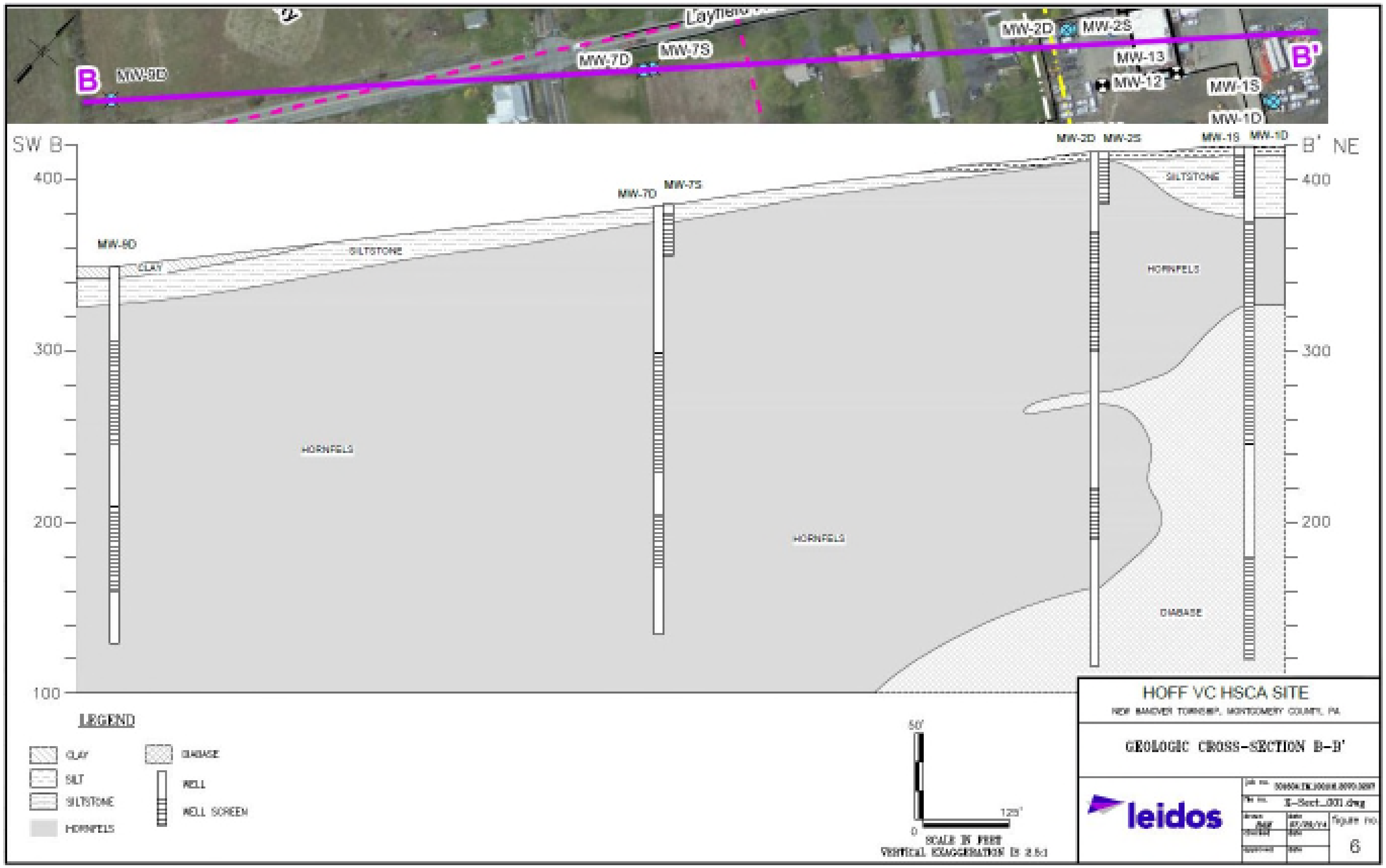
Model Domain – Geology – Diabase Intrusion



Model Domain and Layering – Geology and Cross-Section Locations

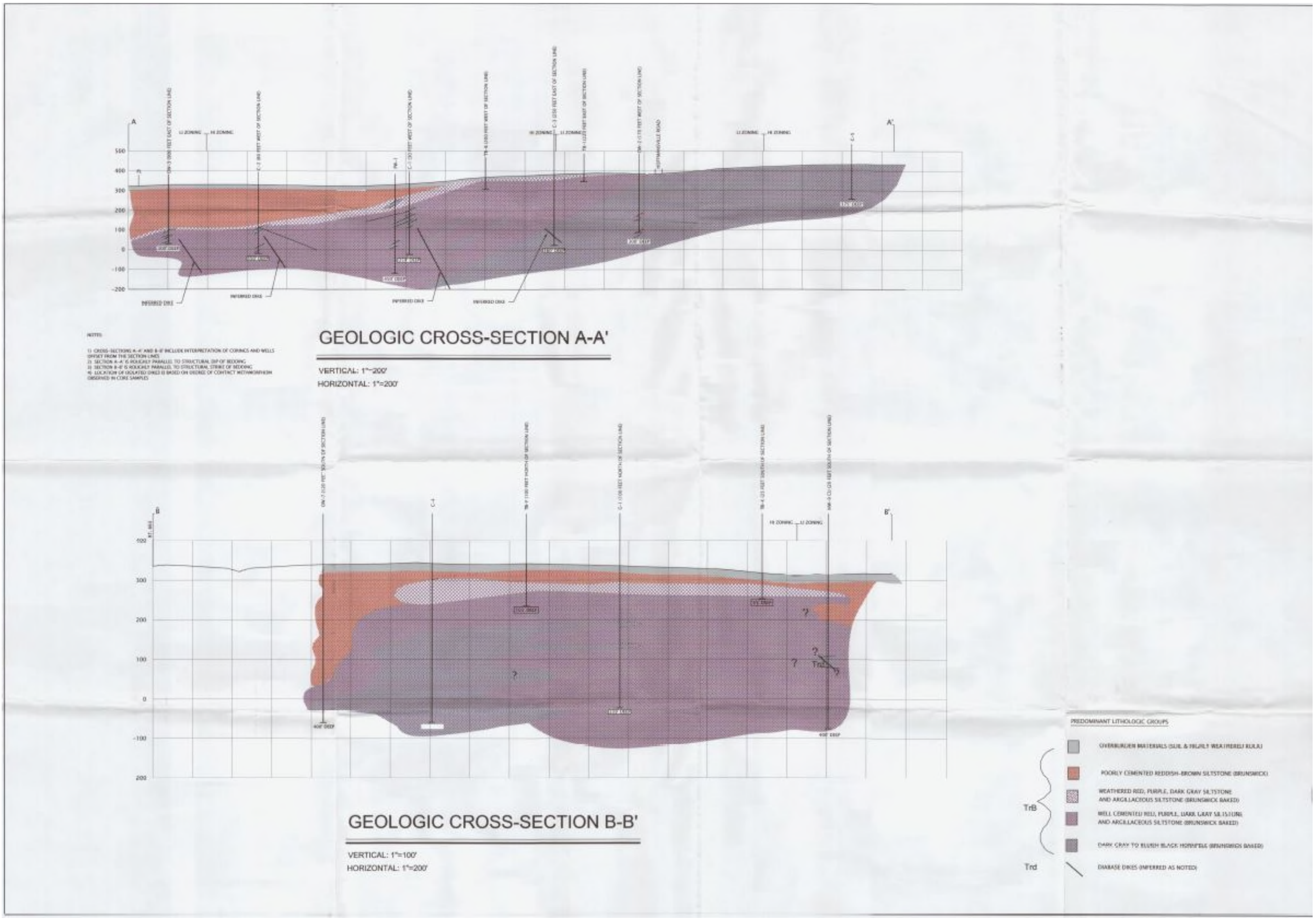


Model Domain – Geology – Cross Section A-A’



Model Domain – Geology – Cross Section B-B’

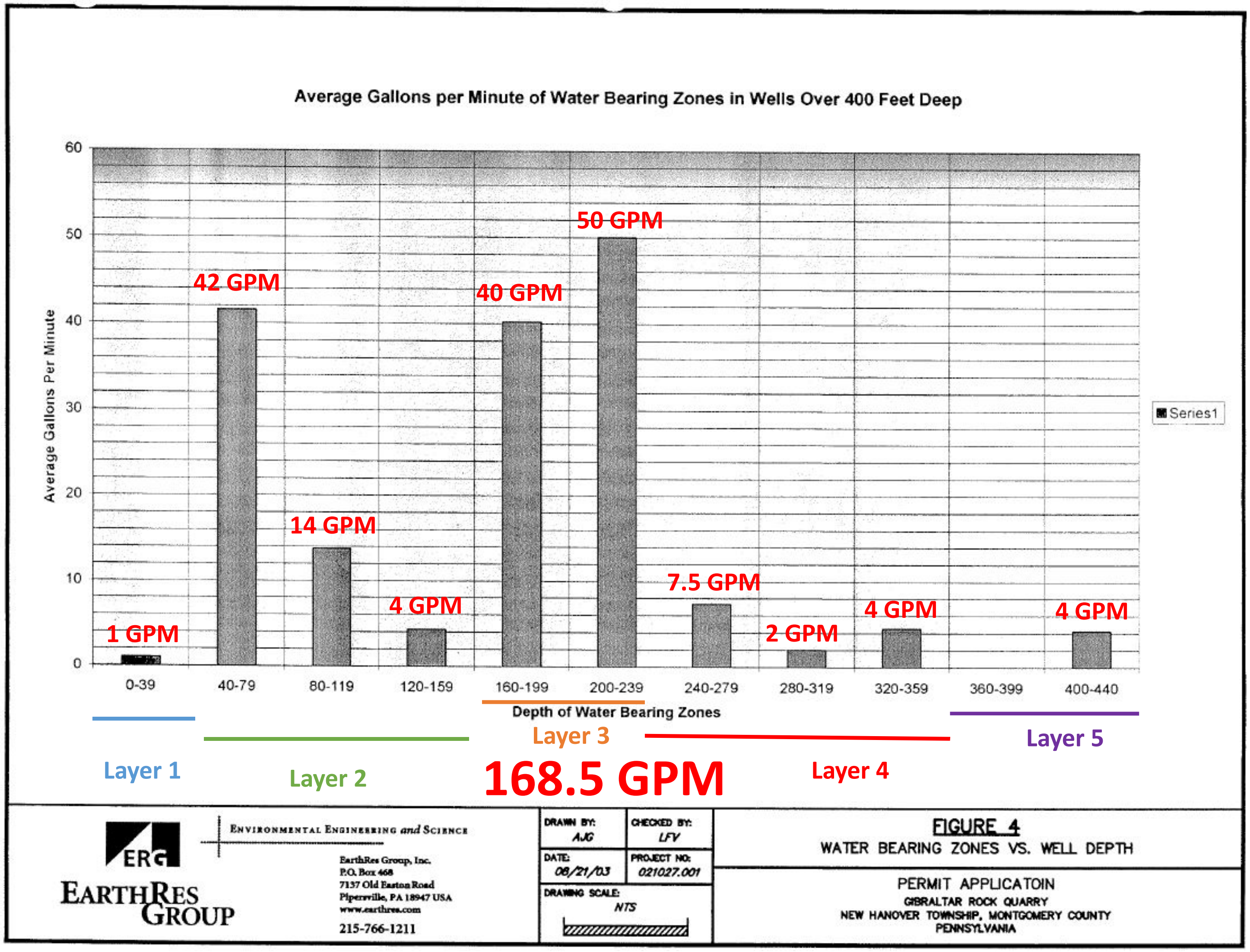
Model Domain – Geology – Cross Sections Quarry



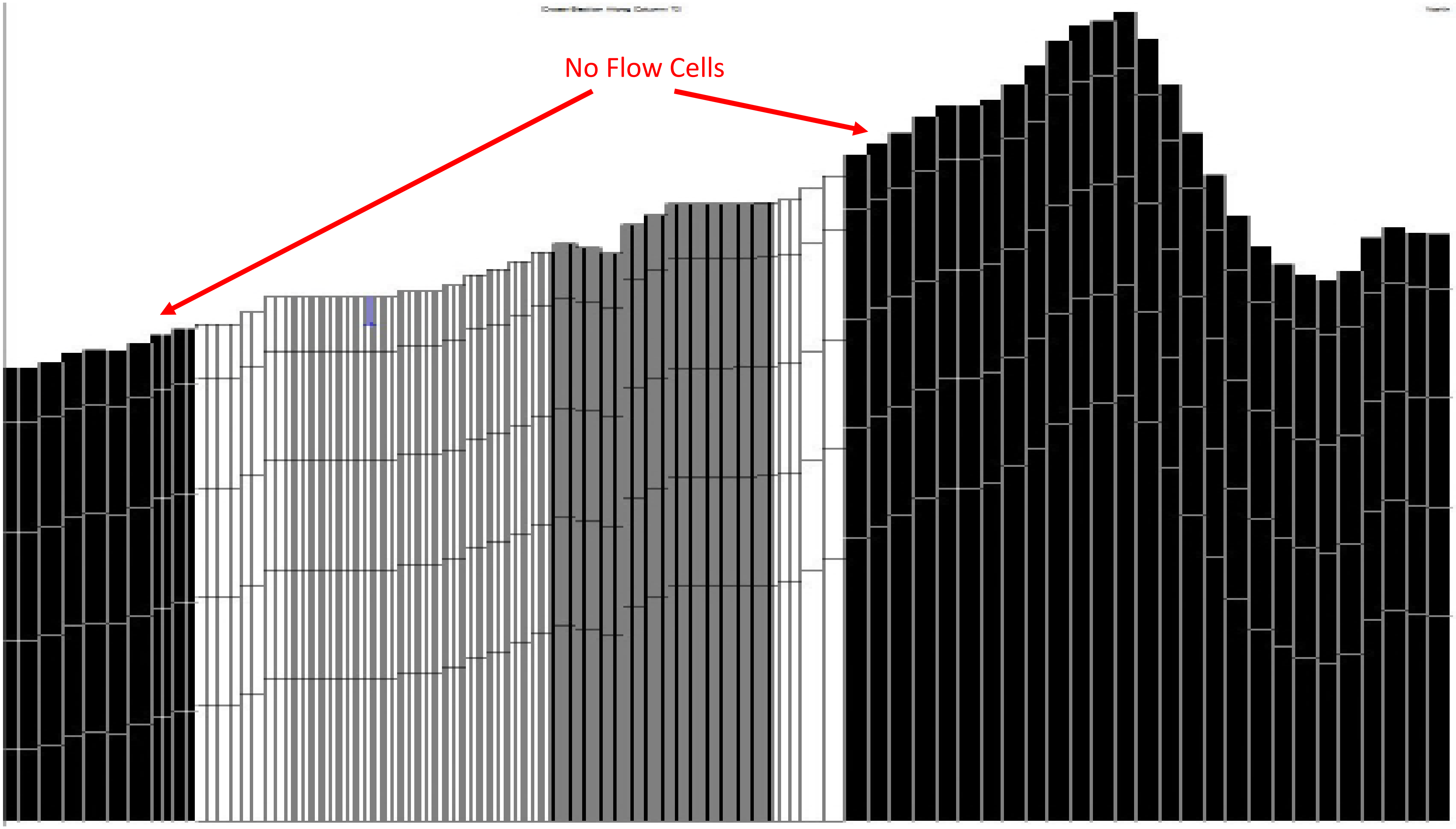
Model Domain – Geology – Cross Sections Quarry

Model Layering

- Model Layer based on groundwater monitoring wells at Hoff VC Site and open borehole wells at Gibraltar Rock Quarry
- Additionally, water bearing zones versus well depth was considered (Figure 4 of Appendix D)
  - Most productive water bearing zones are –
    - 40 to 79 feet bgs
    - 160 to 199 feet bgs
    - 200 to 239 feet bgs
  - Upper 40 feet least productive water bearing zone!
- Five model layers were used
  - Layer 1 – Ground surface to 50 feet bgs
  - Layers 2 through 4 – 100 feet thick
  - Layer 5 – Bottom set to -150 feet MSL (variable thickness)
- Ground Surface estimated from PA LIDAR data sets (2 foot contours)



Water Bearing Zones Versus Well Depth – from Gibraltar Report



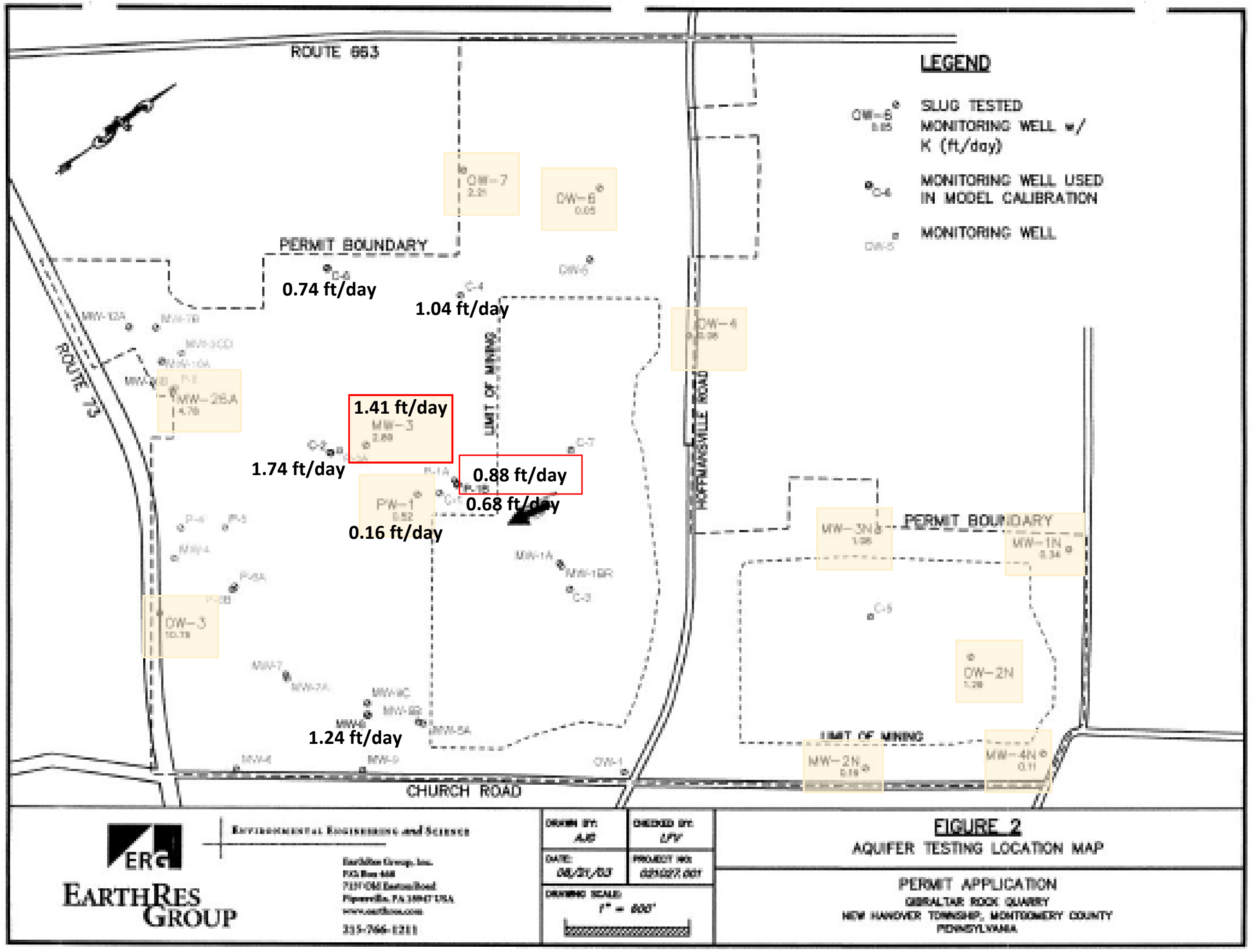
Model Layering – North South Transect through Hoff Site

Physical Properties – Hydraulic Conductivity

- Permeability is generally low in all units and not distinct within any unit
  - Geology does not control groundwater flow
  - Interconnectedness of bedrock fractures controls groundwater flow, as wells as changes in potentiometric head.

- Hydraulic conductivity estimated from –
  - Slug testing
  - 72-Hour pumping test

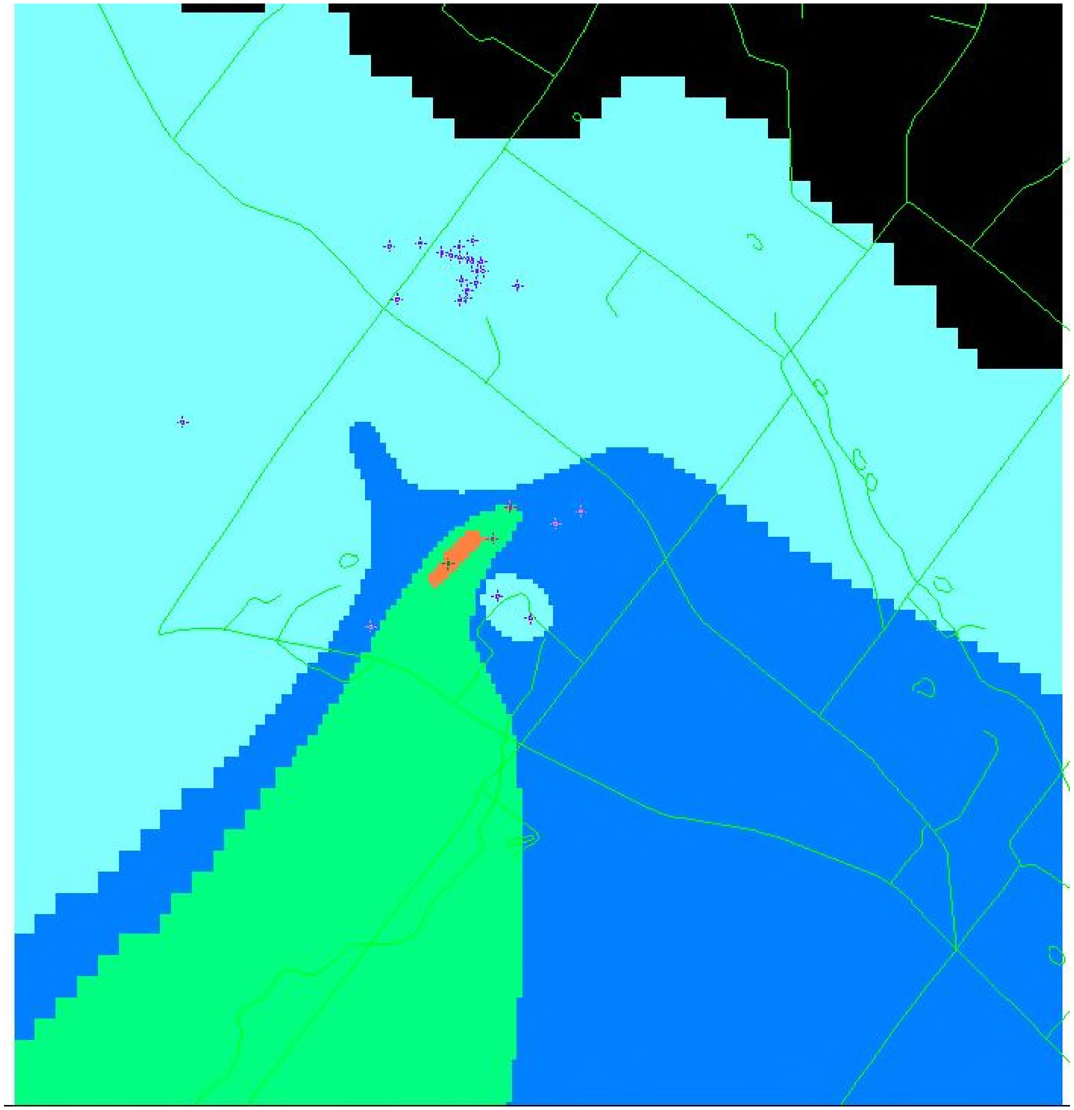
- Hydraulic conductivity partitioned by model layer based on water bearing zones
  - Accounts for results obtained in open borehole wells to individual model layers



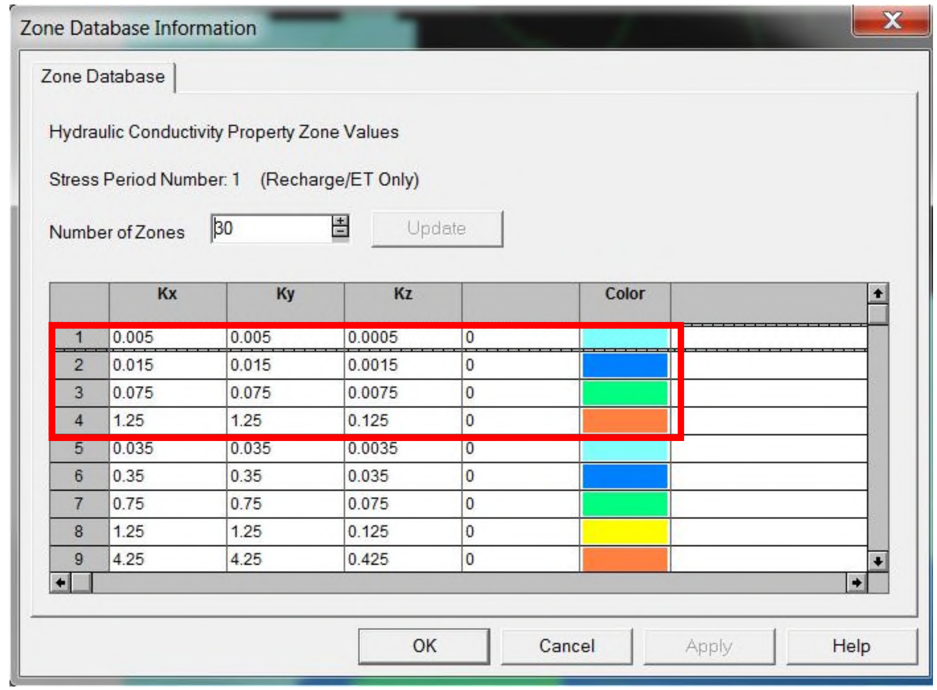
All Quarry Wells – Hydraulic Conductivity Results

	Hydraulic Conductivity				Model Layer 1	Model Layer 2	Model Layer 3	Model Layer 4	Model Layer 5
Well ID	feet/day	Screened or Open Interval	Total Depth		0 to 50 ft bgs	50 to 150 ft bgs	150 to 250 ft bgs	250 to 350 ft bgs	> 350 ft bgs
PW-1	0.16	40 feet to 450 feet	450		0.001	0.057	0.085	0.013	0.004
C-1	0.68	20 feet to 359 feet	359		0.004	0.248	0.372	0.056	--
P-1B	0.88	11 feet to 31 feet	31		0.880	--	–	--	--
MW-3	1.41	21 feet to 40 feet	40		1.410	--	–	--	--
C-2	1.74	26 feet to 350 feet	350		0.011	0.635	0.952	0.143	--
C-4	1.04	12 feet to 400 feet	400		0.006	0.379	0.569	0.085	--
C-6	0.74	13 feet to 400 feet	400		0.004	0.270	0.405	0.061	--
MW-8	1.24	42 feet to 150 feet	150		0.020	1.220	–	--	--
MW-1N	0.34	10 feet to 440 feet	440		0.002	0.121	0.182	0.027	0.008
MW-2N	0.19	19 feet to 425 feet	425		0.001	0.068	0.101	0.015	0.005
MW-3N	1.08	1 feet to 445 feet	445		0.006	0.385	0.577	0.087	0.026
MW-4N	0.11	8 feet to 410 feet	410		0.001	0.039	0.059	0.009	0.003
OW-2N	1.29	12 feet to 438 feet	438		0.008	0.459	0.689	0.103	0.031
OW-4	0.08	8 feet to 310 feet	310		0.000	0.029	0.044	0.007	--
OW-6	0.05	1 feet to 380 feet	380		0.000	0.018	0.027	0.004	--
MW-3	2.89	15 feet to 21 feet	20.5		2.89	--	–	--	--
OW-7	2.21	4 feet to 380 feet	380		0.013	0.806	1.209	0.181	--
PW-1	0.52	40 feet to 450 feet	450		0.003	0.185	0.278	0.042	0.012
MW-26A	4.78	1 feet to 103 feet	103		0.078	4.702	–	--	--
OW-3	10.76	15 feet to 280	280		0.065	3.925	5.887	0.883	--

Partitioned Hydraulic Conductivity based on Water Bearing Zones

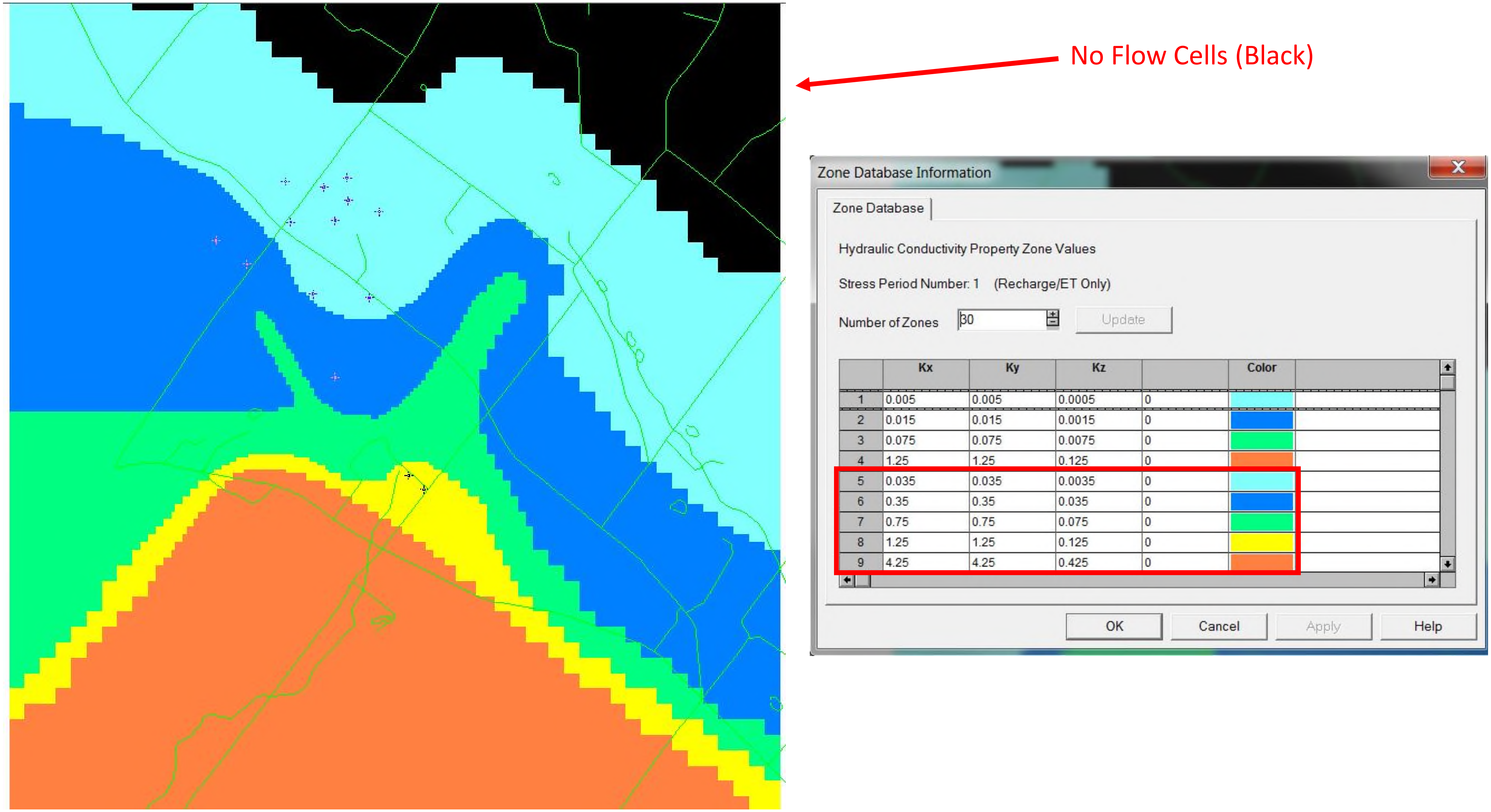


No Flow Cells (Black)

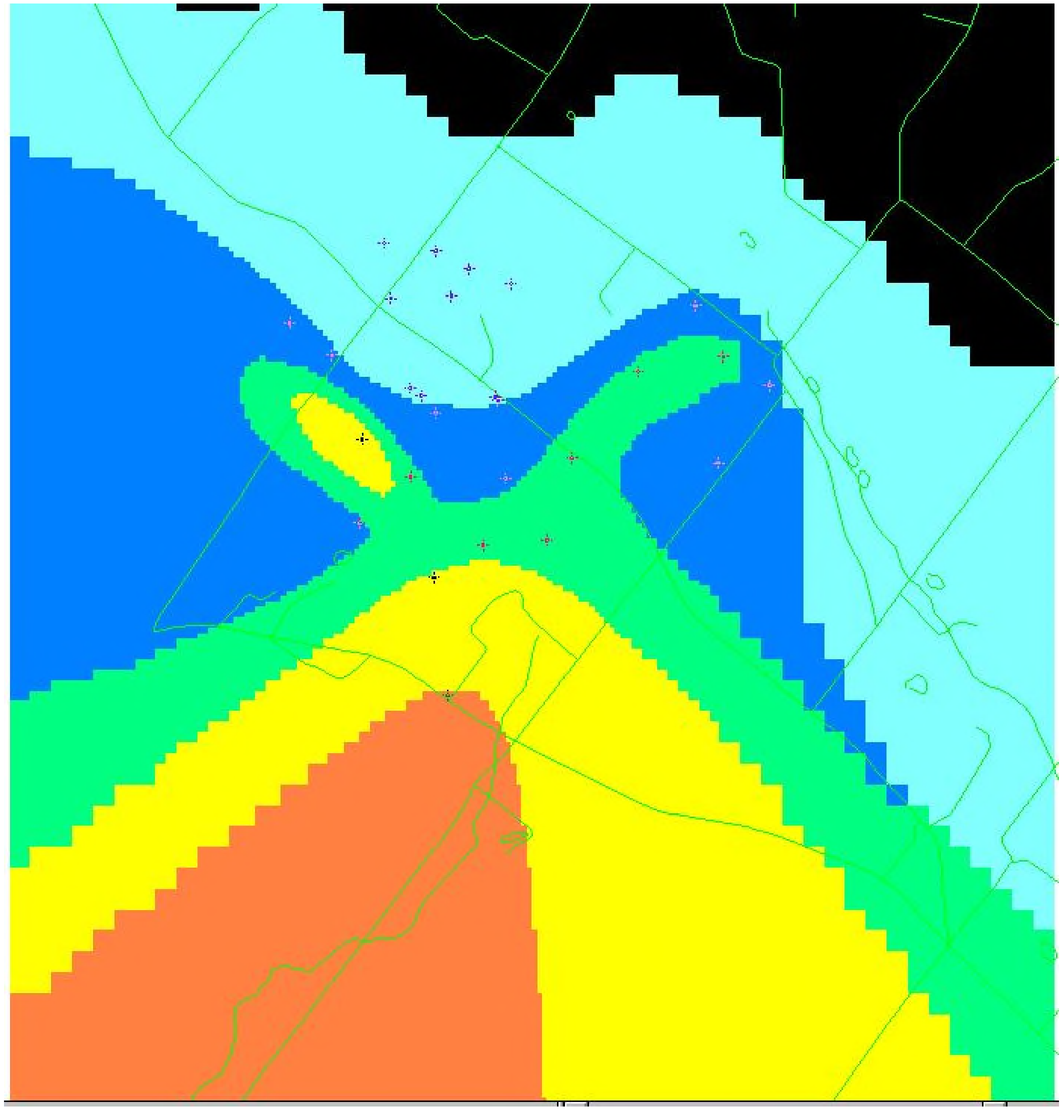


	Kx	Ky	Kz		Color
1	0.005	0.005	0.0005	0	
2	0.015	0.015	0.0015	0	
3	0.075	0.075	0.0075	0	
4	1.25	1.25	0.125	0	
5	0.035	0.035	0.0035	0	
6	0.35	0.35	0.035	0	
7	0.75	0.75	0.075	0	
8	1.25	1.25	0.125	0	
9	4.25	4.25	0.425	0	

Hydraulic Conductivity Zonation – Layer 1



Hydraulic Conductivity Zonation – Layer 2



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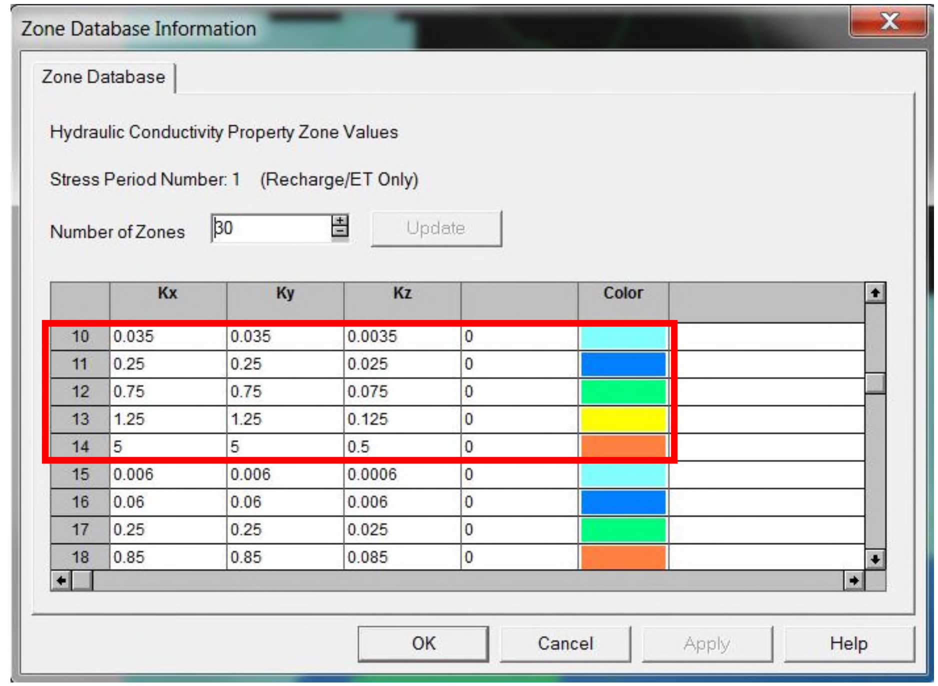
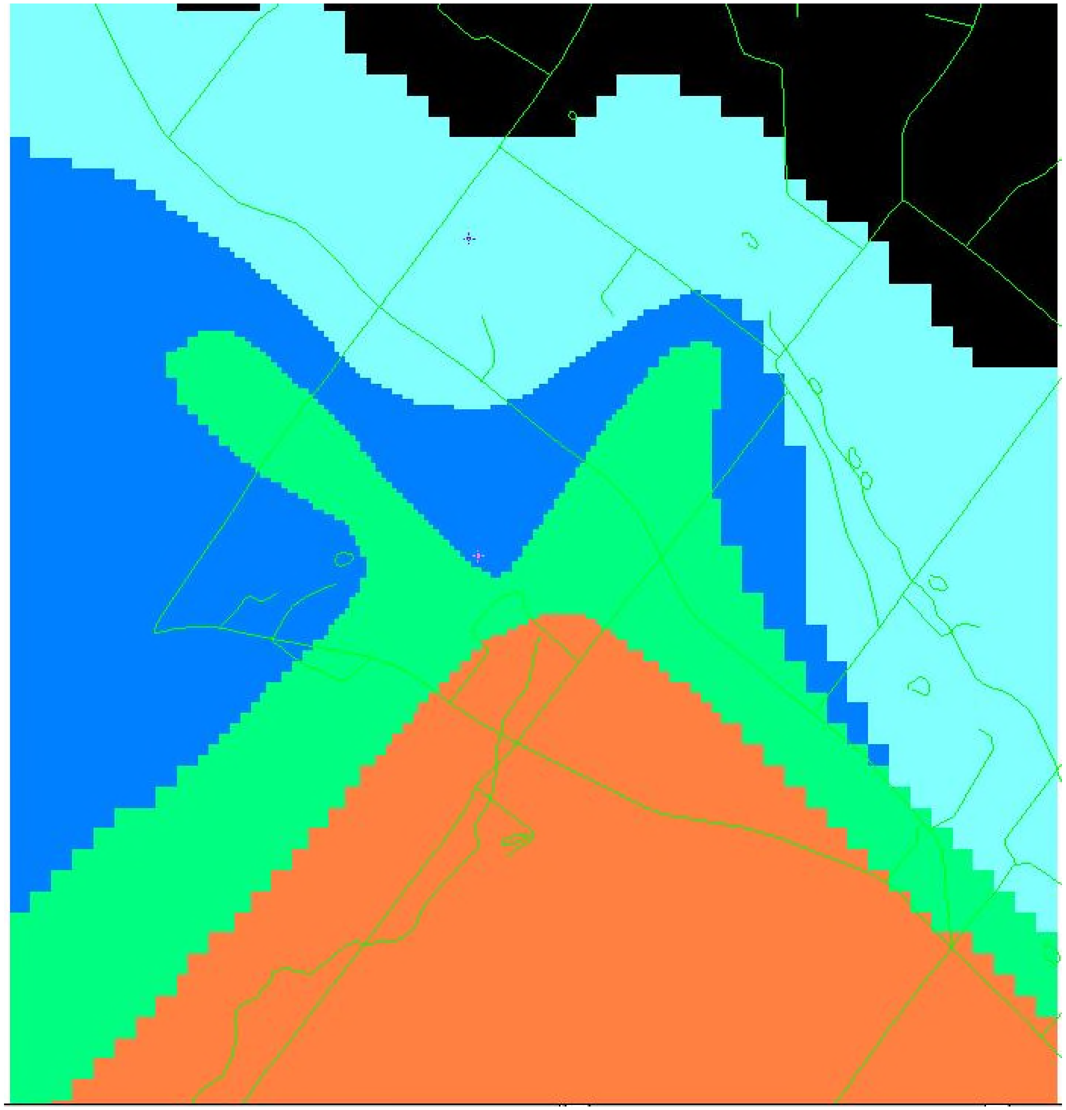


	Kx	Ky	Kz		Color
10	0.035	0.035	0.0035	0	
11	0.25	0.25	0.025	0	
12	0.75	0.75	0.075	0	
13	1.25	1.25	0.125	0	
14	5	5	0.5	0	
15	0.006	0.006	0.0006	0	
16	0.06	0.06	0.006	0	
17	0.25	0.25	0.025	0	
18	0.85	0.85	0.085	0	

Hydraulic Conductivity Zonation – Layer 3



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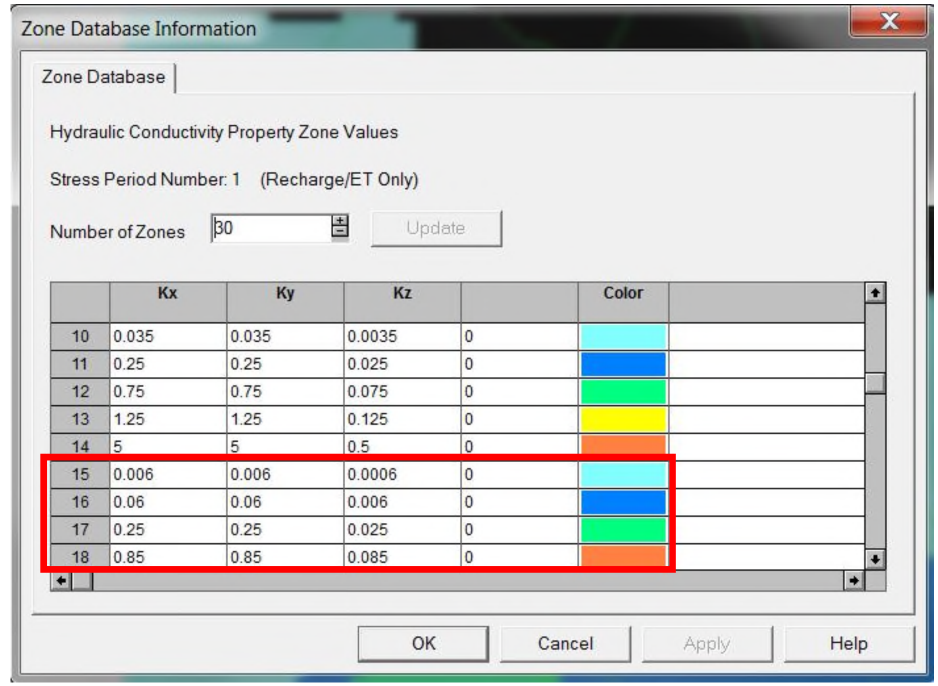
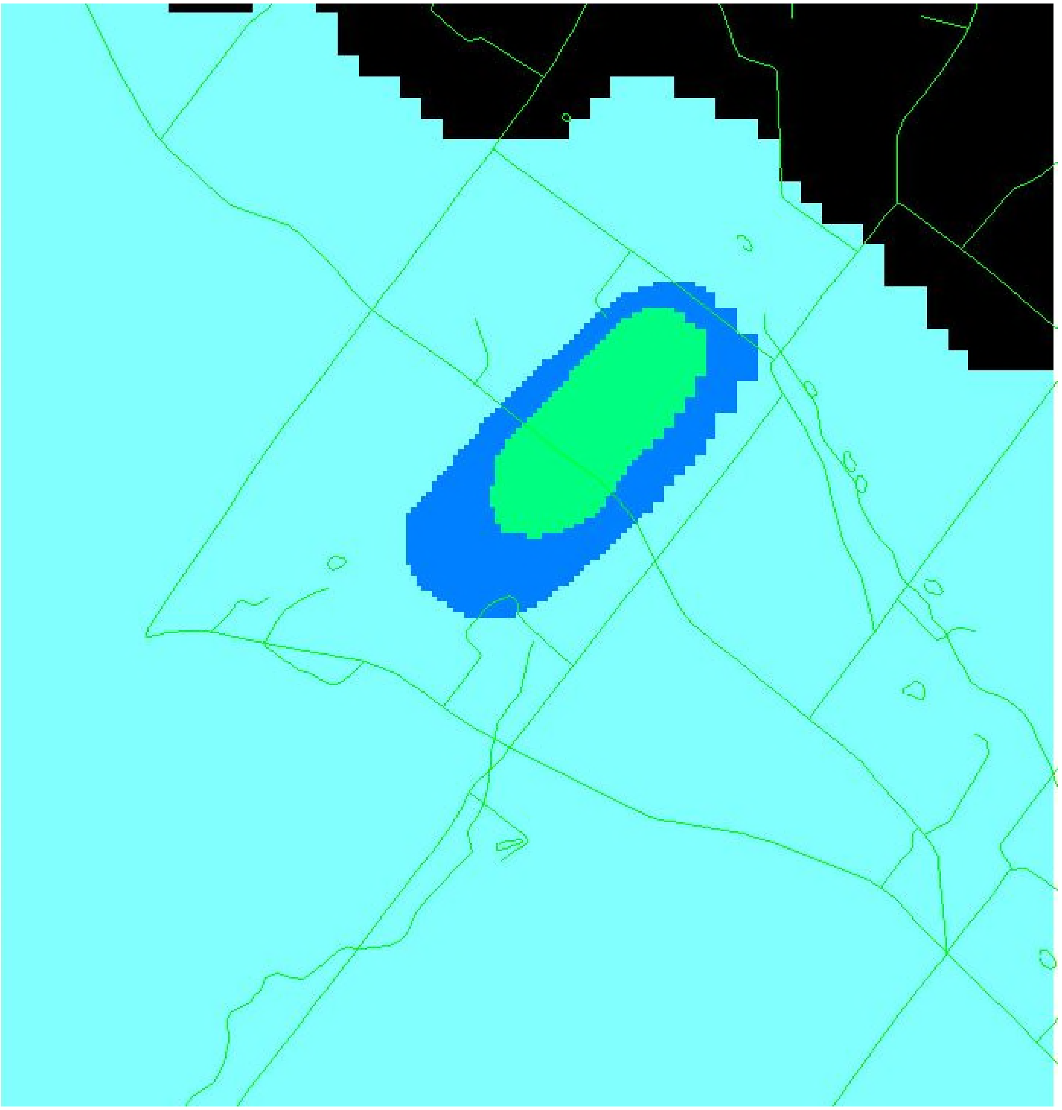
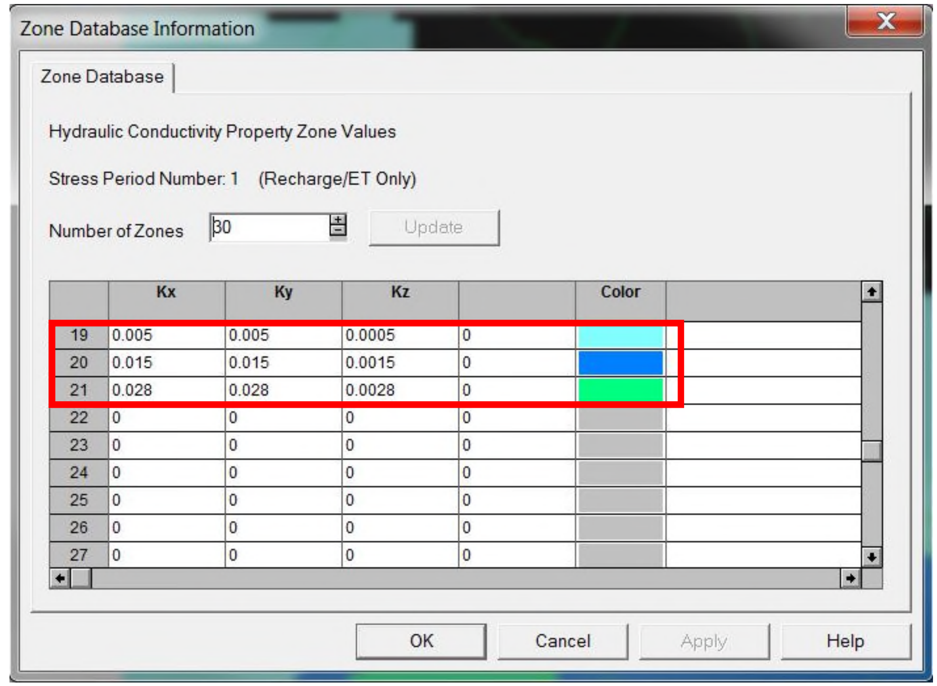


	Kx	Ky	Kz		Color
10	0.035	0.035	0.0035	0	
11	0.25	0.25	0.025	0	
12	0.75	0.75	0.075	0	
13	1.25	1.25	0.125	0	
14	5	5	0.5	0	
15	0.006	0.006	0.0006	0	
16	0.06	0.06	0.006	0	
17	0.25	0.25	0.025	0	
18	0.85	0.85	0.085	0	

Hydraulic Conductivity Zonation – Layer 4



No Flow Cells (Black)



Zone Database Information

Zone Database

Hydraulic Conductivity Property Zone Values

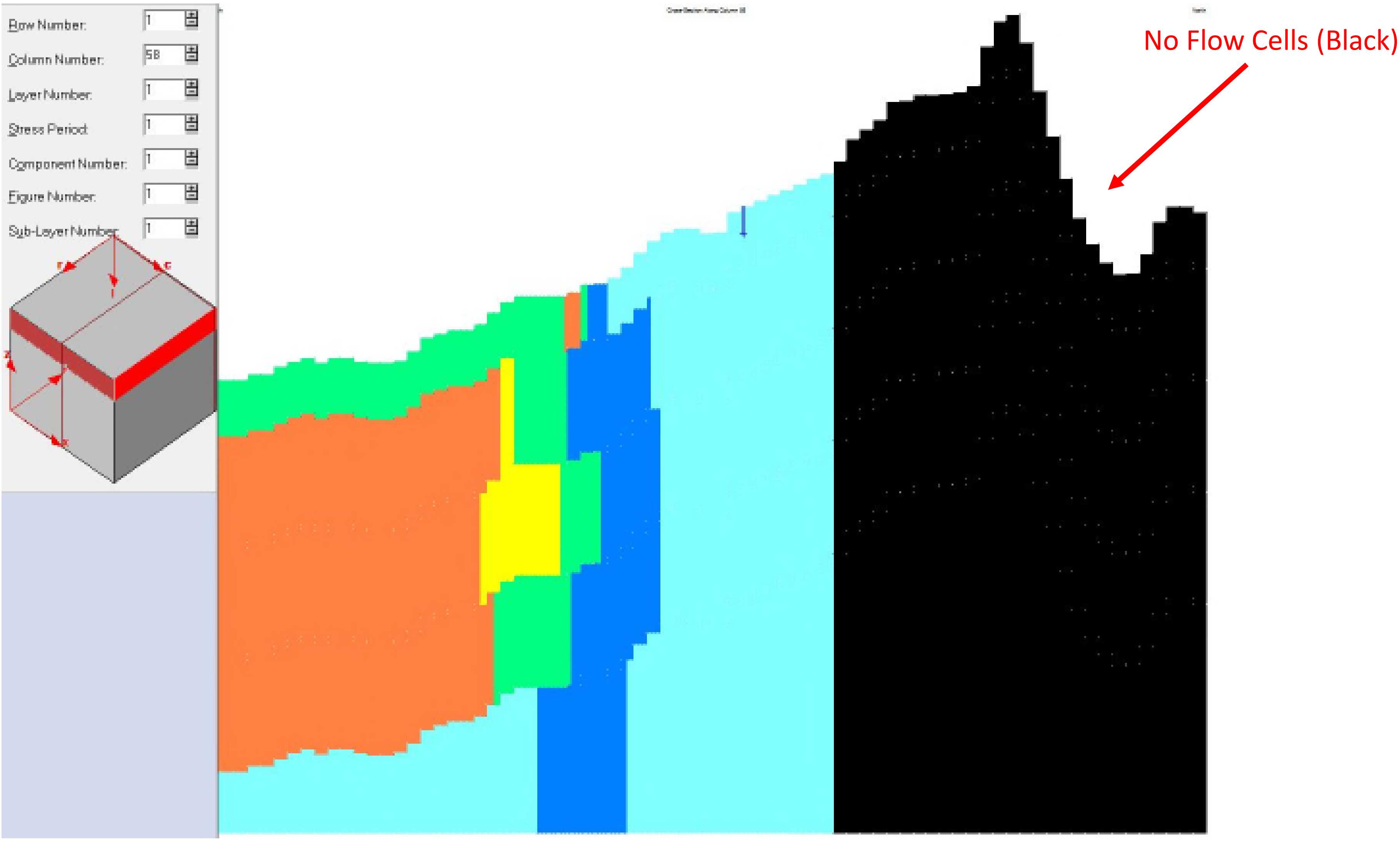
Stress Period Number: 1 (Recharge/ET Only)

Number of Zones 30 Update

	Kx	Ky	Kz		Color
19	0.005	0.005	0.0005	0	
20	0.015	0.015	0.0015	0	
21	0.028	0.028	0.0028	0	
22	0	0	0	0	
23	0	0	0	0	
24	0	0	0	0	
25	0	0	0	0	
26	0	0	0	0	
27	0	0	0	0	

OK Cancel Apply Help

Hydraulic Conductivity Zonation – Layer 5



Hydraulic Conductivity Zonation – Layers 1 to 5 – South-North Through Site

Groundwater Potentiometrics

- Groundwater monitoring wells from Hoff VC Site and Gibraltar Rock Quarry utilized for understanding area wide groundwater potentiometrics and flow (direction and magnitude)

- July 2014 data set used for Hoff VC Site
  - Most recent data set with comprehensive site-wide coverage
  - Based on Leidos Report, flow fields are consistent with previous potentiometric events

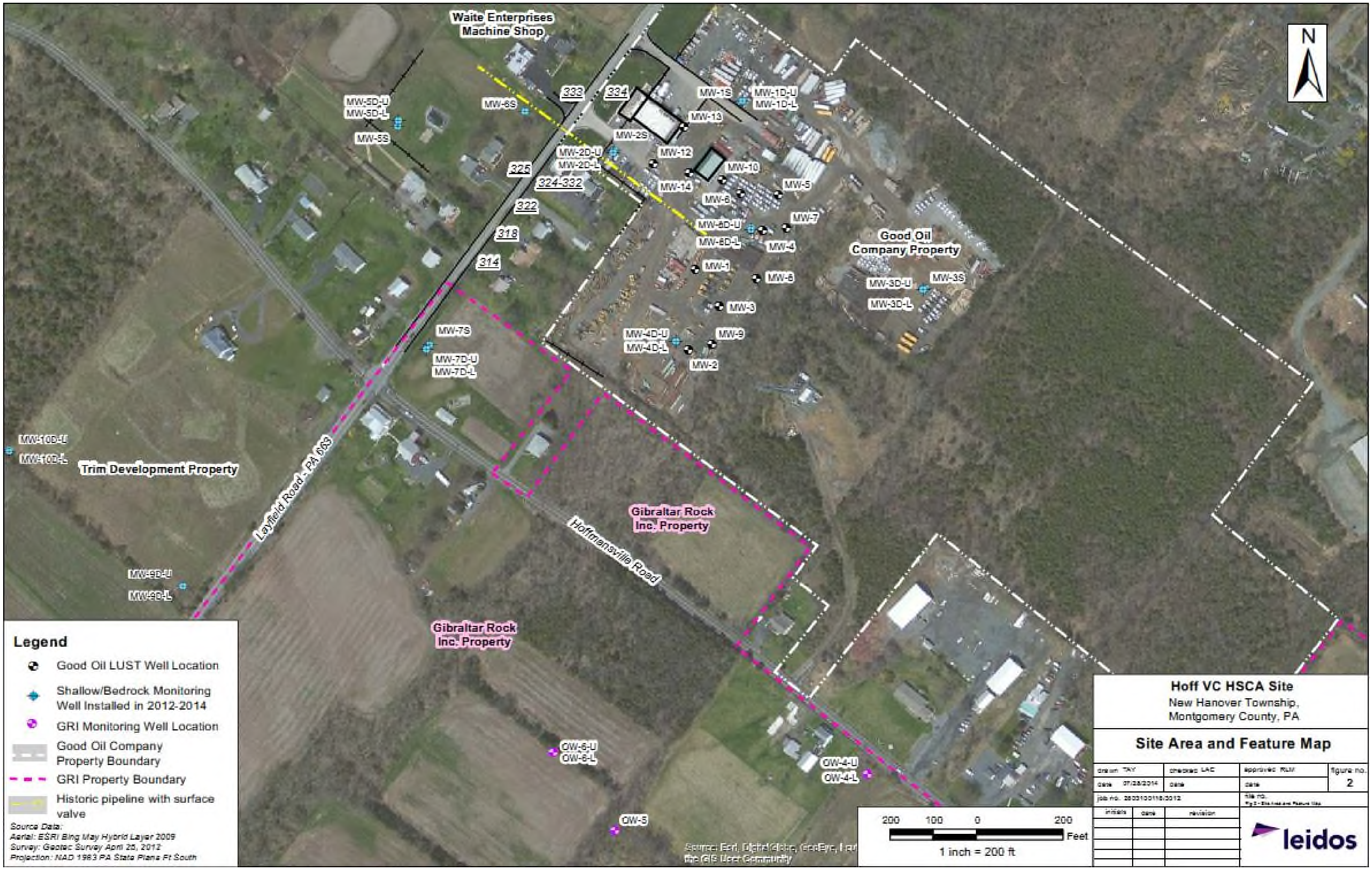
- July 2001 data set used for Gibratar Rock Quarry
  - Static levels prior to 72 hour aquifer testing
  - Appear to be generally consistent with July 2014 data set

- Overall range of heads from 300 feet MSL to 420 feet MSL

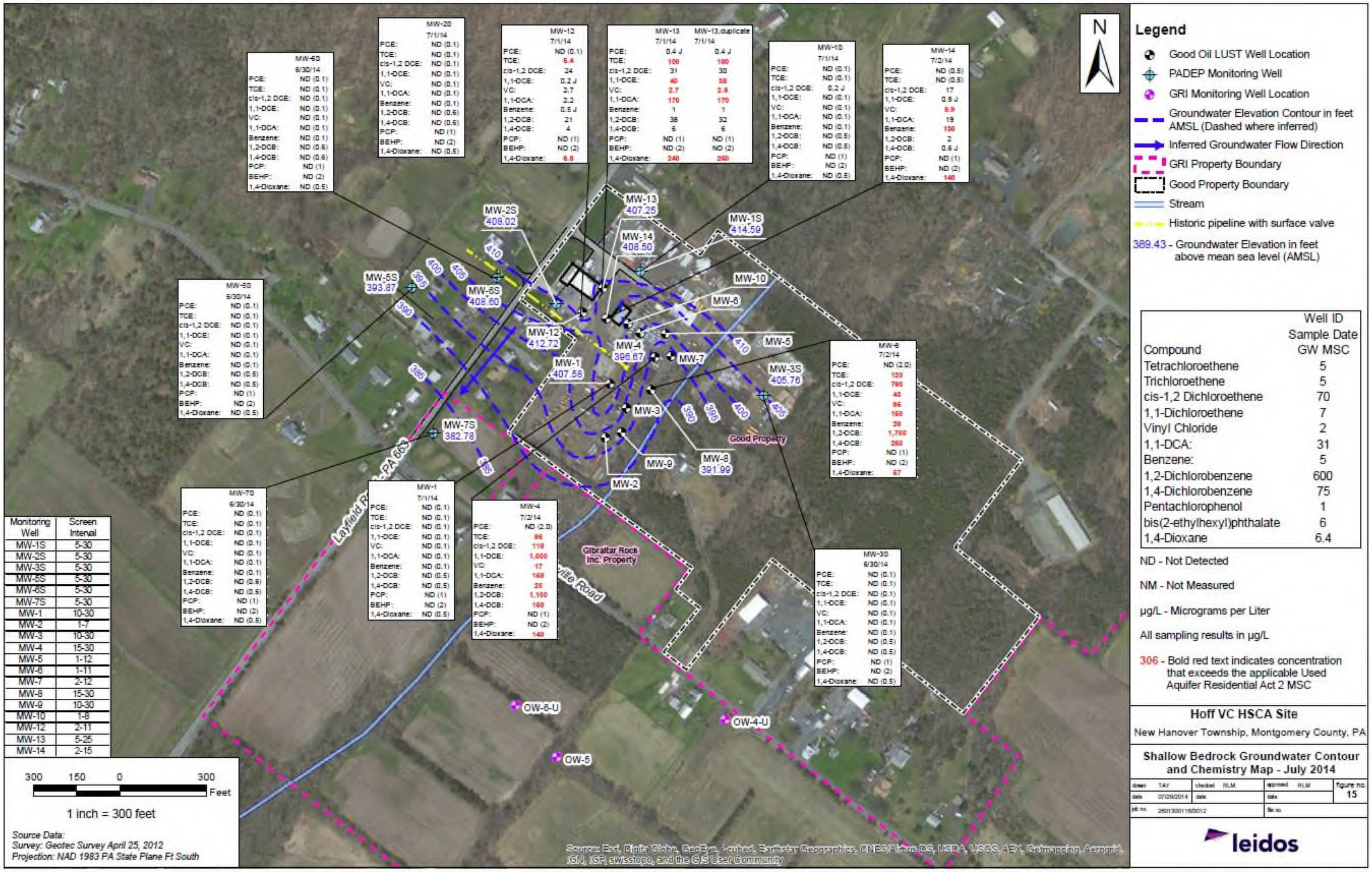
Well	Install Date	Well Diameter (inches)	Screen Length (feet)	Casing Length (feet)	Total Depth of Well (fbg)	Screened Interval (fbg)	Top of Steel Casing Elevation (famsl)	Top of PVC Casing Elevation (famsl)	Latitude	Longitude	Notes:
PADEP Monitoring Wells											
MW-1S	4/12/2012	2	25	-	30	5-30	-	419.46	40.329534	-75.554923	Opening: 0.010 Slot
MW-1D	3/28/2012	6	-	40	300	-	419.08	419.08	40.329540	-75.554902	Open Borehole
MW-1D Upper	9/11/2012	2	130	-	174	44-174	419.08	418.64	40.329540	-75.554902	Opening: 0.040 Slot
MW-1D Lower	9/5/2012	2	60	-	300	240-300	419.08	418.43	40.329540	-75.554902	Opening: 0.040 Slot
MW-2S	4/4/2012	2	25	-	30	5-30	-	416.62	40.329245	-75.555981	Opening: 0.010 Slot
MW-2D	4/3/2012	6	-	40	300	-	416.22	416.22	40.329233	-75.555992	Open Borehole
MW-2D Upper	9/12/2012	2	70	-	116.5	46.5-116.5	416.22	415.88	40.329233	-75.555992	Opening: 0.040 Slot
MW-2D Lower	9/10/2012	2	30	-	226	196-226	416.22	415.88	40.329233	-75.555992	Opening: 0.040 Slot
MW-3S	4/11/2012	2	25	-	30	5-30	-	411.18	40.328322	-75.553425	Opening: 0.010 Slot
MW-3D	3/26/2012	6	-	40	250	-	410.62	410.62	40.328311	-75.553442	Open Borehole
MW-3D Upper	6/26/2013	2	60	-	106.5	46.5-106.5	410.62	410.21	40.328311	-75.553442	Opening: 0.020 Slot
MW-3D Lower	6/26/2013	2	60	-	210	150.5-210.5	410.62	410.26	40.328311	-75.553442	Opening: 0.020 Slot
MW-4D	3/30/2012	6	-	40	250	—	405.86	405.86	40.328022	-75.555506	Open Borehole
MW-4D Upper	9/18/2012	2	30	-	118	88-118	405.86	405.62	40.328022	-75.555506	Opening: 0.040 Slot
MW-4D Lower	9/18/2012	2	30	-	245	215-245	405.86	405.42	40.328022	-75.555506	Opening: 0.040 Slot
MW-5S	4/5/2012	2	25	-	30	5-30	-	400.9	40.329433	-75.557775	Opening: 0.010 Slot
MW-5D	4/5/2012	6	-	40	250	-	400.64	400.64	40.329470	-75.557766	Open Borehole
MW-5D Upper	9/14/2012	2	40	-	93	53-93	400.64	400.39	40.329470	-75.557766	Opening: 0.040 Slot
MW-5D Lower	9/13/2012	2	50	-	187.5	137.5-187.5	400.64	400.29	40.329470	-75.557766	Opening: 0.040 Slot
MW-6S	4/9/2012	2	25	-	30	5-30	-	412.45	40.329506	-75.556714	Opening: 0.010 Slot
MW-7S	4/9/2012	2	25	-	30	5-30	-	385.28	40.328042	-75.557553	Opening: 0.010 Slot
MW-7D	4/9/2012	6	-	40	250	-	383.94	383.94	40.328014	-75.557582	Open Borehole
MW-7D Upper	9/17/2012	2	70	-	155	85-155	383.94	383.38	40.328014	-75.557582	Opening: 0.040 Slot
MW-7D Lower	9/17/2012	2	30	-	210	180-210	383.94	383.32	40.328014	-75.557582	Opening: 0.040 Slot
MW-8D	4/9/2013	6	—	40	250	-	409.46	409.46	40.328725	-75.554861	Open Borehole
MW-8D Upper	6/25/2013	2	75	--	119	44.1-119.1	409.46	408.88	40.328725	-75.554861	Opening: 0.020 Slot
MW-8D Lower	6/25/2013	2	70	—	246.5	176.5-246.5	409.46	408.98	40.328725	-75.554861	Opening: 0.020 Slot
MW-9D	5/13/2014	6	-	38	220	-	349.86	349.86	40.326547	-75.559654	Open Borehole
MW-9D Upper	6/17/2014	2	60	-	103.5	43.5-103.5	349.86	349.5	40.326547	-75.559654	Opening: 0.020 Slot
MW-9D Lower	6/16/2014	2	50	-	189.5	139.5-189.5	349.86	349.5	40.326547	-75.559654	Opening: 0.020 Slot
MW-10D	5/13/2014	6	-	38	206	-	349.48	349.48	40.327434	-75.561067	Open Borehole
MW-10D Upper	6/26/2014	2	70	-	110.5	40.5-110.5	349.48	349.09	40.327434	-75.561067	Opening: 0.020 Slot
MW-10D Lower	6/17/2014	2	30	-	200.5	170.5-200.5	349.48	349.08	40.327434	-75.561067	Opening: 0.020 Slot
OW-4 Upper	9/24/2012	2	70	-	128	58-128	406.05	405.54	40.325246	-75.554002	Opening: 0.040 Slot
OW-4 Lower	9/21/2012	2	70	-	249	179-249	406.05	405.3	40.325246	-75.554002	Opening: 0.040 Slot
OW-6 Upper	9/26/2012	2	90	-	130	40-130	363.94	363.6	40.325430	-75.556613	Opening: 0.040 Slot
OW-6 Lower	9/25/2012	2	50	-	260	210-260	363.94	363.52	40.325430	-75.556613	Opening: 0.040 Slot
Good Oil Company Wells											
MW-1	8/30/2010	4	20	-	30.03	10-30	-	409.65	40.328497	-75.555350	Opening: 0.020 Slot
MW-2	8/30/2010	4	6	-	6.92	1-7	-	405.26	40.327973	-75.555412	Opening: 0.020 Slot
MW-3	8/30/2010	4	20	-	30.23	10-30	-	400.65	40.328243	-75.555143	Opening: 0.020 Slot
MW-4	8/30/2010	4	15	-	29.97	15-30	-	408.97	40.328738	-75.554788	Opening: 0.020 Slot
MW-5	8/30/2010	4	11	-	11.31	1-12	-	409.81	40.328961	-75.554655	Opening: 0.020 Slot
MW-6	8/31/2010	4	10	-	11.94	1-11	-	410.98	40.328976	-75.554969	Opening: 0.020 Slot
MW-7	8/31/2010	4	10	-	12.09	2-12	-	403.43	40.328730	-75.554572	Opening: 0.020 Slot
MW-8	9/1/2010	4	15	-	30.07	15-30	-	407.59	40.328431	-75.554841	Opening: 0.020 Slot
MW-9	9/1/2010	4	20	-	30.81	10-30	-	404.92	40.328031	-75.555210	Opening: 0.020 Slot
MW-10	8/31/2010	4	7	-	7.51	1-8	-	411.75	40.329064	-75.555119	Opening: 0.020 Slot
MW-11 (Destroyed)	NA	2	8.7	-	9.3	.5-9.3	-	NM	NA	NA	Opening: 0.020 Slot
MW-12	5/11/2011	4	9	-	11	2-11	-	415.87	40.329159	-75.555688	Opening: 0.020 Slot
MW-13	5/11/2011	4	20	-	25	5-25	-	417.25	40.329390	-75.555400	Opening: 0.020 Slot
MW-14	5/11/2011	4	10	-	15	2-15	-	415.75	40.329102	-75.555383	Opening: 0.020 Slot

Notes:
fbg = feet below ground
famsl = feet above mean sea level

Hoff Site Wells – Construction Table



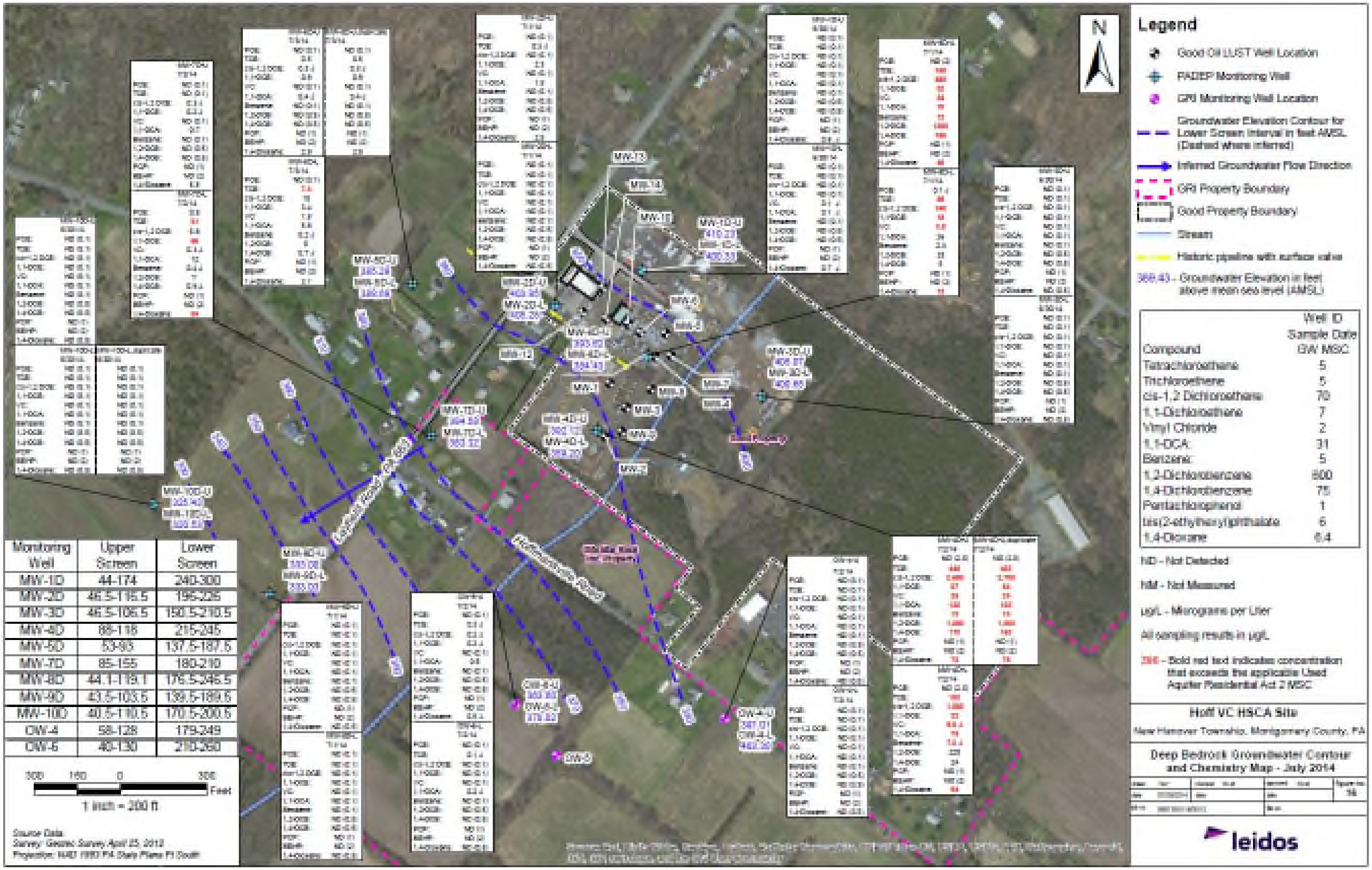
Hoff Site Wells – Site Area and Features



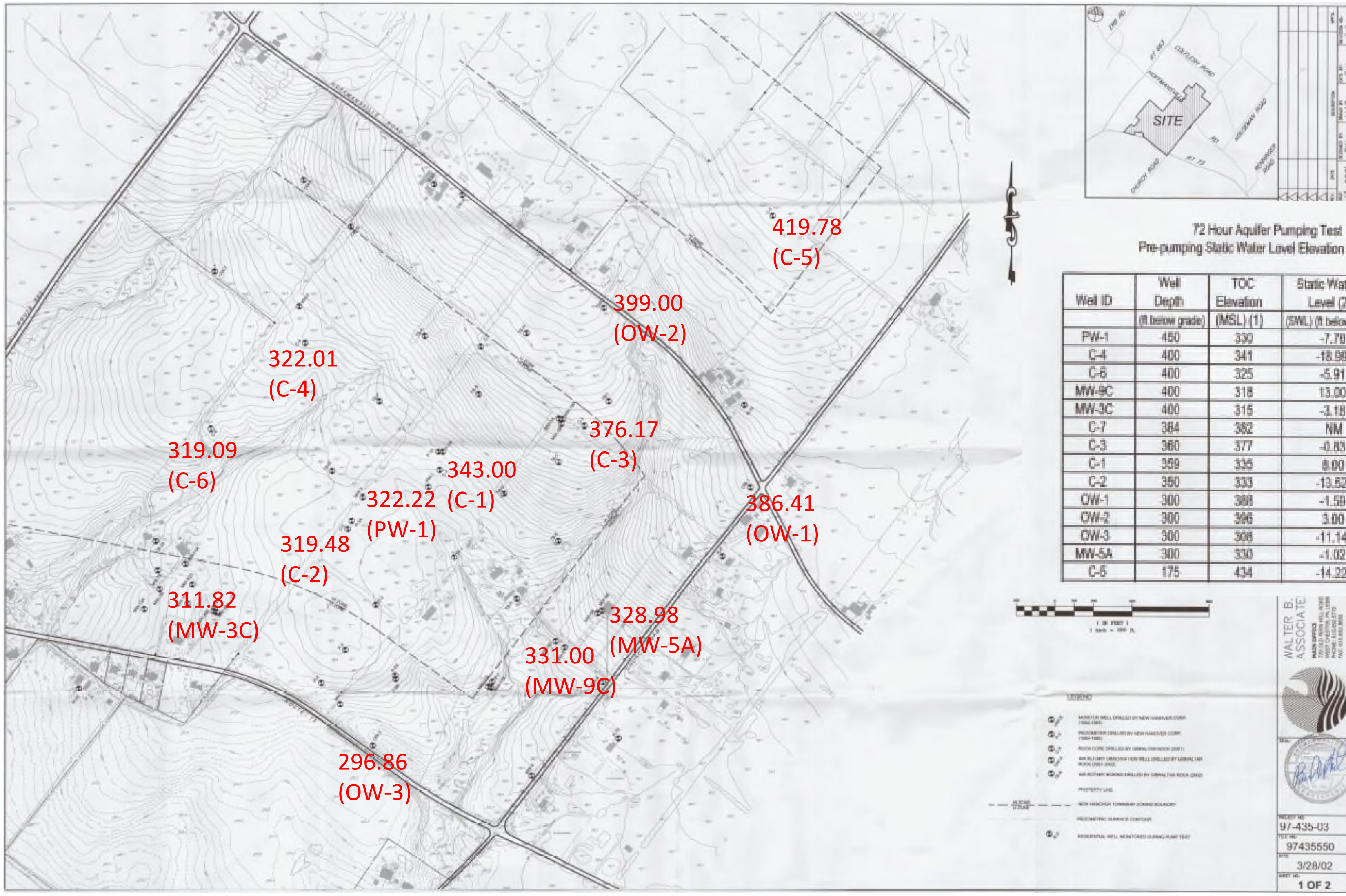
Compound	Well ID Sample Date GW MSC
Tetrachloroethene	5
Trichloroethene	5
cis-1,2 Dichloroethene	70
1,1-Dichloroethene	7
Vinyl Chloride	2
1,1-DCA:	31
Benzene:	5
1,2-Dichlorobenzene	600
1,4-Dichlorobenzene	75
Pentachlorophenol	1
bis(2-ethylhexyl)phthalate	6
1,4-Dioxane	6.4

Monitoring Well	Screen Interval
MW-1S	5-30
MW-2S	5-30
MW-3S	5-30
MW-5S	5-30
MW-6S	5-30
MW-7S	5-30
MW-1	10-30
MW-2	1-7
MW-3	10-30
MW-4	15-30
MW-5	1-12
MW-6	1-11
MW-7	2-12
MW-8	15-30
MW-9	10-30
MW-10	1-8
MW-12	2-11
MW-13	6-25
MW-14	2-15

Shallow Groundwater Potentiometrics – July 2014



Deep Groundwater Potentiometrics – July 2014



72 Hour Aquifer Pumping Test
Pre-pumping Static Water Level Elevation Summary

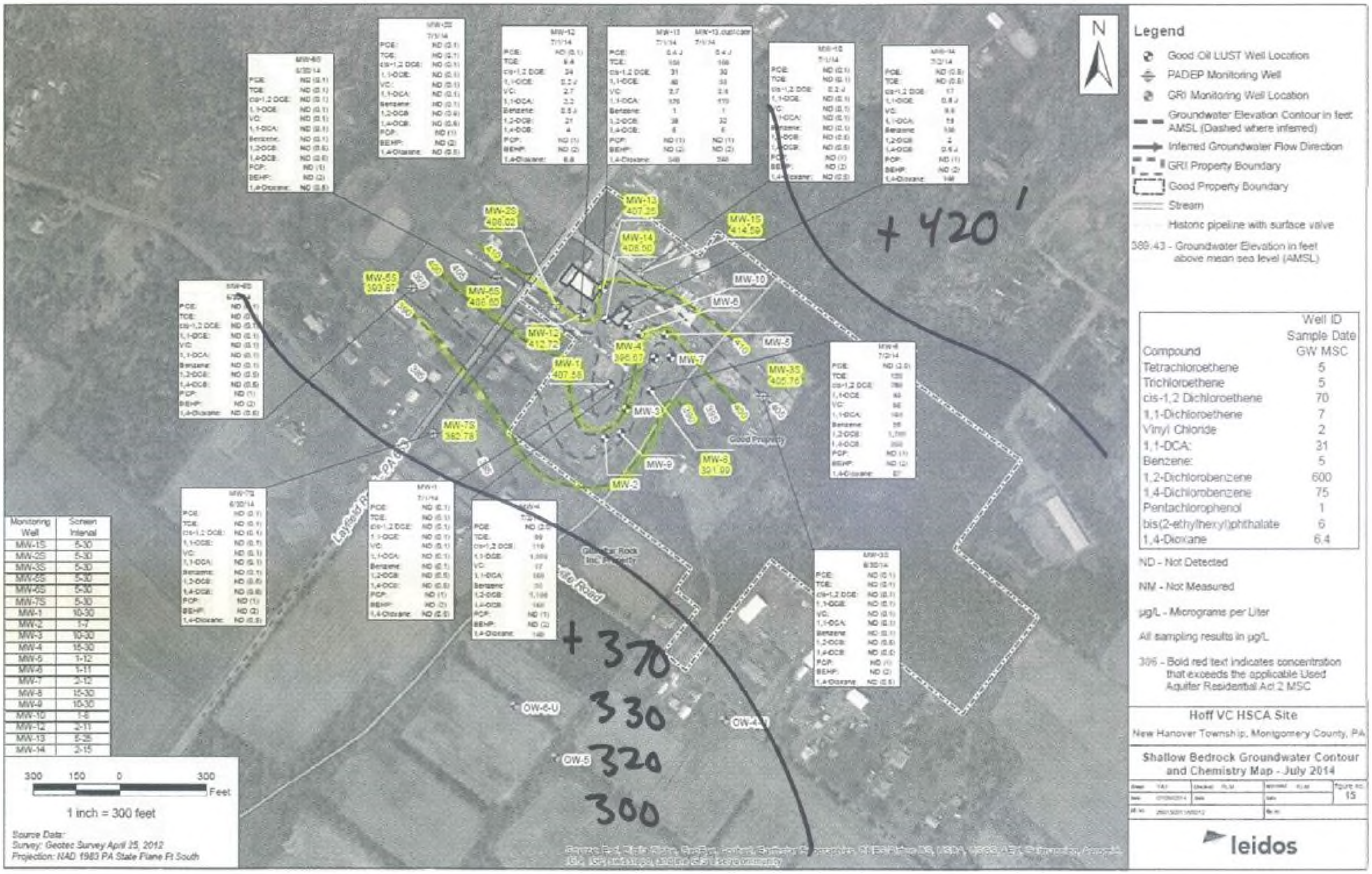
Well ID	Well Depth	TOC Elevation	Static Water Level (2)	SWL Elevation
	(ft below grade)	(MSL) (1)	(SWL) (ft below TOC)	
PW-1	450	330	-7.78	322.22
C-4	400	341	-18.99	322.01
C-6	400	325	-5.91	319.09
MW-9C	400	318	13.00	331.00
MW-3C	400	315	-3.18	311.82
C-7	384	382	NM	NM
C-3	360	377	-0.83	376.17
C-1	359	335	8.00	343.00
C-2	350	333	-13.52	319.48
OW-1	300	388	-1.59	386.41
OW-2	300	396	3.00	399.00
OW-3	300	308	-11.14	296.86
MW-5A	300	330	-1.02	328.98
C-5	175	434	-14.22	419.78

Static Groundwater Potentiometrics – Pre-72 Hour Test (July 2001)

Site-Specific Boundary Conditions – Constant Heads and No Flow Cells

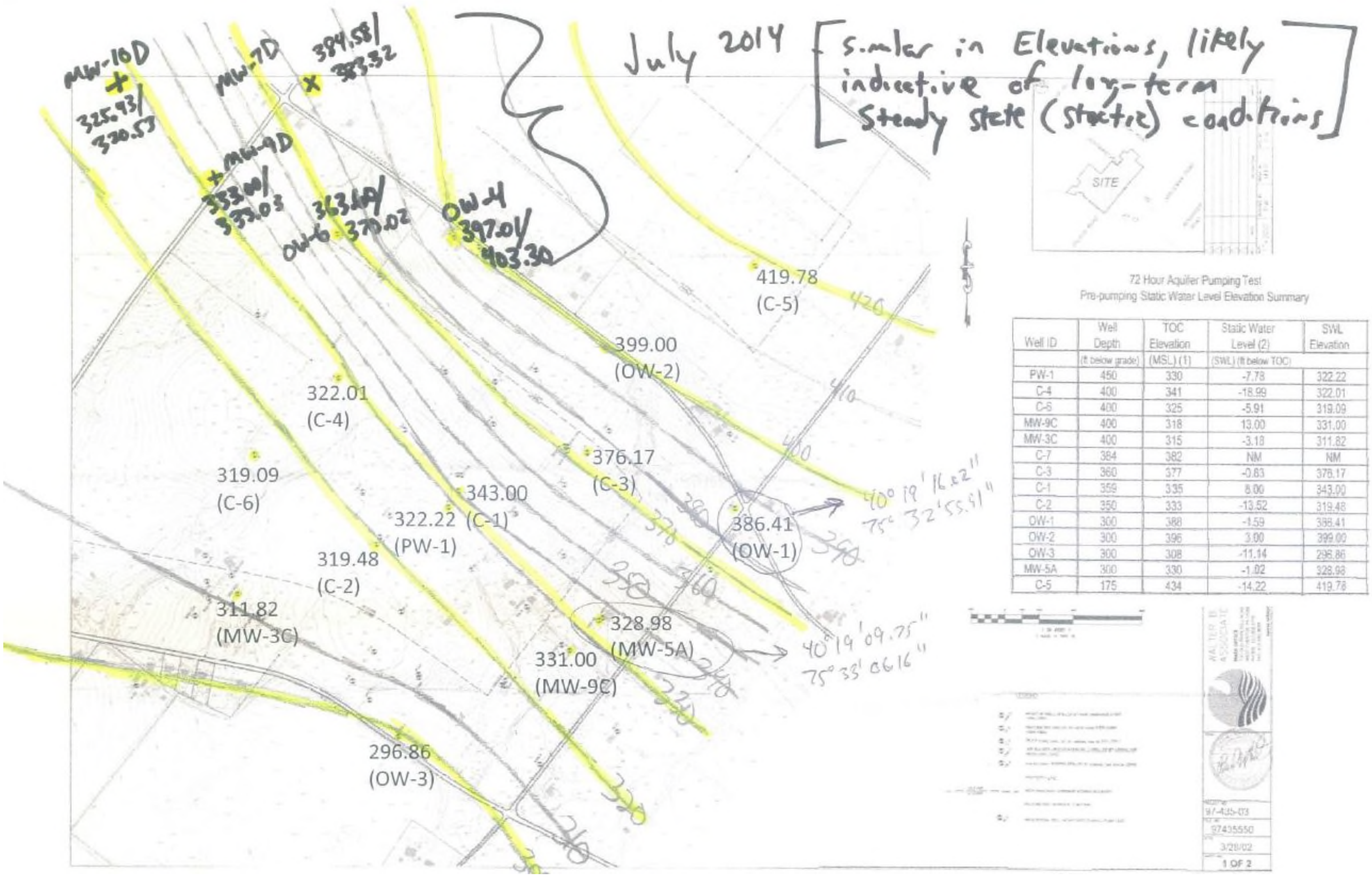
- Constant Heads
  - Utilized potentiometrics from July 2001 and July 2014 to assign heads based on interpreted potentiometric levels
  - Was able to account for complex flow patterns and magnitudes in shallow zone (Layer 1 – top 50 feet bgs)
  - Unique flow fields for Layers 1 through 4
    - Accurately reflect flow direction and magnitude
    - Accurately reflect vertical gradients (flow between zones)
      - Important since transport is along vertical fractures

- No Flow Cells
  - Used for areas of model where large changes in surface elevations occur
  - Assigned to areas where surface elevations –
    - Above 450 feet MSL – areas higher than highest WLs observed
    - Below 300 feet MSL – areas lower than lowest WLs observed



Shallow Groundwater Potentiometrics – July 2014 – BCs Layer 1

Deep Groundwater Potentiometrics – July 2014 – BCs Layers 2 to 5 – Hoff Site Only



Well ID	Well Depth	TOC Elevation	Static Water Level (2)	SWL Elevation
	(ft below grade)	(MSL) (1)	(SWL) (ft below TOC)	
PW-1	450	330	-7.78	322.22
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MW-9C	400	318	13.00	331.00
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C-7	384	382	NM	NM
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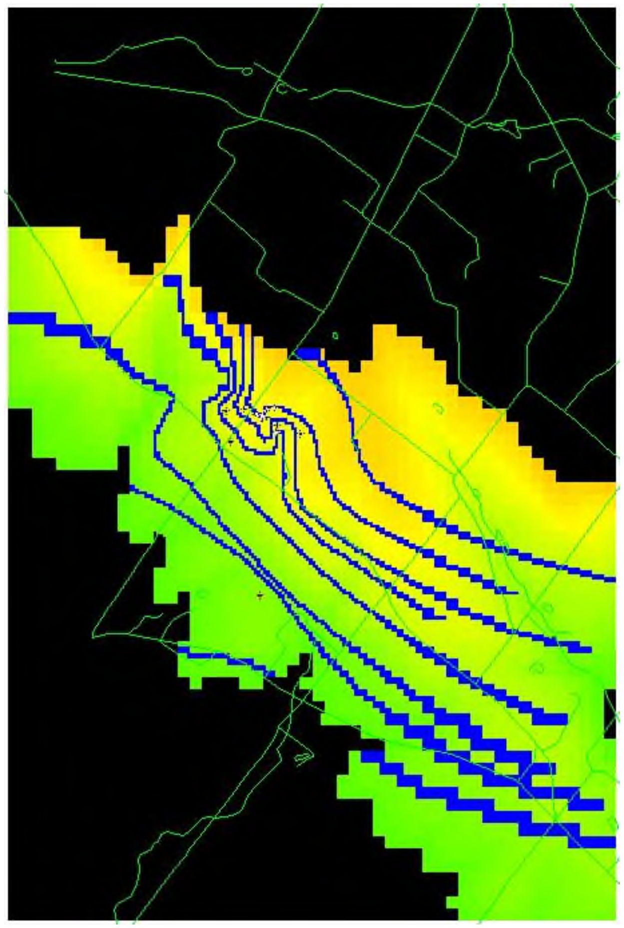
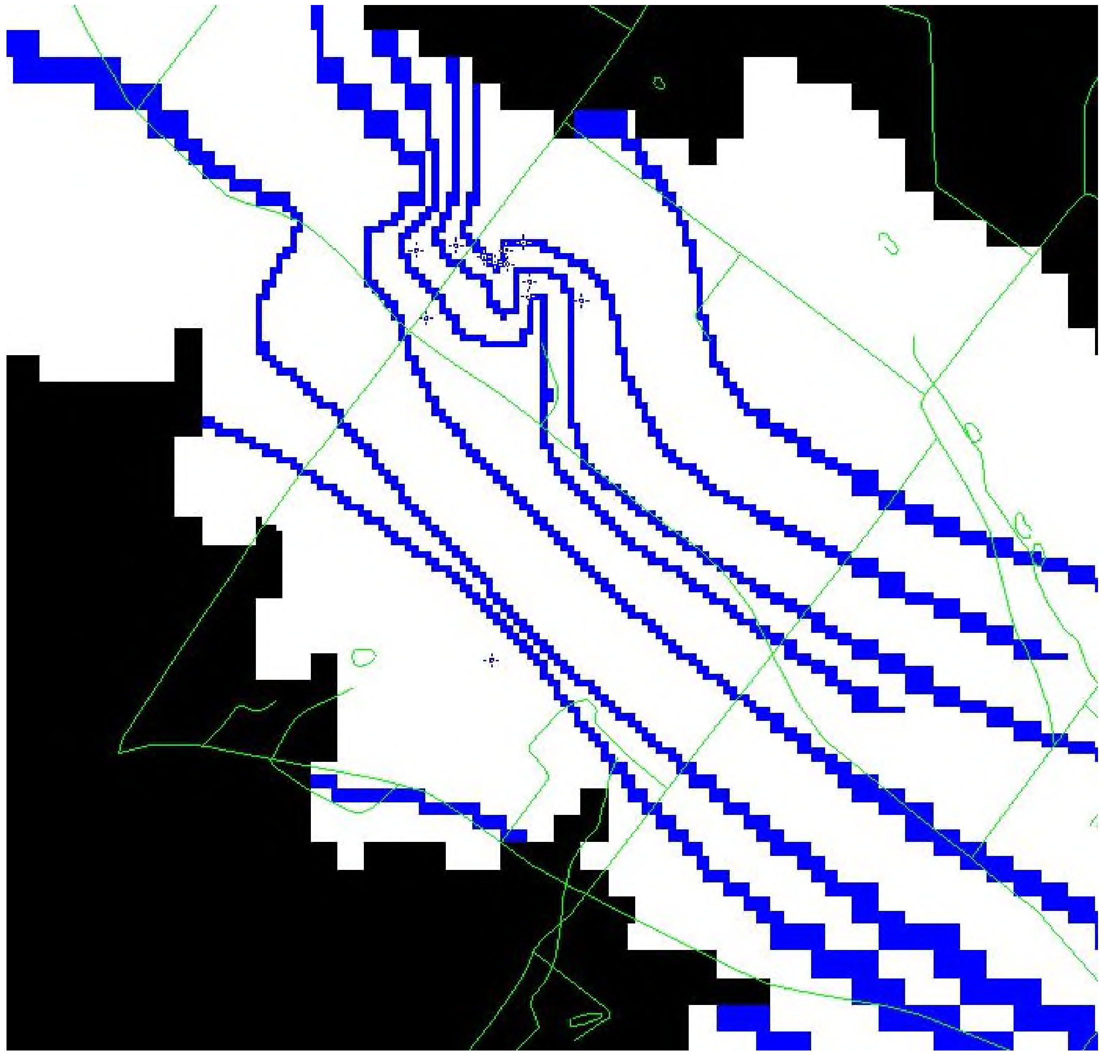
C-1	359	335	8.00	343.00
C-2	350	333	-13.52	319.48
OW-1	300	388	-1.59	386.41
OW-2	300	396	3.00	399.00
OW-3	300	308	-11.14	296.86
MW-5A	300	330	-1.02	328.98
C-5	175	434	-14.22	419.78

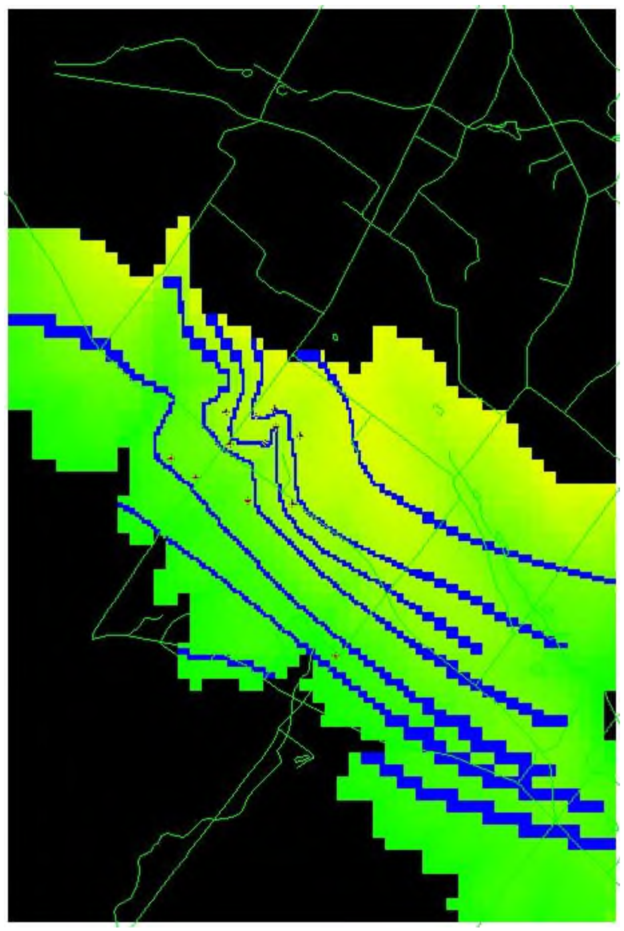
Deep Groundwater Potentiometrics – July 2014 – BCs Layers 2 to 5 – Hoff and Quarry Sites



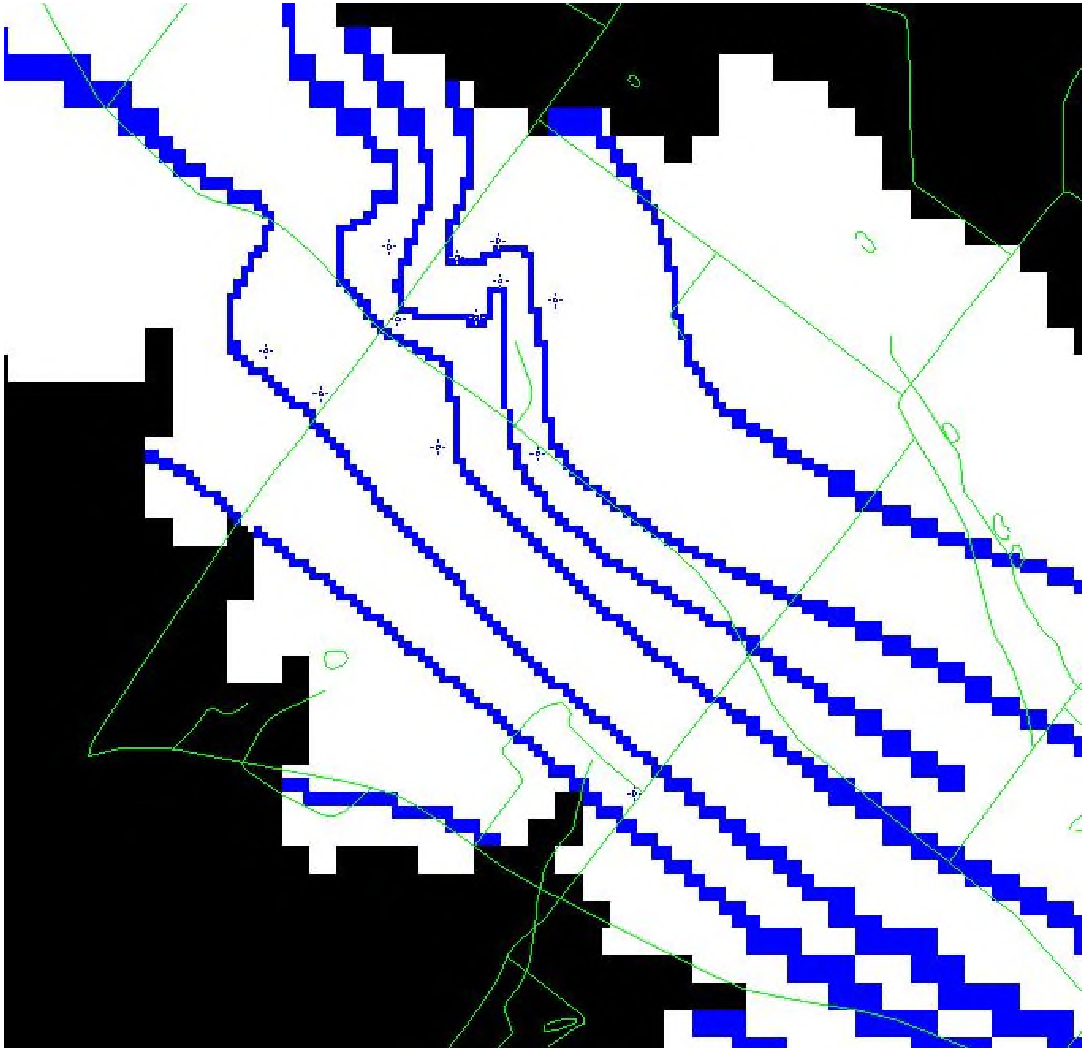
With Top of Model Elevations



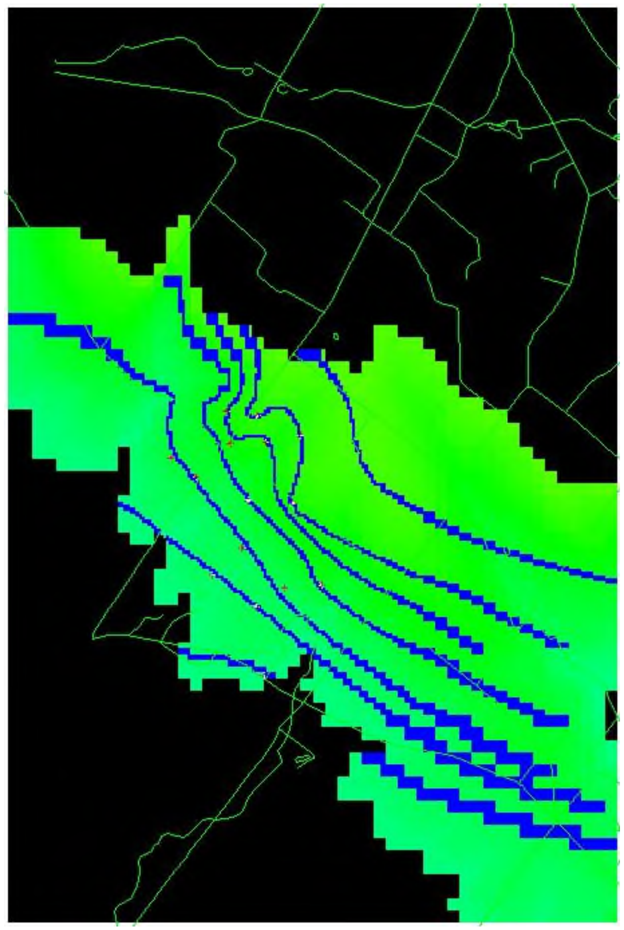
Model Layer 1 – Boundary Conditions – No Flows, Constant Heads



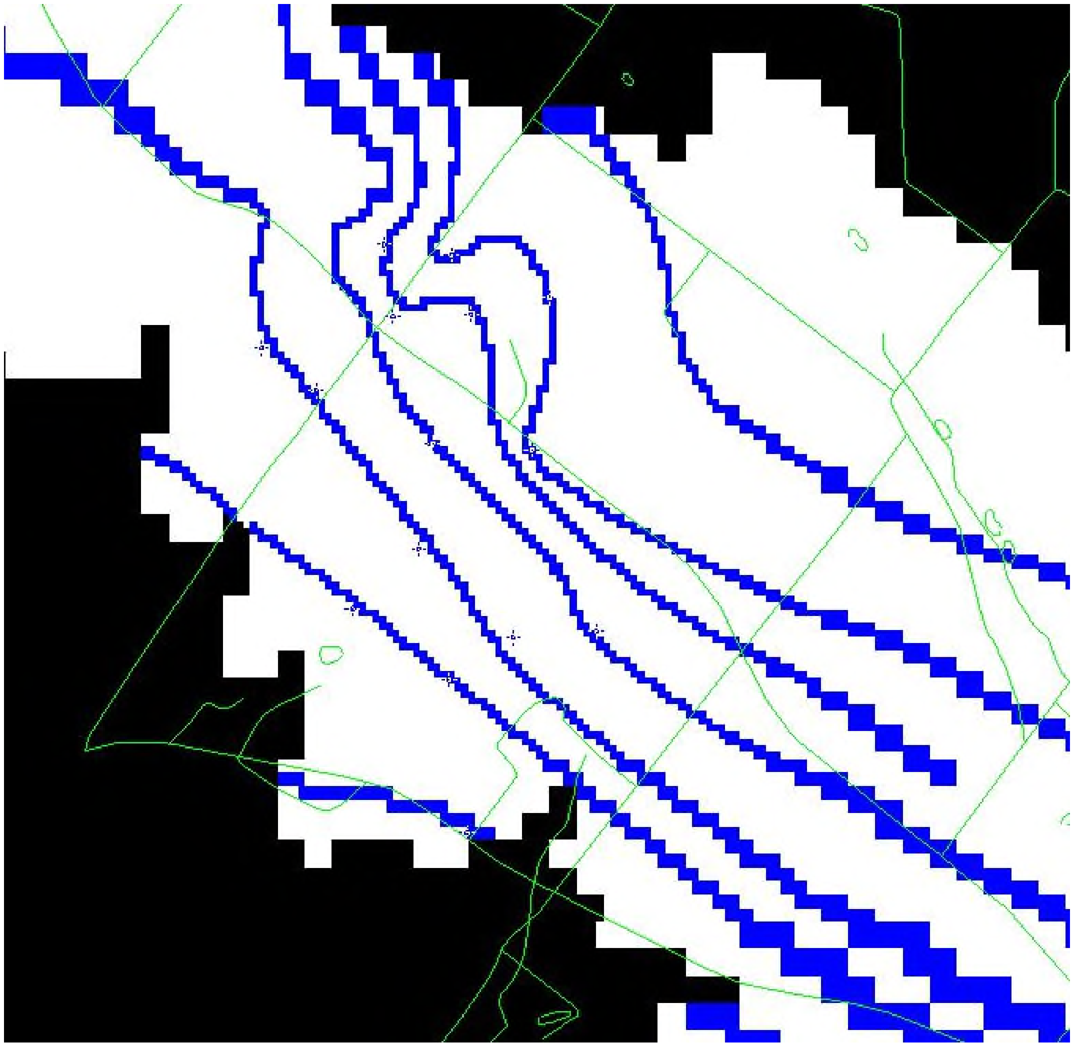
With Top of Model Elevations



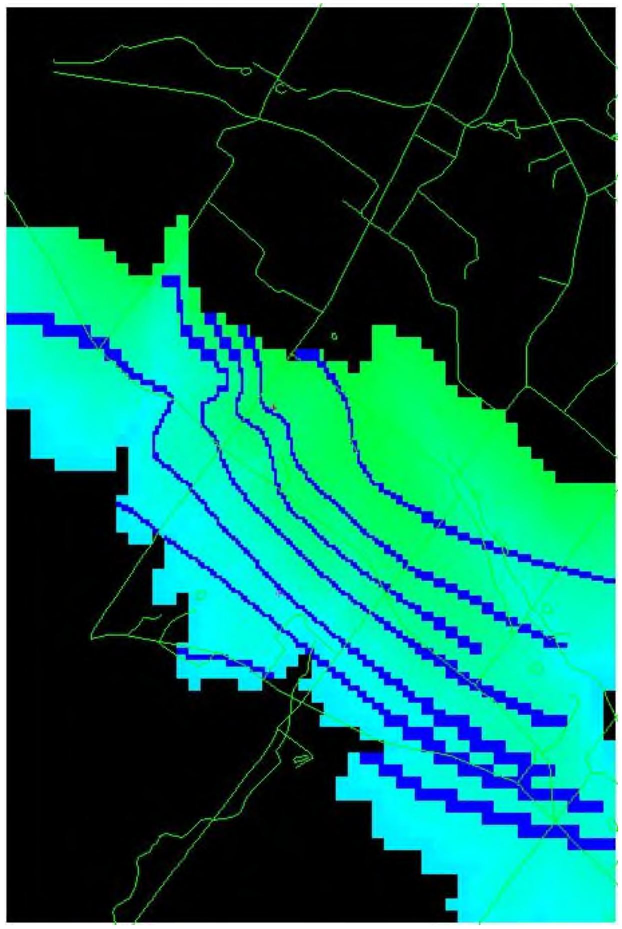
Model Layer 2 – Boundary Conditions – No Flows, Constant Heads



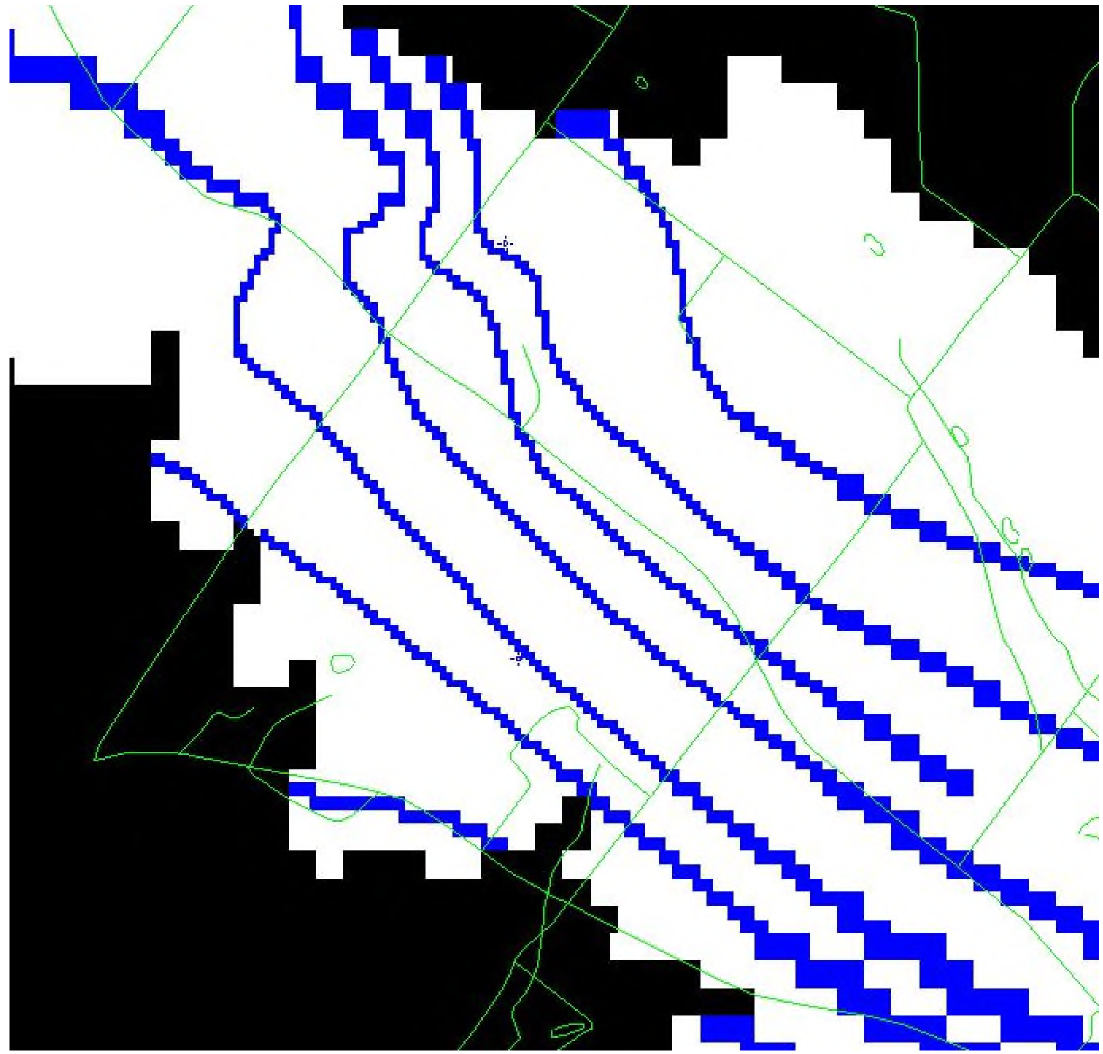
With Top of Model Elevations



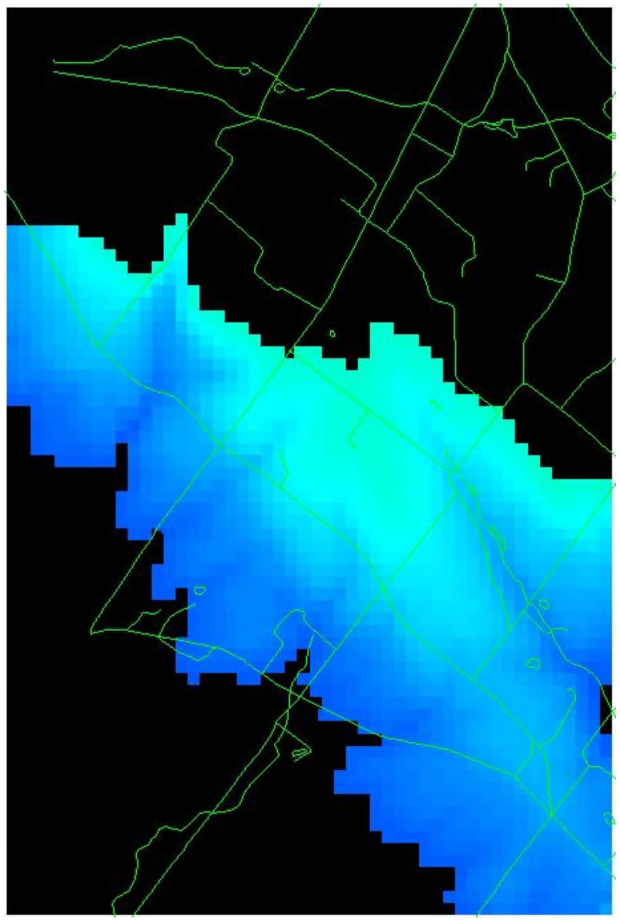
Model Layer 3 – Boundary Conditions – No Flows, Constant Heads



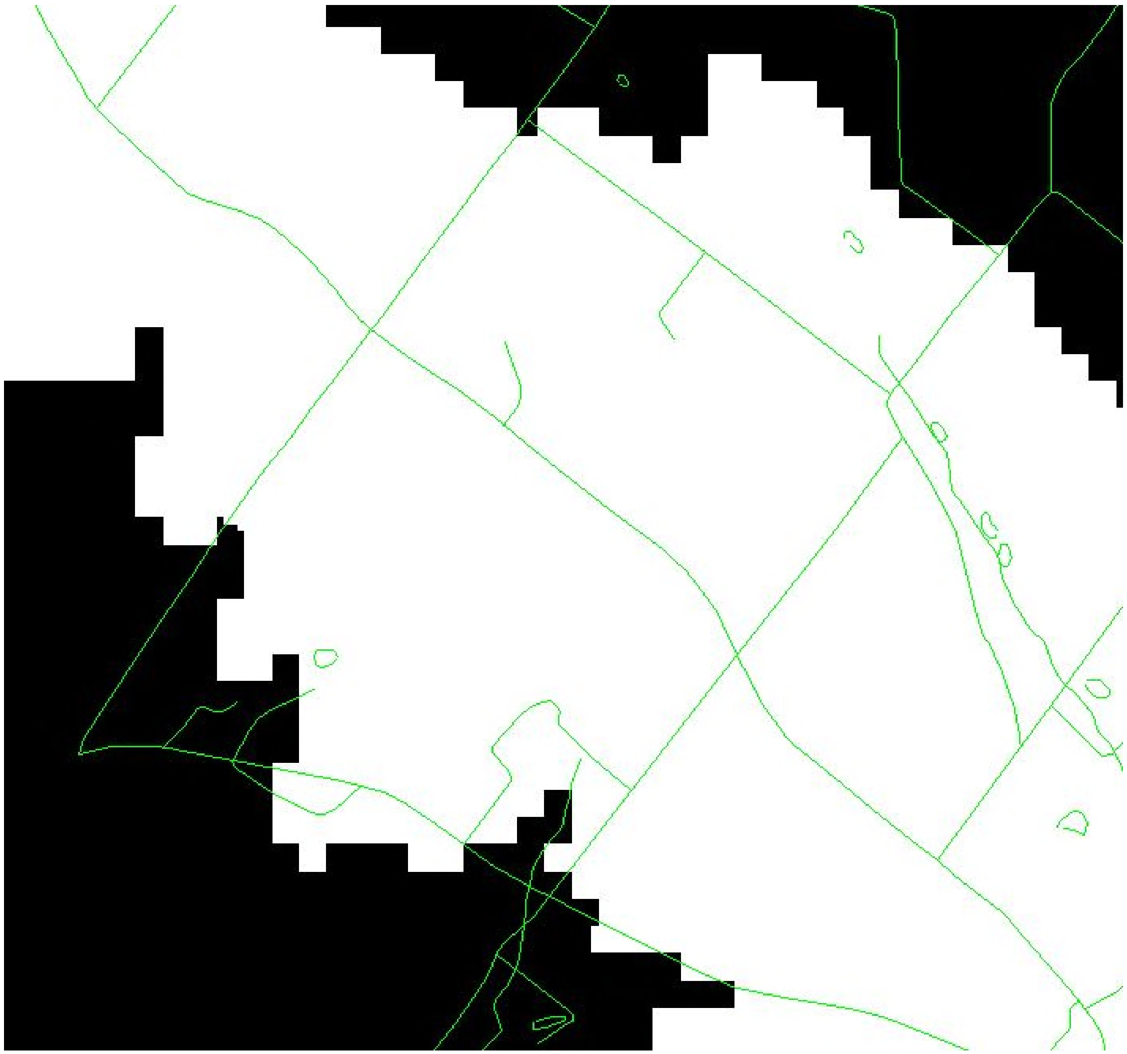
With Top of Model Elevations



Model Layer 4 – Boundary Conditions – No Flows, Constant Heads



With Top of Model Elevations



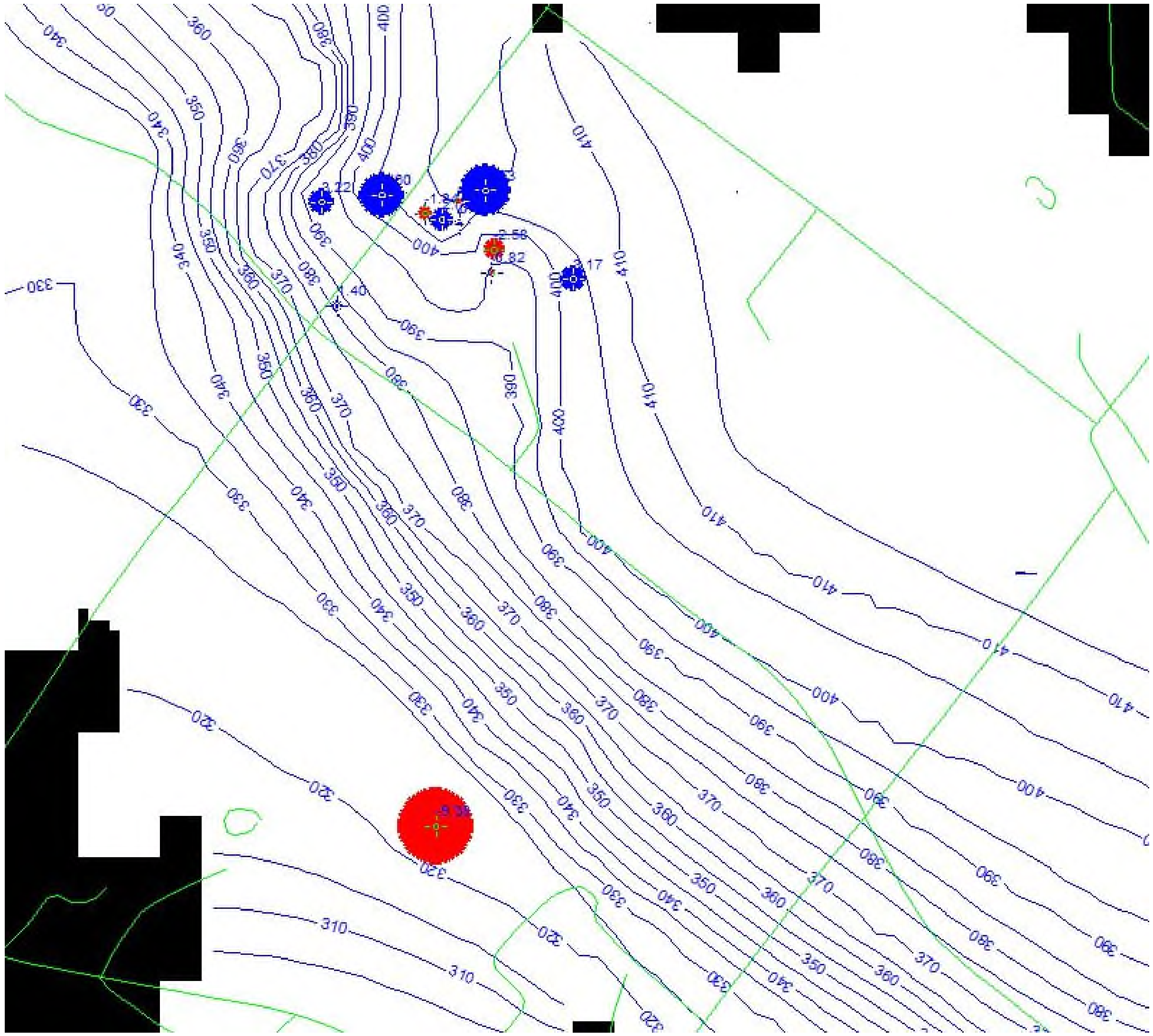
Model Layer 5 – Boundary Conditions – No Flows, Constant Heads

Model “Calibration” – Comparison to Observed Conditions

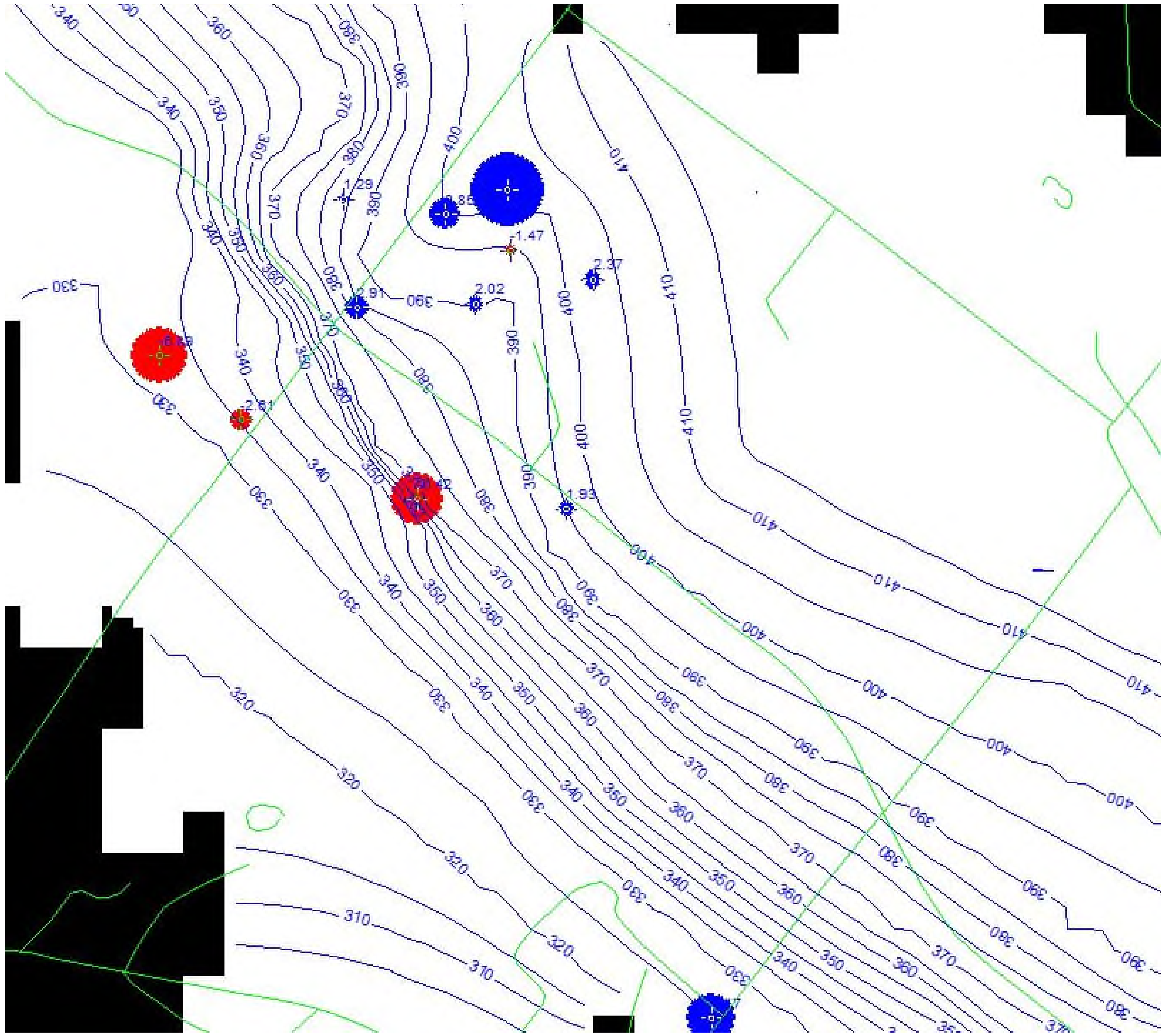
- While the groundwater model was not formally calibrated, constant heads were adjusted from initial estimates based on potentiometric maps in order to provide a more precise match to observed groundwater elevations on a layer by layer basis.

- Calibration focused on matching calculated groundwater elevations compared to observed groundwater elevations
  - Difference between two is “residual”
  - Residuals can be positive (not enough water) or negative (too much water)

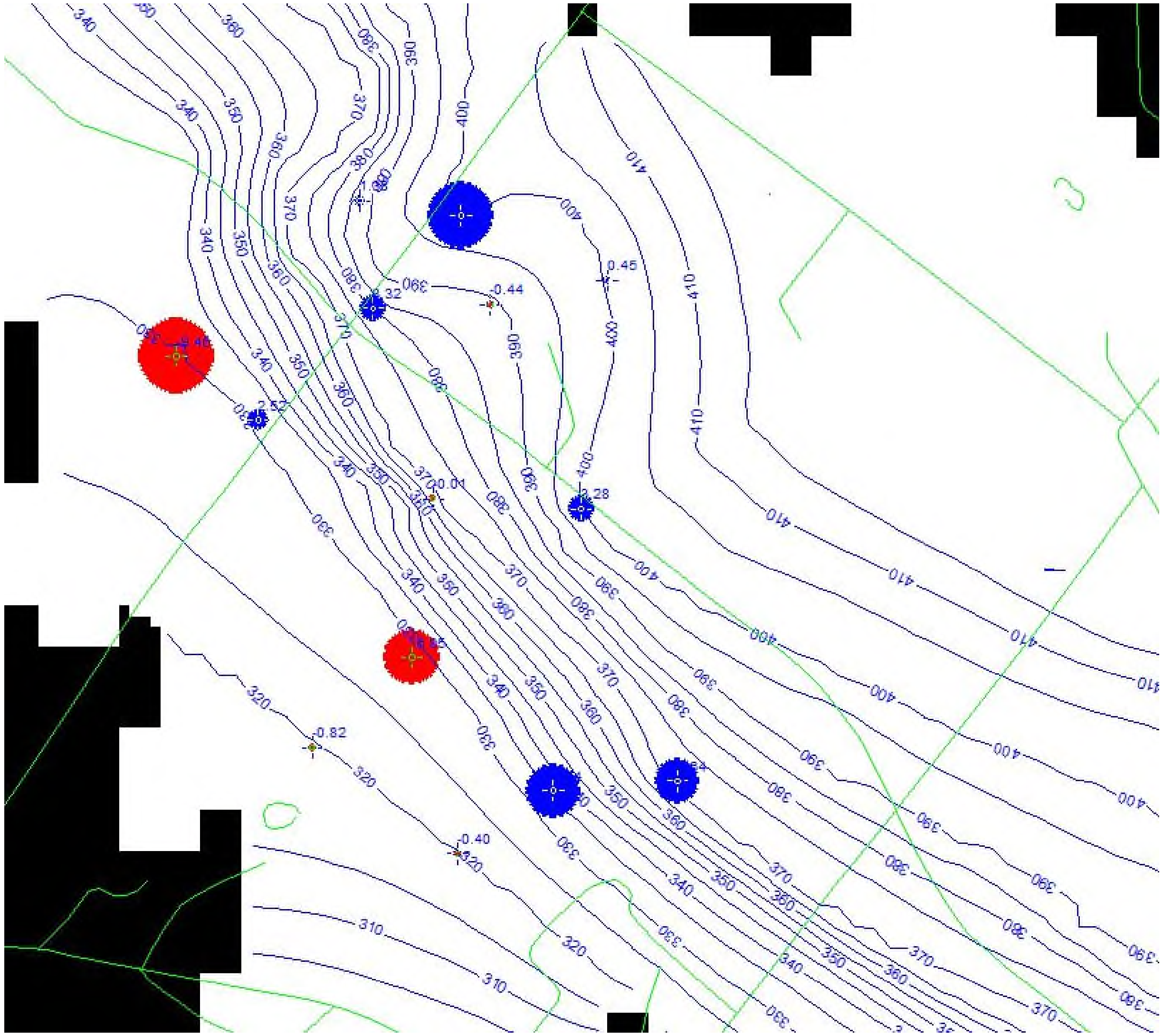
- Standard model calibration protocols were considered –
  - Residual mean close to zero (balance of positive and negative residuals)
  - Absolute residual mean less than 10% of observed head range



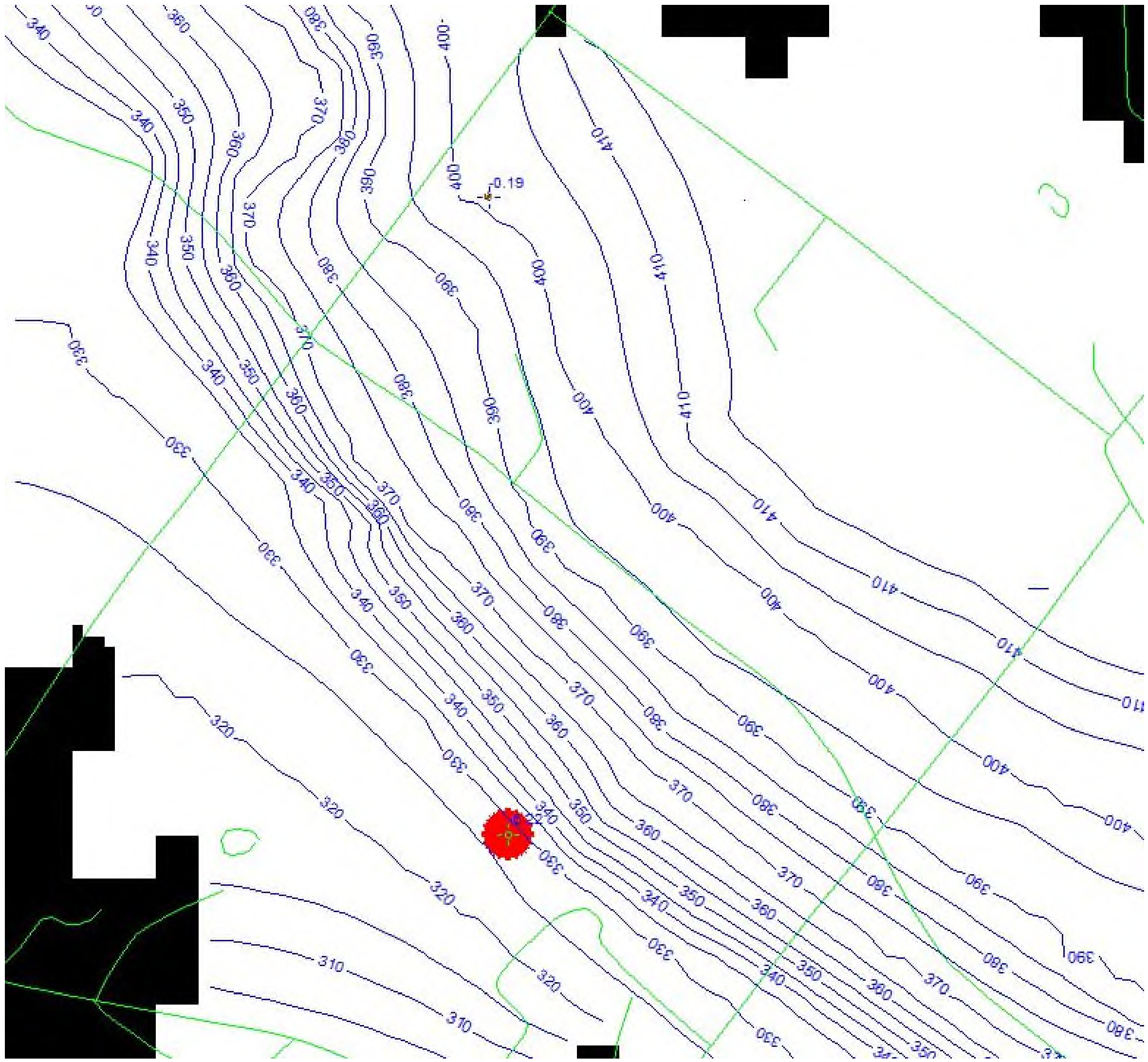
Model Layer 1 – Computed Groundwater Potentiometrics – Residuals with Radius



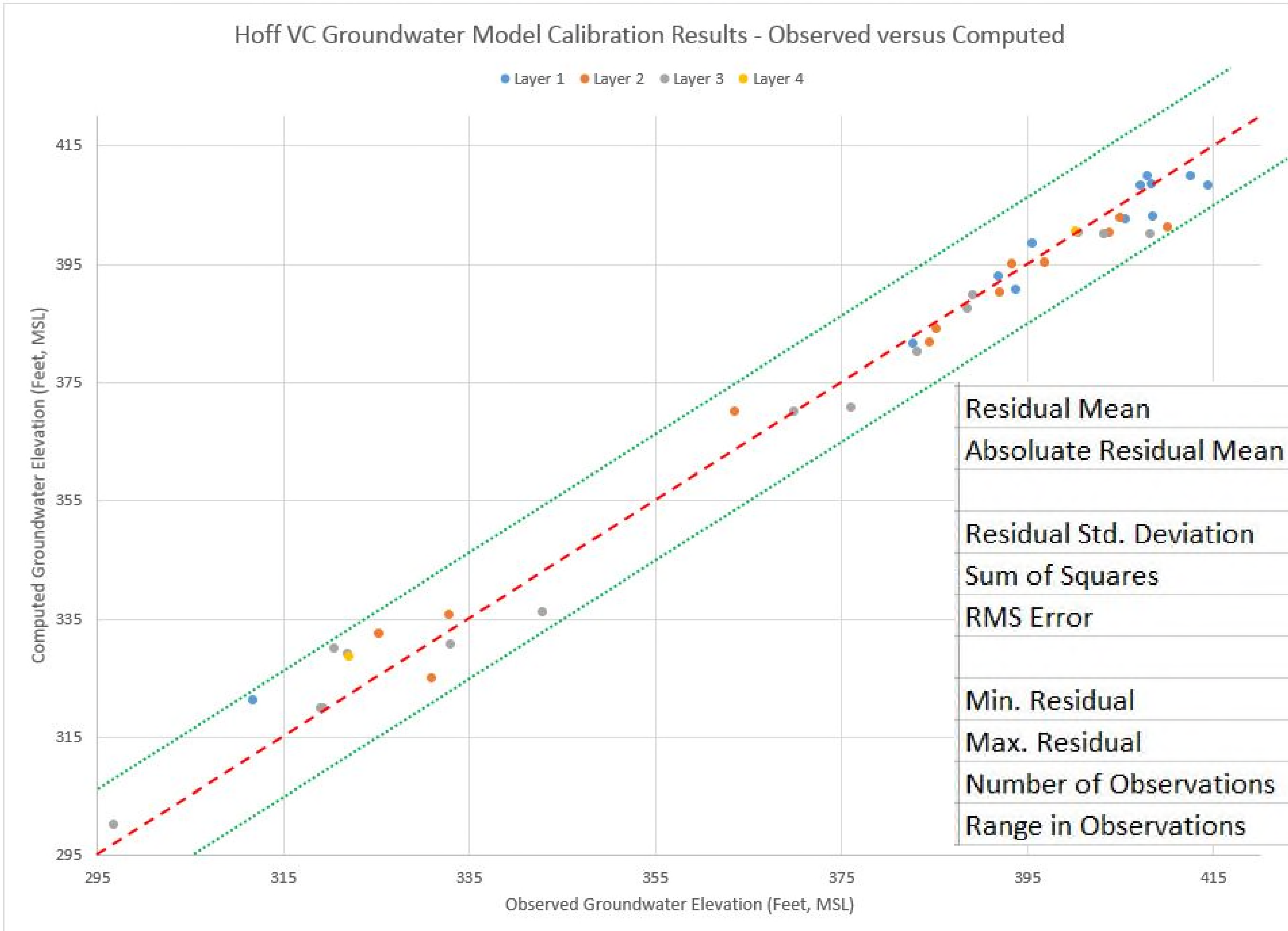
Model Layer 2 – Computed Groundwater Potentiometrics – Residuals with Radius



Model Layer 3 – Computed Groundwater Potentiometrics – Residuals with Radius



Model Layer 4 – Computed Groundwater Potentiometrics – Residuals with Radius



Residual Mean	0.572019
Absoluate Residual Mean	3.528685
Residual Std. Deviation	4.444874
Sum of Squares	823.44862
RMS Error	4.48153
Min. Residual	-9.458881
Max. Residual	9.080347
Number of Observations	41
Range in Observations	117.73

Comparison of Observed versus Computed Groundwater Elevations

Fate and Transport Analysis

- Groundwater chemistry from July 2014 data utilized for fate and transport analysis
  - Most recent comprehensive sampling event
  - TCE, 1,2-Dichlorobenzene, 1,4-Dioxane, MTBE analyzed

- Geochemical and parameter specific transport input utilized from Leidos Report (Section 8.3)

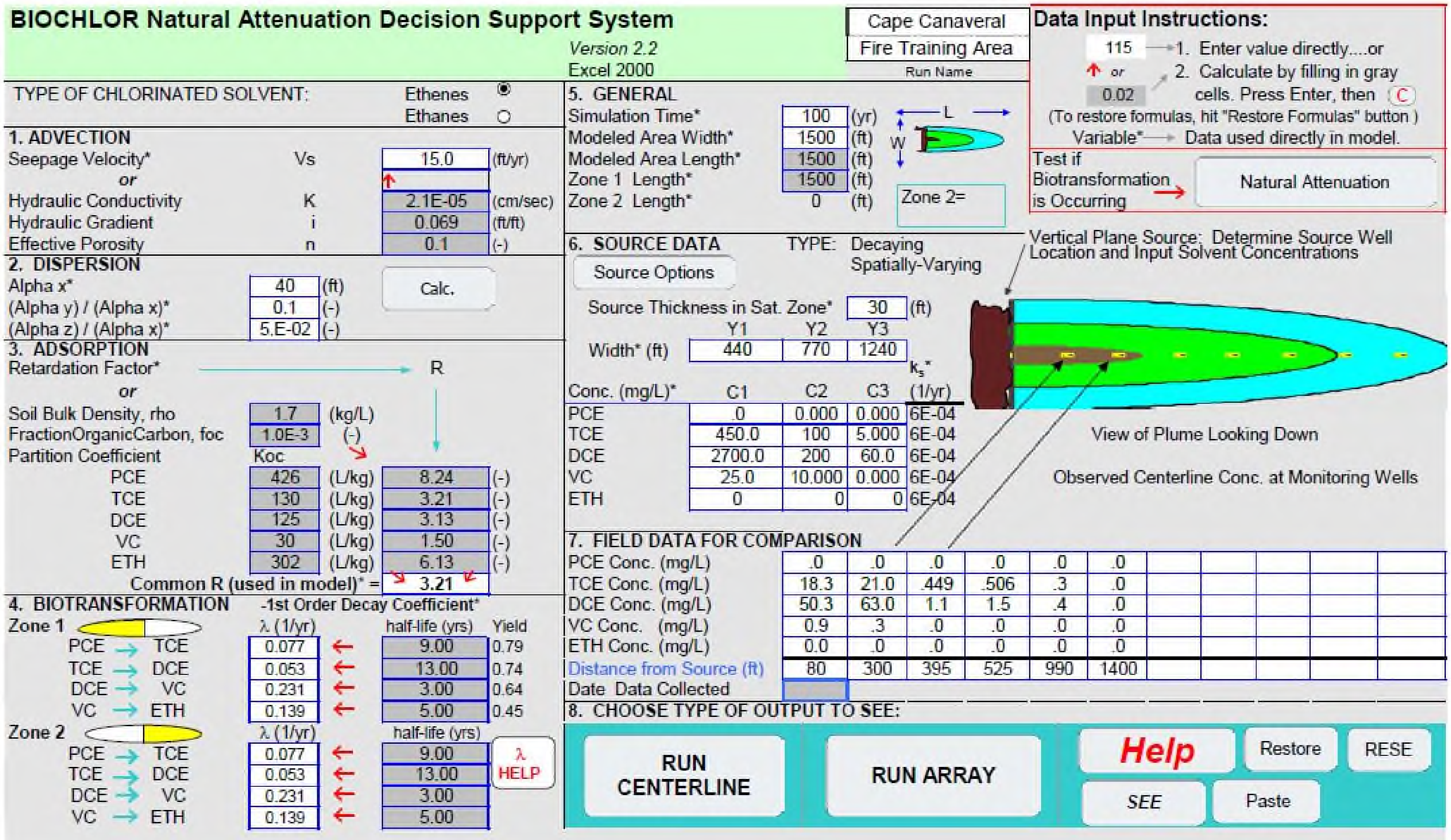
- Initial concentrations entered specifically for Layers 1, 2 and 3

- Model grid reduced to 25 feet by 25 feet across Hoff VC Site and most of Gibraltar Rock Quarry to aid in site-specific entry of initial conditions.

- Porosity set to 0.01 which is typical for fracture dominated groundwater flow

Fate and Transport Analysis – Input Data from Leidos Report Section 8.3

TCE Fate and Transport Input



BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel 2000

Cape Canaveral
Fire Training Area
Run Name

Data Input Instructions:
115 → 1. Enter value directly....or
or 2. Calculate by filling in gray
0.02 cells. Press Enter, then (C)
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation

TYPE OF CHLORINATED SOLVENT: Ethenes (selected) / Ethanes

1. ADVECTION

Seepage Velocity*	Vs		15.0	(ft/yr)
or				
Hydraulic Conductivity	K		2.1E-05	(cm/sec)
Hydraulic Gradient	i		0.069	(ft/ft)
Effective Porosity	n		0.1	(-)

2. DISPERSION

Alpha x*	40	(ft)
(Alpha y) / (Alpha x)*	0.1	(-)
(Alpha z) / (Alpha x)*	5.E-02	(-)

Calc.

3. ADSORPTION

Retardation Factor* → R
or

Soil Bulk Density, rho	1.7	(kg/L)
FractionOrganicCarbon, foc	1.0E-3	(-)

Partition Coefficient	Koc		R	
PCE	426	(L/kg)	8.24	(-)
TCE	130	(L/kg)	3.21	(-)
DCE	125	(L/kg)	3.13	(-)
VC	30	(L/kg)	1.50	(-)
ETH	302	(L/kg)	6.13	(-)

Common R (used in model)* = 3.21

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

Zone 1	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	0.077	9.00	0.79
TCE → DCE	0.053	13.00	0.74
DCE → VC	0.231	3.00	0.64
VC → ETH	0.139	5.00	0.45

Zone 2	λ (1/yr)	half-life (yrs)
PCE → TCE	0.077	9.00
TCE → DCE	0.053	13.00
DCE → VC	0.231	3.00
VC → ETH	0.139	5.00

λ HELP

5. GENERAL

Simulation Time*	100	(yr)
Modeled Area Width*	1500	(ft)
Modeled Area Length*	1500	(ft)
Zone 1 Length*	1500	(ft)
Zone 2 Length*	0	(ft)

Zone 2=

6. SOURCE DATA TYPE: Decaying Spatially-Varying

Source Options

Source Thickness in Sat. Zone* 30 (ft)

	Y1	Y2	Y3	
Width* (ft)	440	770	1240	
Conc. (mg/L)*	C1	C2	C3	k_s* (1/yr)
PCE	.0	0.000	0.000	6E-04
TCE	450.0	100	5.000	6E-04
DCE	2700.0	200	60.0	6E-04
VC	25.0	10.000	0.000	6E-04
ETH	0	0	0	6E-04

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)	.0	.0	.0	.0	.0	.0					
TCE Conc. (mg/L)	18.3	21.0	.449	.506	.3	.0					
DCE Conc. (mg/L)	50.3	63.0	1.1	1.5	.4	.0					
VC Conc. (mg/L)	0.9	.3	.0	.0	.0	.0					
ETH Conc. (mg/L)	0.0	.0	.0	.0	.0	.0					
Distance from Source (ft)	80	300	395	525	990	1400					
Date Data Collected											

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE | RUN ARRAY | Help | Restore | RESE | SEE | Paste

Fate and Transport Analysis – Input Data from Leidos Report Section 8.3

MTBE Fate and Transport Input

The following input parameters were used in the PADEP Quick Domenico simulation for MTBE:

- Source: Assumed to be a release near MW-14 (4,870 ppb)
- Model Length, Width: 1,000 ft, 200 ft (distance from MW-14 to location SW of 2104 Hoffmansville Road)
- Ax: 100 ft (default value, 0.1*X where X is model length)
- Ay: 10 ft (default value, 0.1*Ax)
- Az: 0.001 (default value)
- Lambda: 0 (default value, assumes no decay)
- Source Width: 150 ft (distance between MW-12 and MW-10)
- Source Thickness: 10 ft (estimated)
- Time: 25, 30, and 35 years
- Hydraulic Conductivity: 0.06 ft/day (value for OW-04 from GRI Report 2003)
- Hydraulic Gradient: 0.0531 ft/ft (MW-14 to MW-7S)
- Porosity: 0.2 (assume shallow flow through fractured argillite)
- Soil Bulk Density: 1.7 g/cm^3 (estimated)
- KOC: 12 L/kg (default for MTBE)
- Fraction Organic Carbon: 0.001 (estimated)
- Field Data Source: MW-1, MW7S, MW-14, Apartments, 322 Layfield Road, 318 Layfield Road, 314 Layfield Road, 2104 Hoffmansville Road.

Fate and Transport Analysis – Input Data from Leidos Report Section 8.3

1,4-Dioxane Fate and Transport Input

Leidos utilized similar input parameters for each Quick Domenico simulation. Difference between the input parameters for the MTBE model and the 1,4-dioxane model are listed below:

- Source: Assumed to be a release near MW-13 (250 ppb)
- Model Length, Width: 1,740 ft, 200 ft (distance from MW-13 to MW-10D)
- Ax: 174 ft (default value, 0.1*X where X is model length)
- Ay: 17.4 ft (default value, 0.1*Ax)
- Az: 0.001 (default value)
- Source Width: 240 ft (estimated based on MW-2S, MW-10, MW-14)
- Source Thickness: 20 ft (estimated)
- Time: 50, 75, and 100 years
- KOC: 7.8 L/kg (default for MTBE)
- Field Data Source: MW-12, MW-13, MW-14, MW-5S, MW-7D, MW-10D, Apartments, 322 Layfield Road, 318 Layfield Road, 314 Layfield Road, 317 Layfield Road, 325 Layfield Road, 313 Layfield Road, and 2024 Hoffmansville Road.

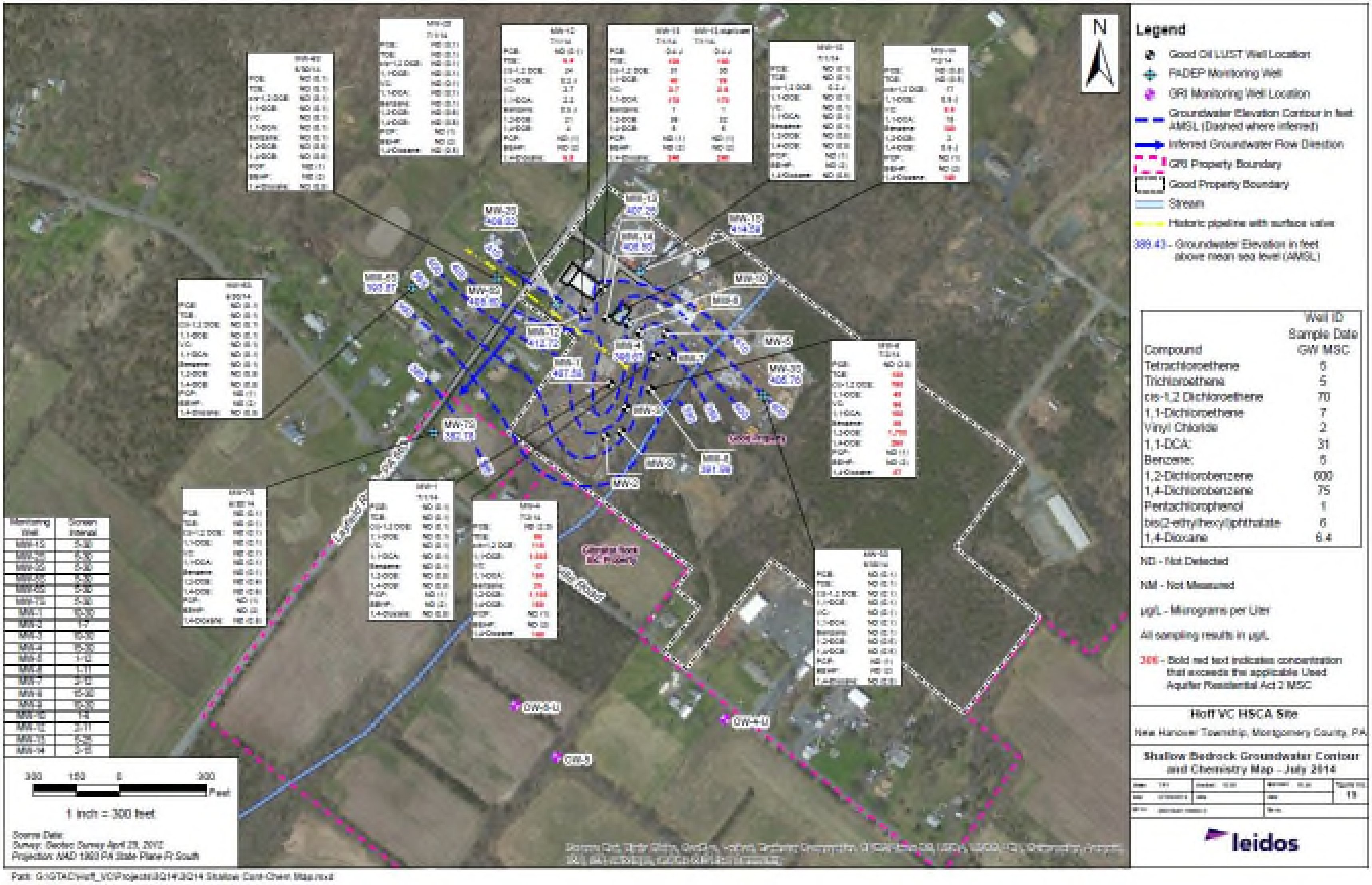
Fate and Transport Analysis – Input Data from Leidos Report Section 8.3

1,2-DCB Fate and Transport Input

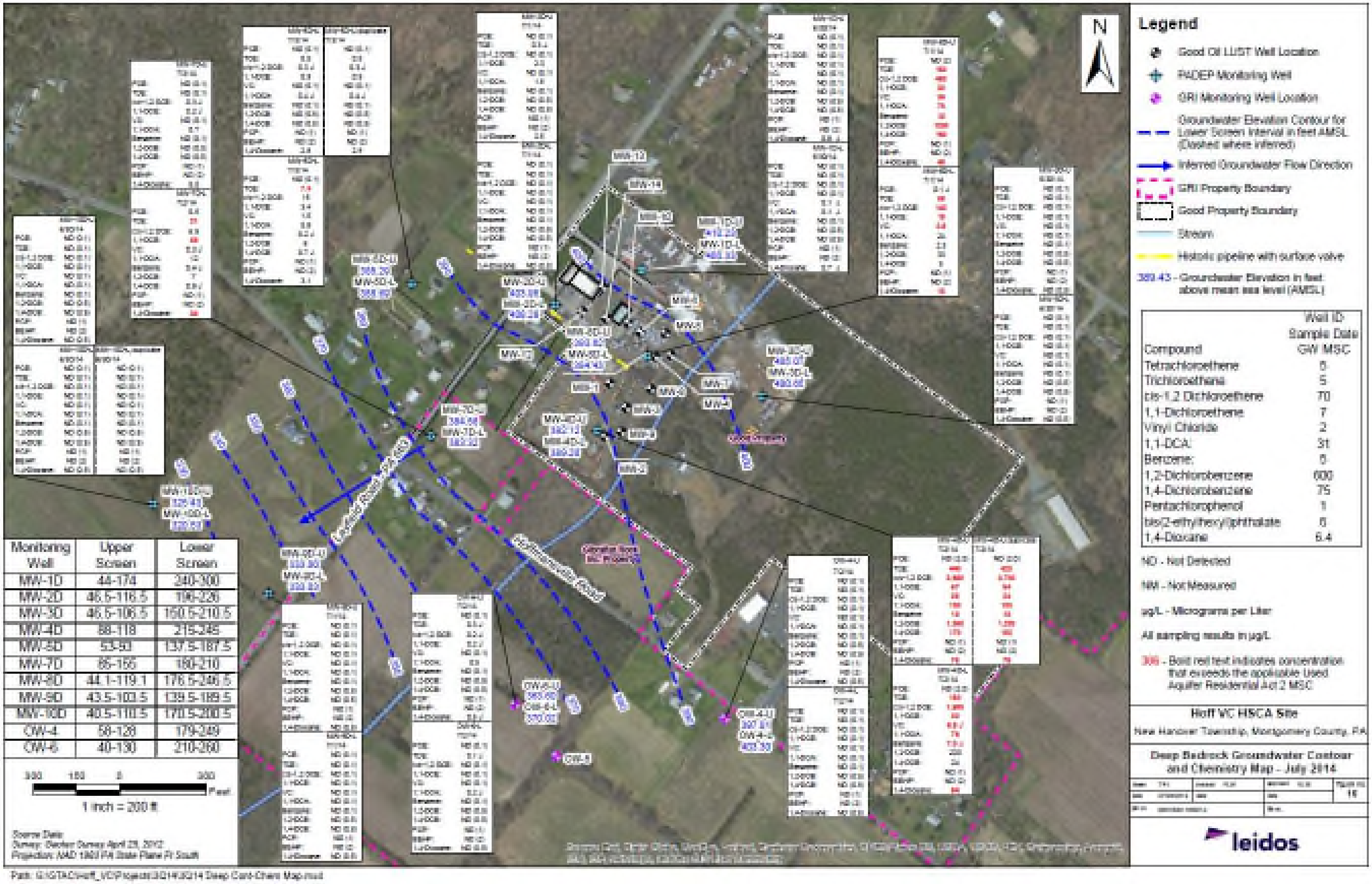
- Source: Assumed to be a release near MW-8 and MW-4 (1,700 and 1,300 ppb)
- Model Length, Width: 1,000 ft, 200 ft (based on EV model)
- Ax: 500 ft (estimated value based on sample concentrations)
- Ay: 10 ft (estimated value)
- Az: 0.001 (default value)
- Source Width: 200 ft (estimated based on MW-2S, MW-10, MW-14)
- Source Thickness: 20 ft (estimated)
- Time: 50, 75, and 100 years
- KOC: 350 L/kg (default for MTBE)
- Field Data Source: MW-4D, MW-8D, MW-7, MW-10D, 325 Layfield Road, 318 Layfield Road, 2029 Hoffmansville Road, 2104 Hoffmansville Road, and 2024 Hoffmansville Road.

Modified 1,2-DCB Fate and Transport Input – Used in MT3D

- Ax: 75 ft (compared to 500 ft above)
- Ay: 1 ft (compared to 10 ft above)
- Porosity: 0.1 (compared to 0.2)
- Fraction Organic Carbon: 0.0002 (compared to 0.001)



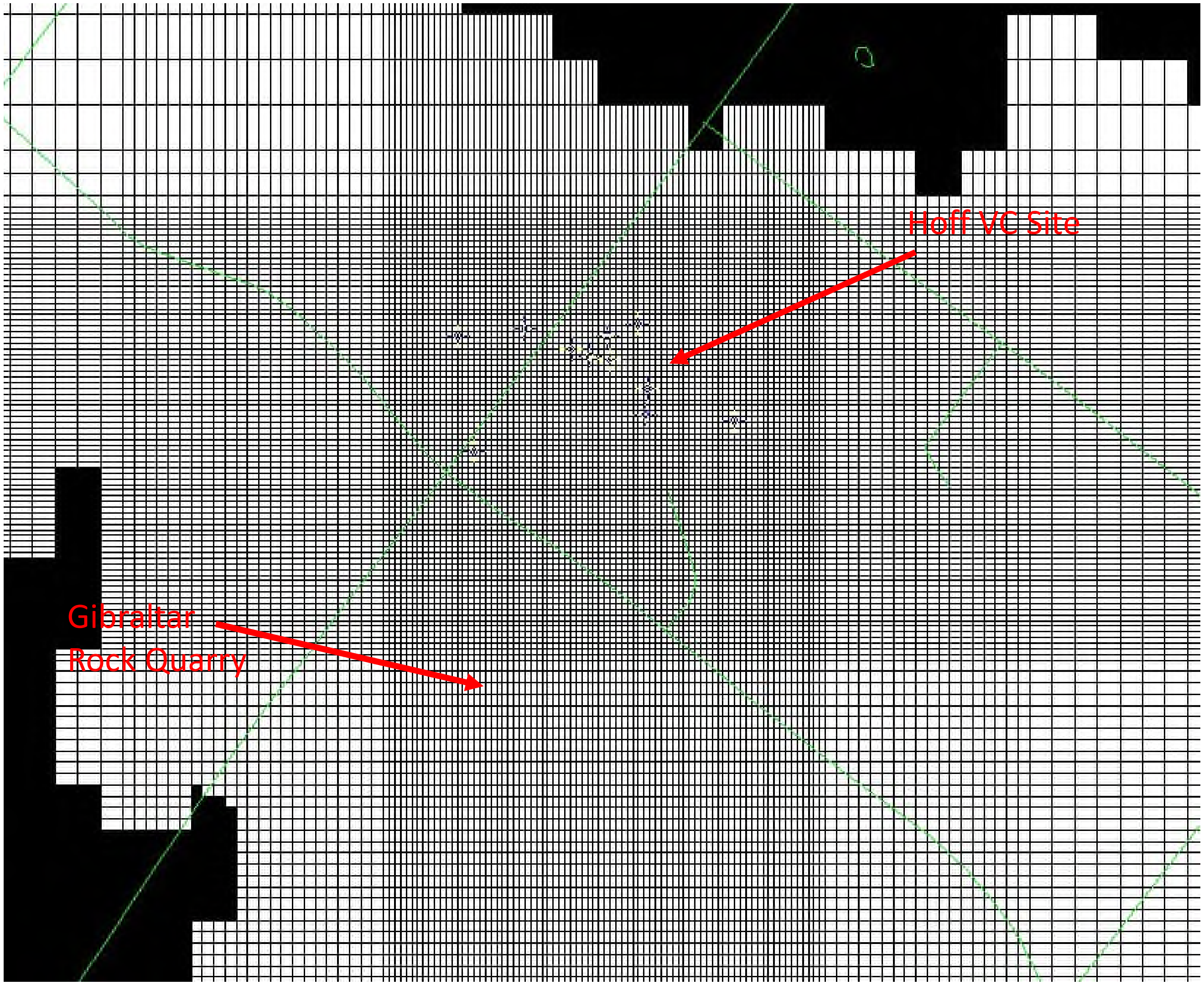
Shallow Bedrock Groundwater and Chemistry – July 2014



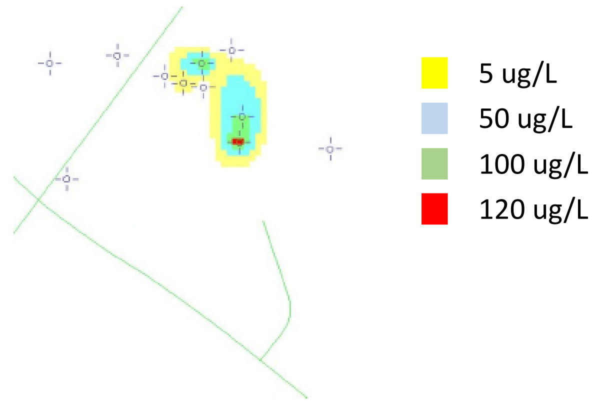
Deep Bedrock Groundwater and Chemistry – July 2014

Variable Grid Spacing with further refinements at Hoff Site for Fate and Transport Modeling–

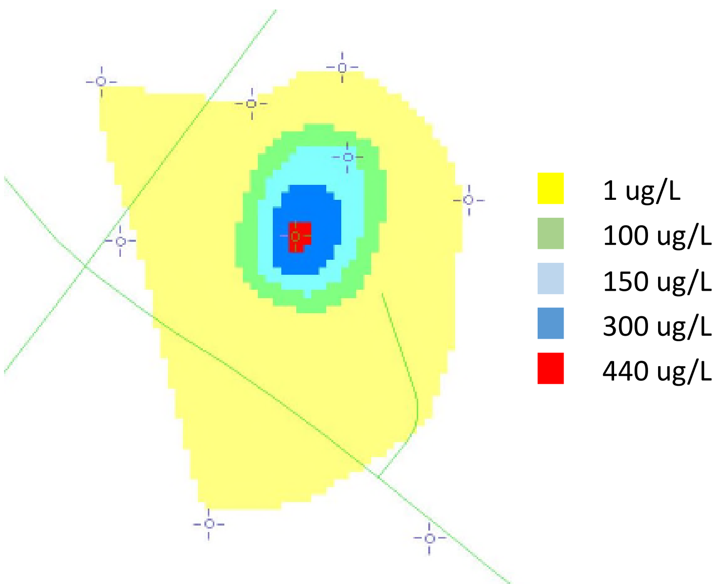
25 feet by 25 feet centered on Hoff Site and Quarry to 200 feet by 200 feet near Model edges



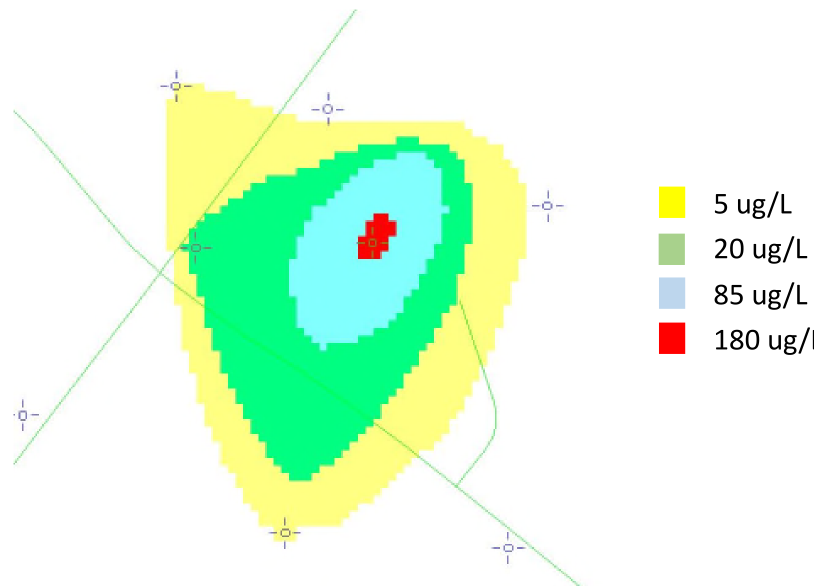
Fate and Transport Model Domain & Grid – Variable Spacing Centered on Hoff Site and Quarry



Model Layer 1

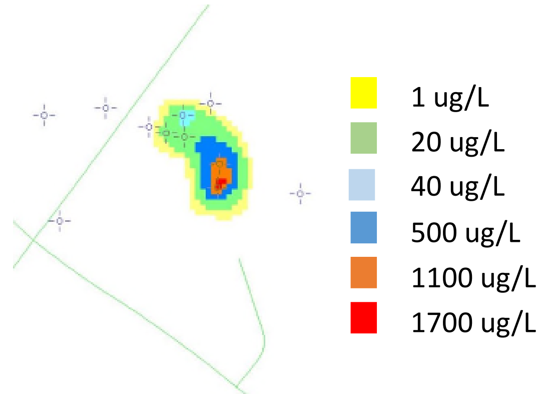


Model Layer 2

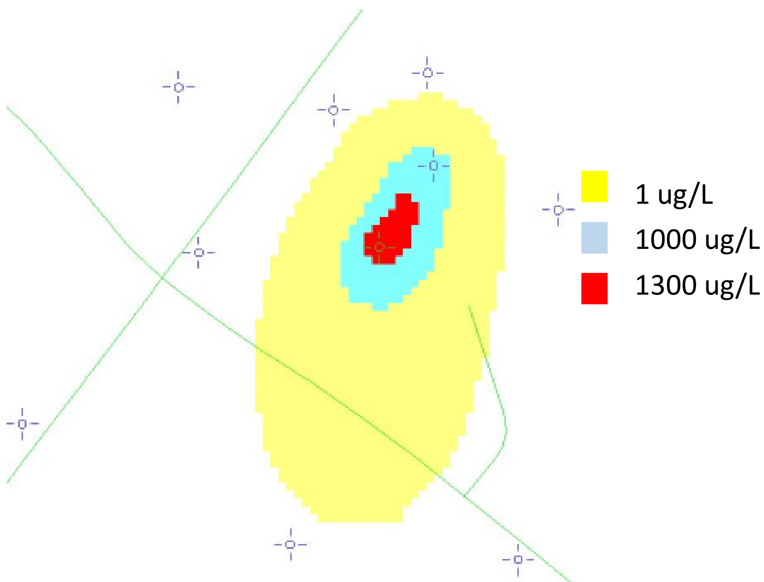


Model Layer 3

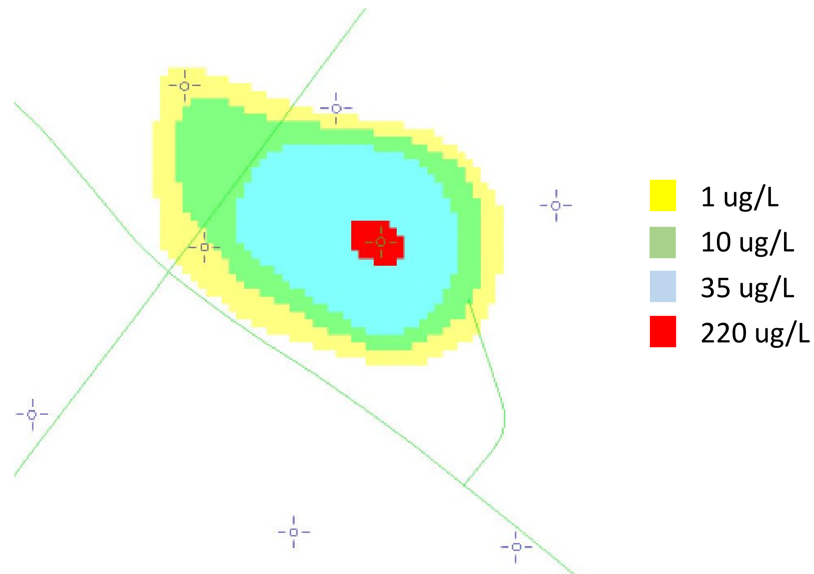
Model TCE Initial Concentrations – Based on July 2014 – Model Layers 1 to 3



Model Layer 1

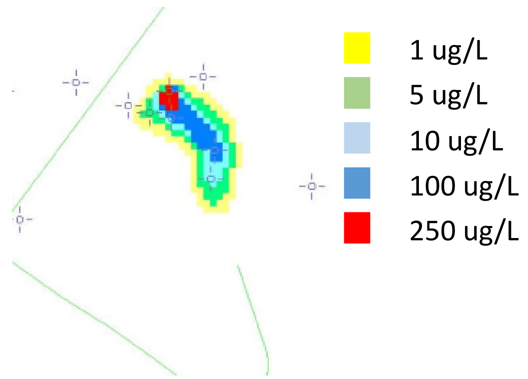


Model Layer 2

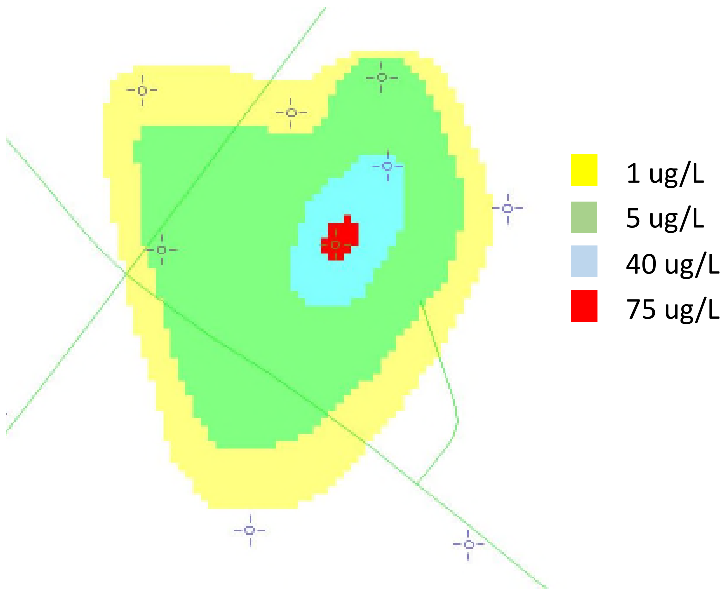


Model Layer 3

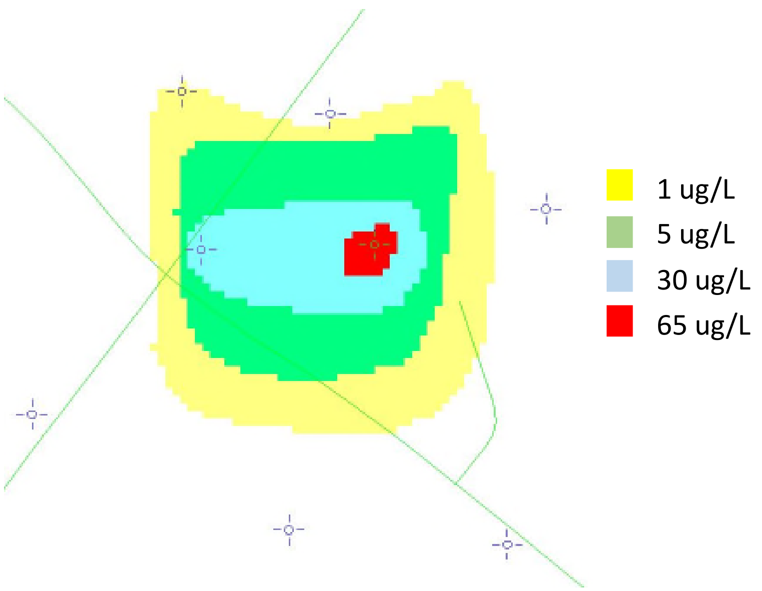
Model 1,2-DCB Initial Concentrations – Based on July 2014 – Model Layers 1 to 3



Model Layer 1

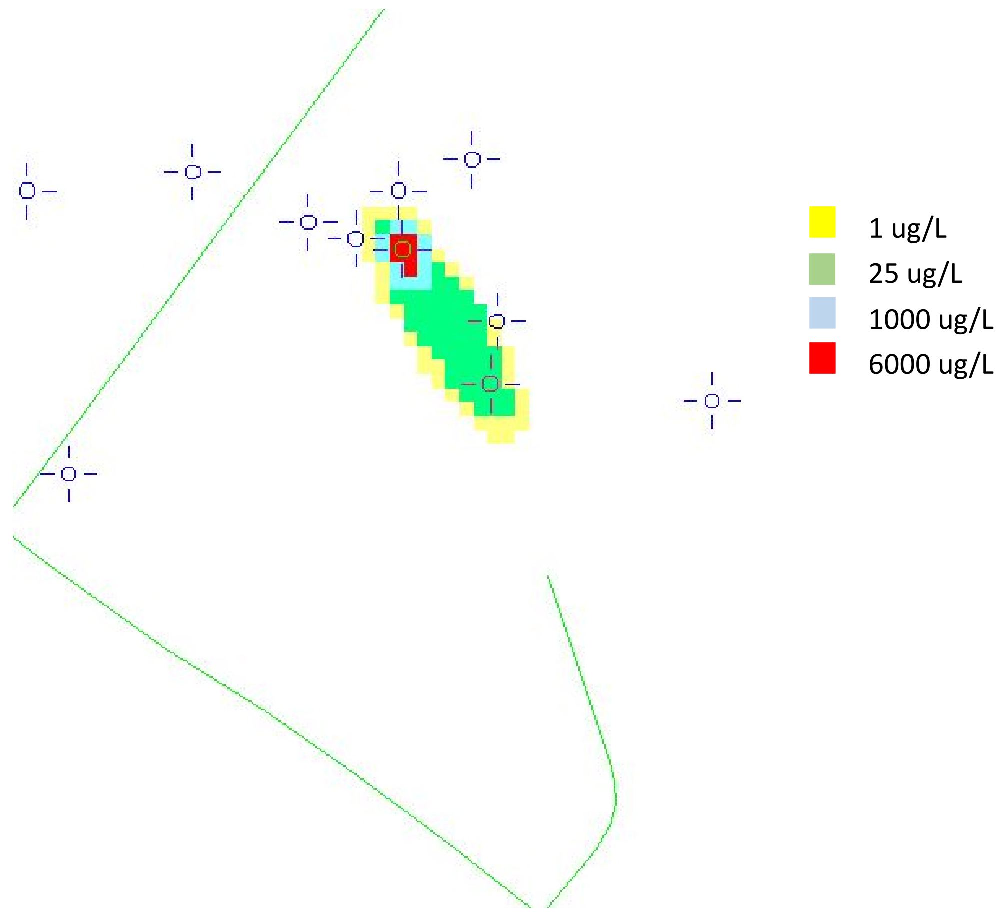


Model Layer 2



Model Layer 3

Model 1,4-Dioxane Initial Concentrations – Based on July 2014 – Model Layers 1 to 3



Model MTBE Initial Concentrations – Based on January 2012 – Model Layer 1

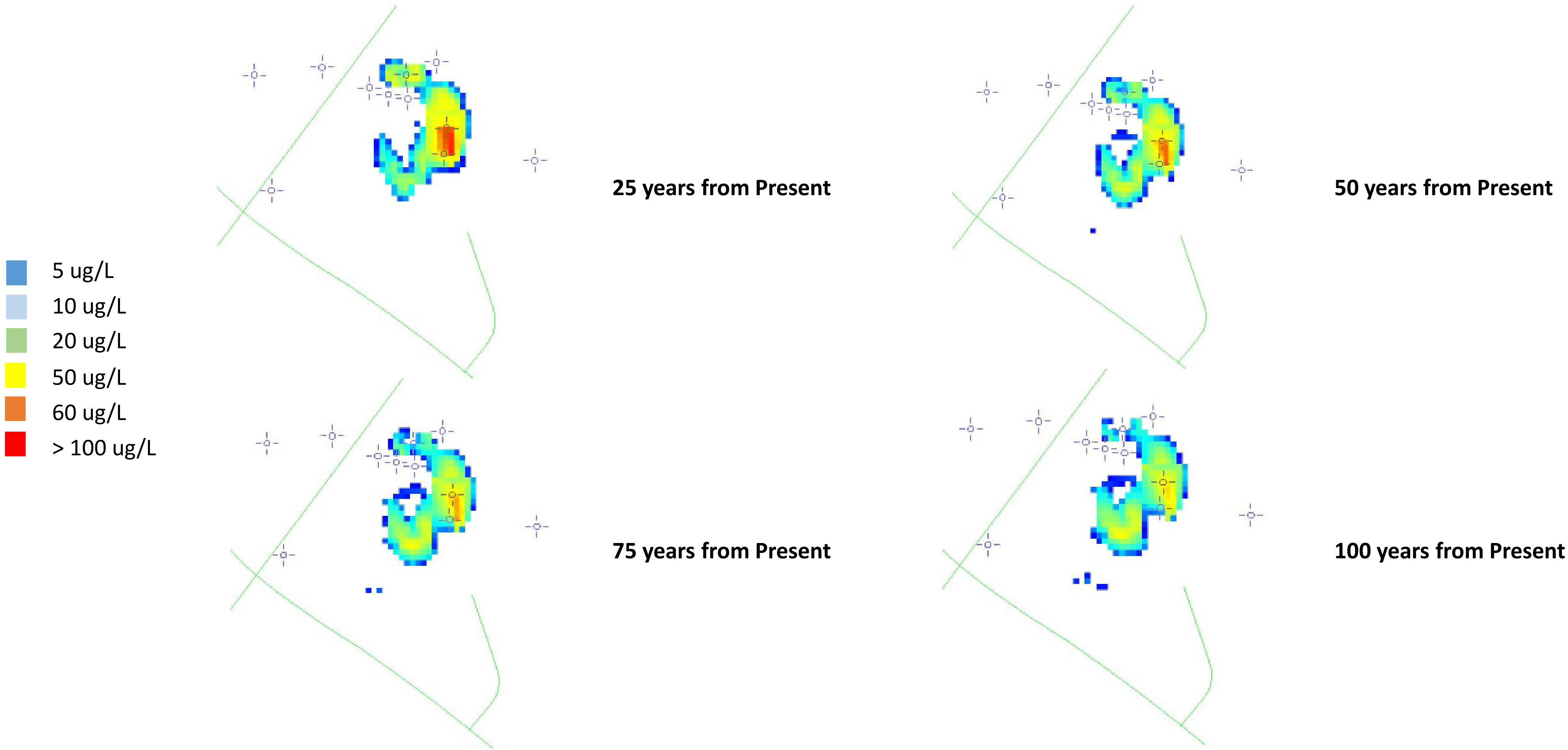
Fate and Transport Analysis – Future Predictions by Chemical and Layer

- Geochemical and parameter specific transport input utilized from Leidos Report (Section 8.3)

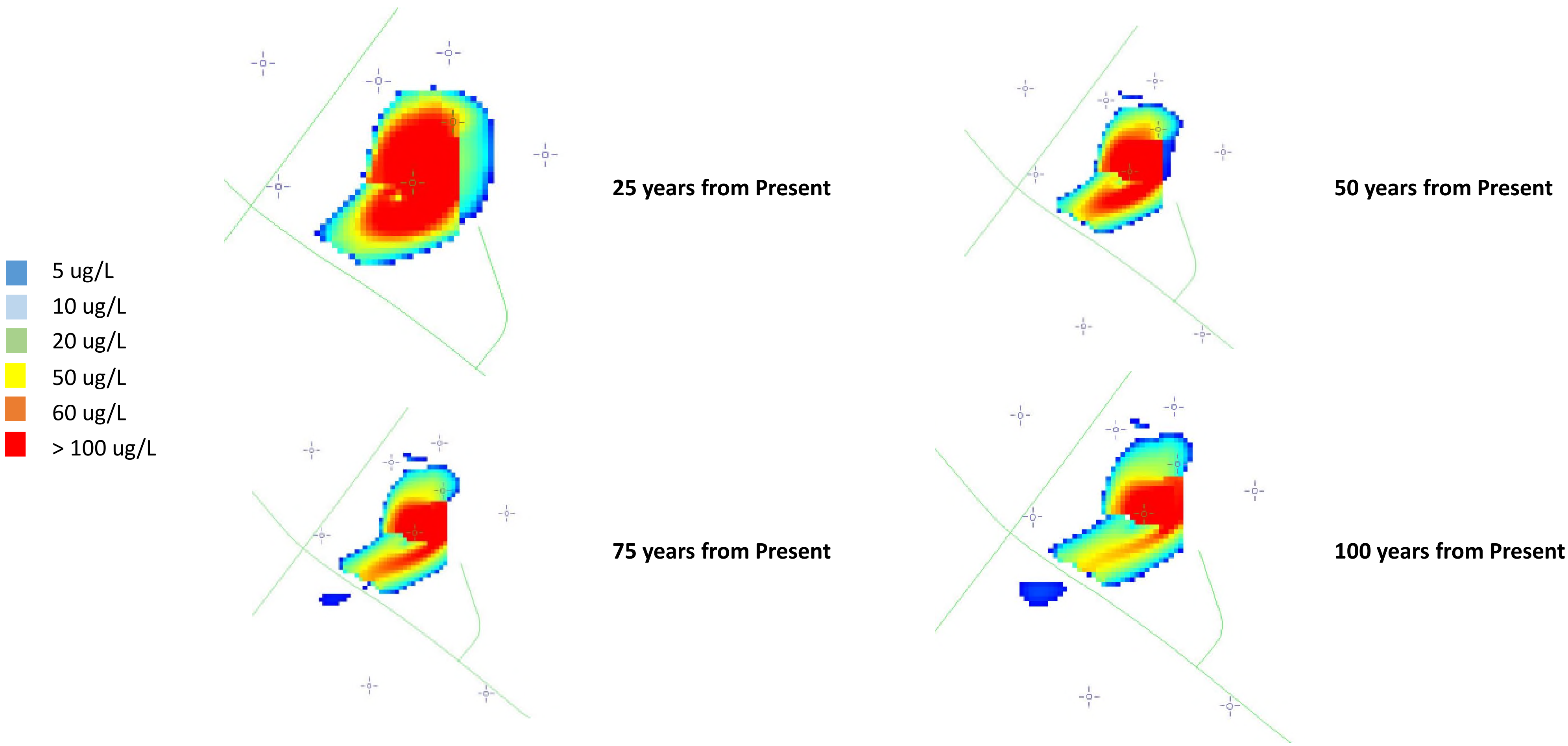
- Calibrated groundwater flow model based on July 2014 potentiometrics utilized for flow component of fate and transport modeling
  - Assumes flow does not change over time

- Initially ran for 30 years, but modified based on Leidos Report Section 8.3 output
  - Most chemicals persistent for more than 30 years

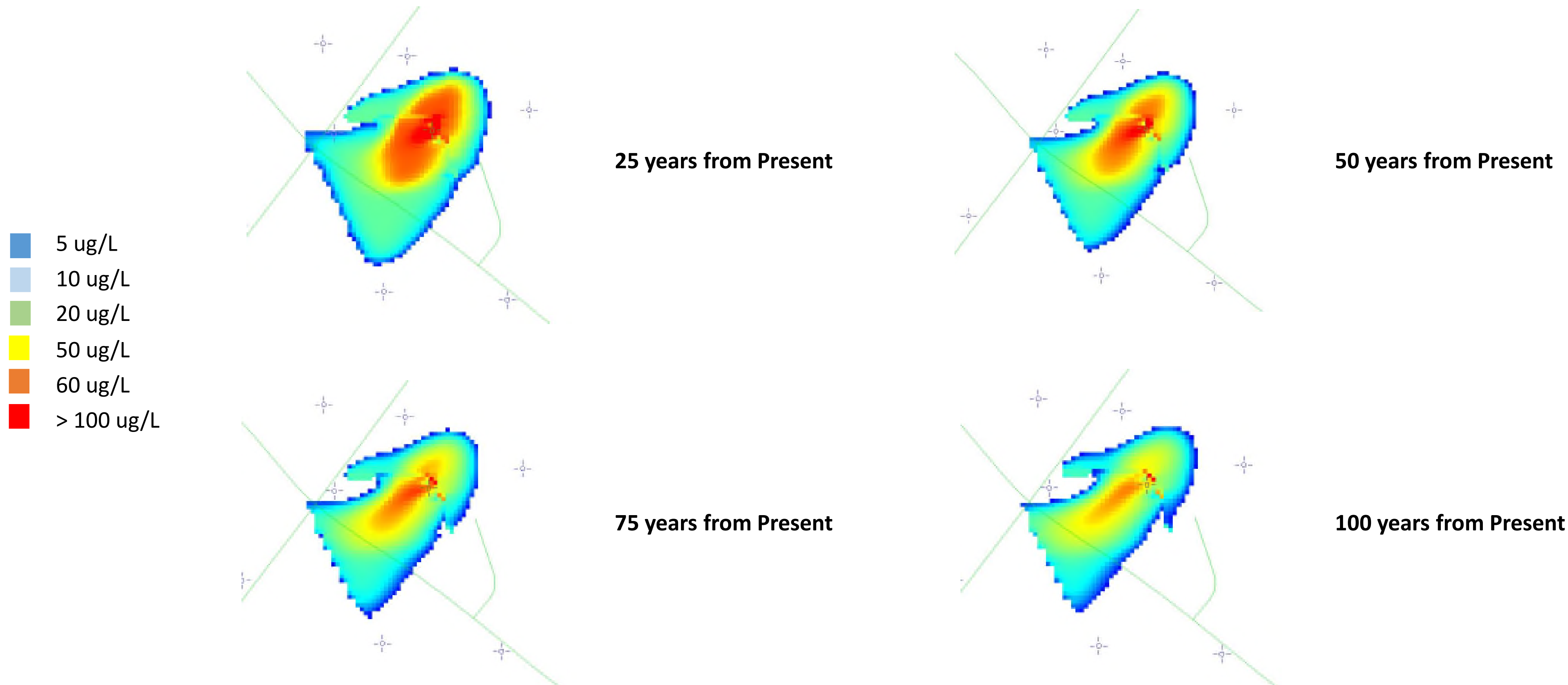
- Chemical output written on 25 year intervals for 100 years



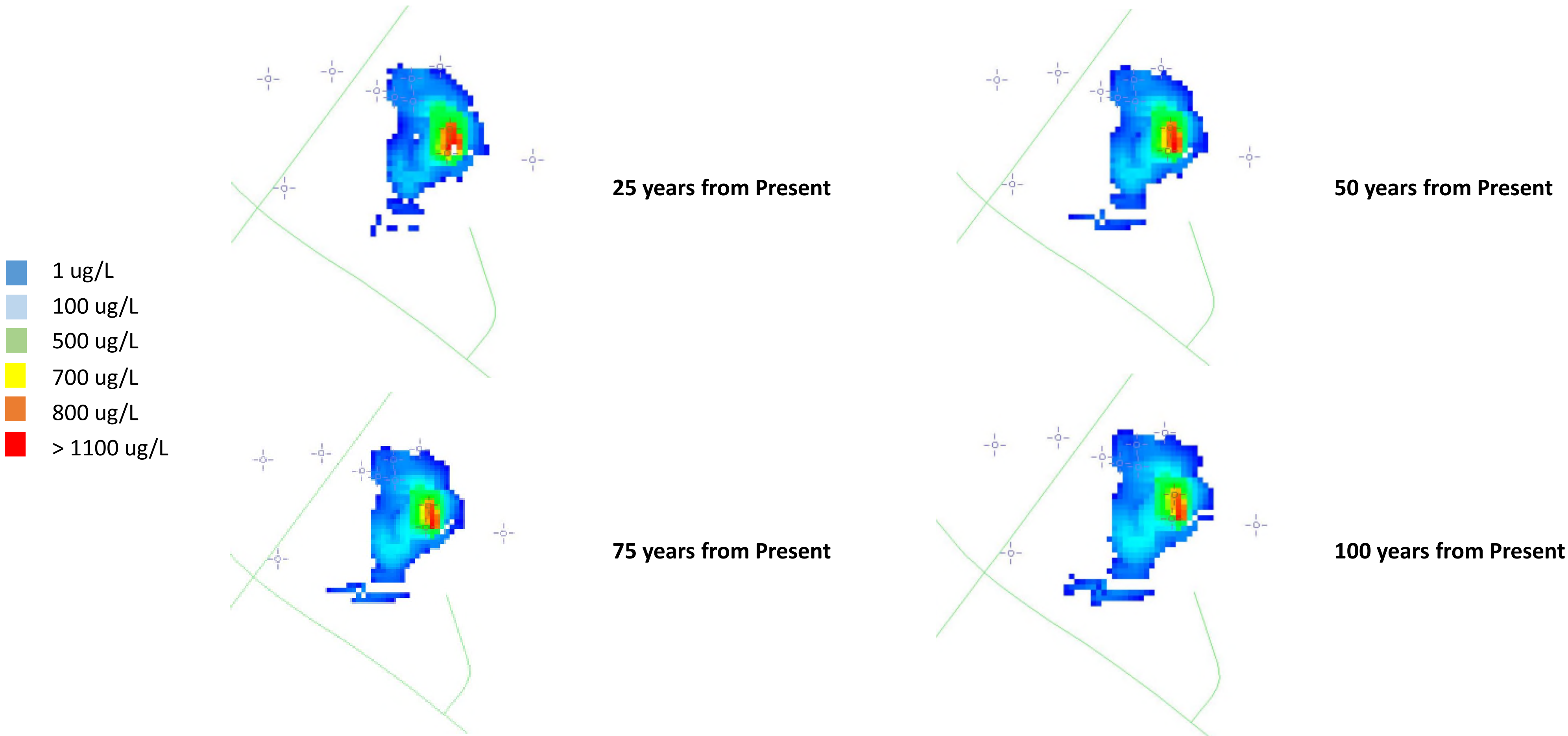
Modeled TCE Concentrations – Model Layer 1



Modeled TCE Concentrations – Model Layer 2

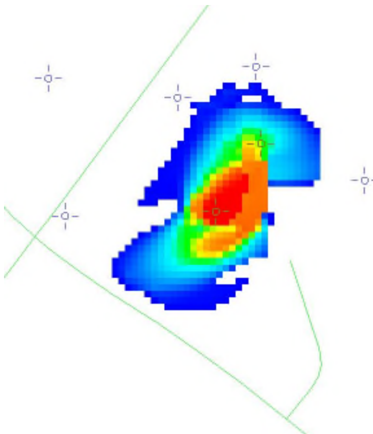


Modeled TCE Concentrations – Model Layer 3

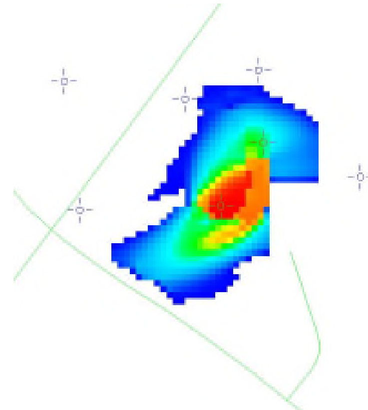


Modeled 1,2-DCB Concentrations – Model Layer 1

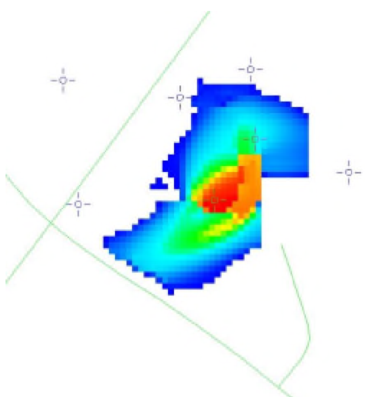
- 1 ug/L
- 100 ug/L
- 500 ug/L
- 700 ug/L
- 800 ug/L
- > 1100 ug/L



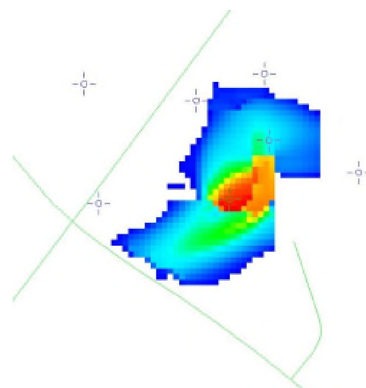
25 years from Present



50 years from Present

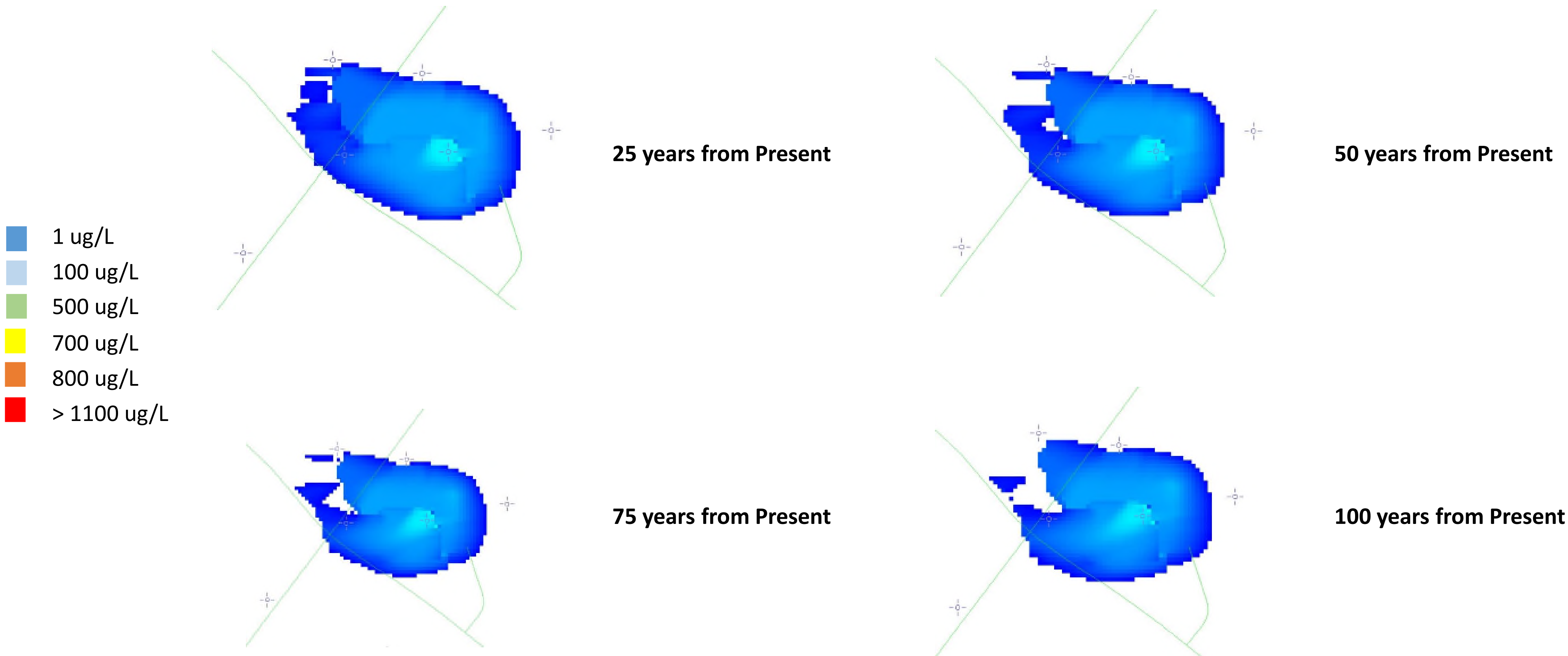


75 years from Present

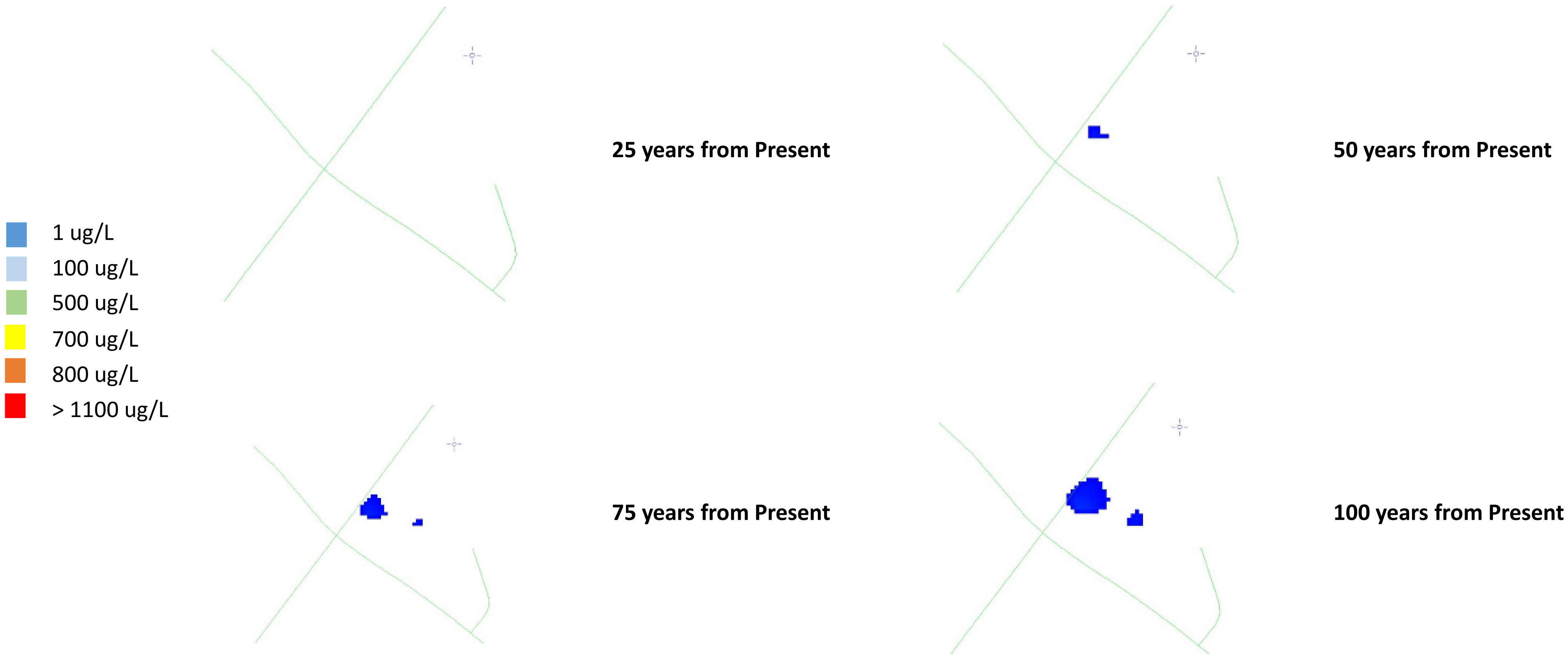


100 years from Present

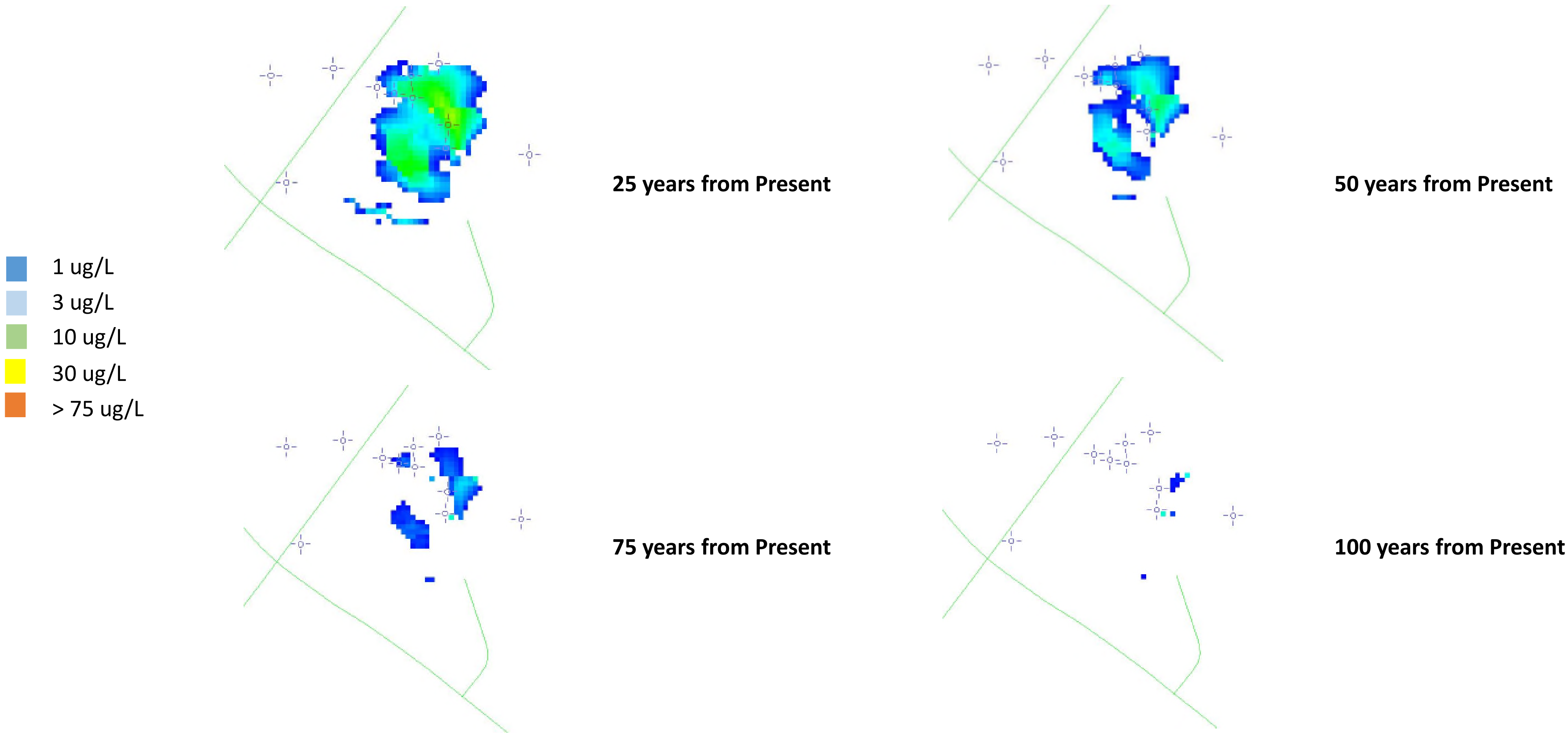
Modeled 1,2-DCB Concentrations – Model Layer 2



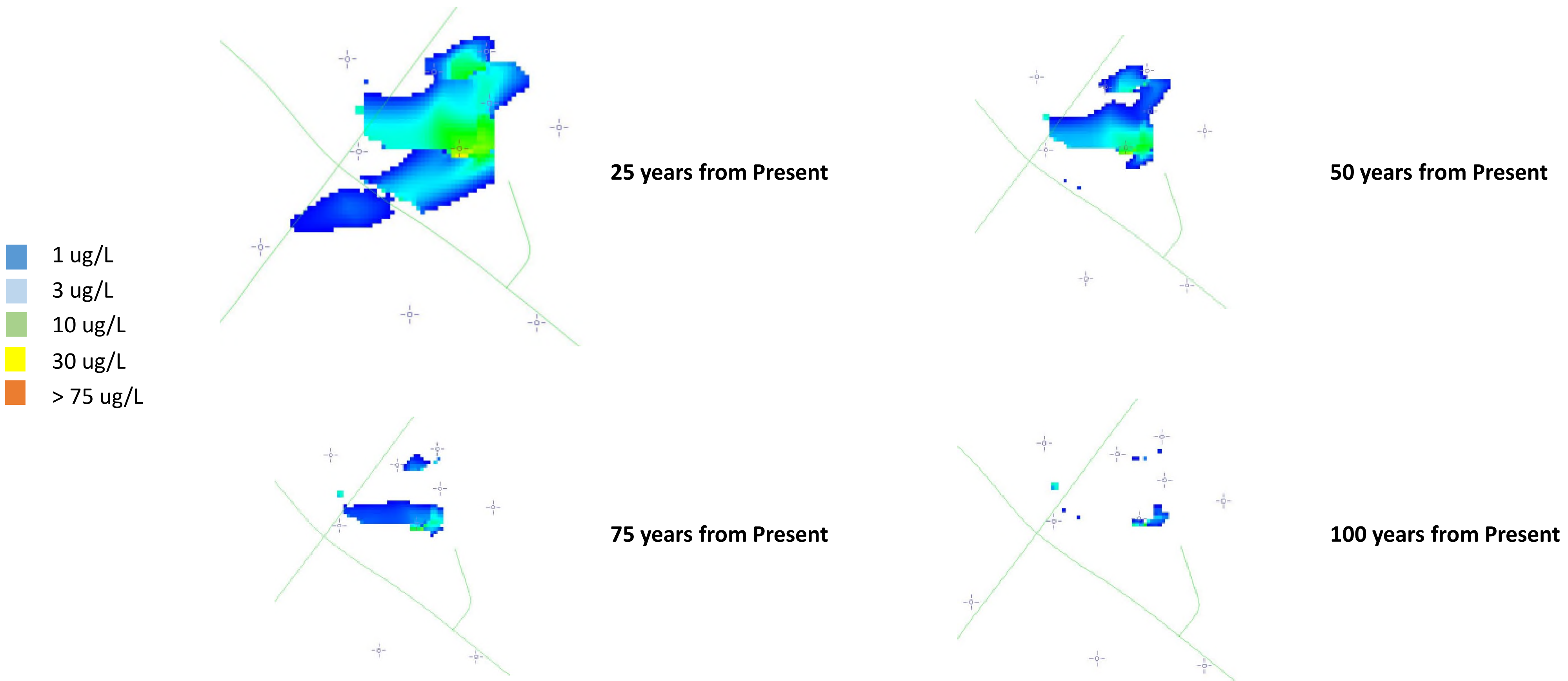
Modeled 1,2-DCB Concentrations – Model Layer 3



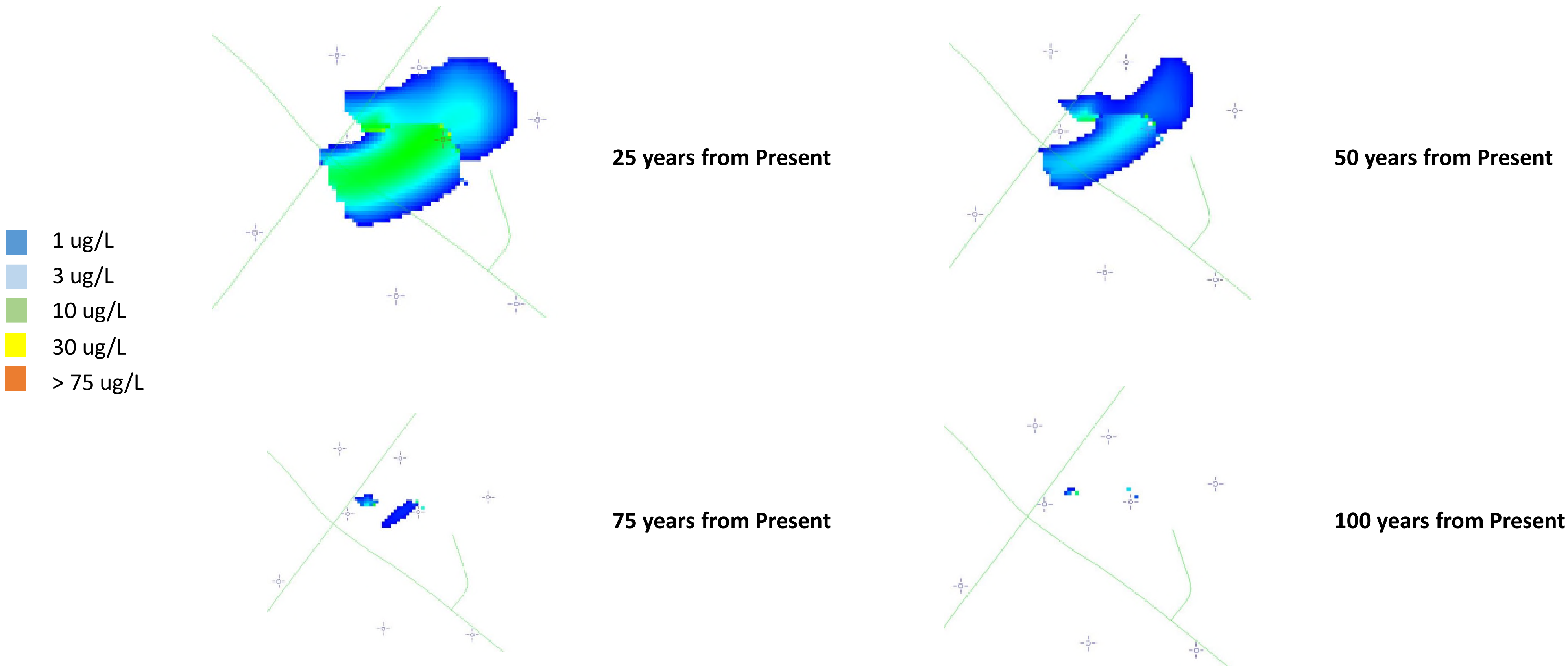
Modeled 1,2-DCB Concentrations – Model Layer 4



Modeled 1,4-DIOX Concentrations – Model Layer 1

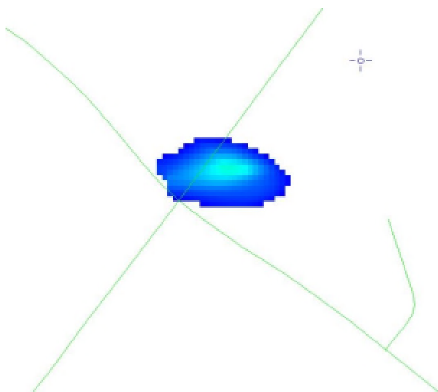


Modeled 1,4-DIOX Concentrations – Model Layer 2

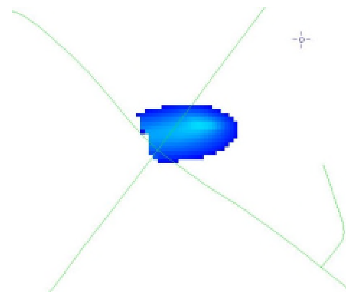


Modeled 1,4-DIOX Concentrations – Model Layer 3

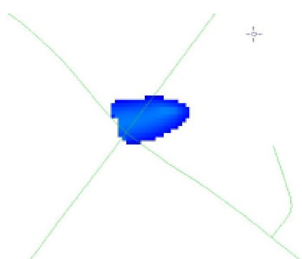
1 ug/L
3 ug/L
10 ug/L
30 ug/L
> 75 ug/L



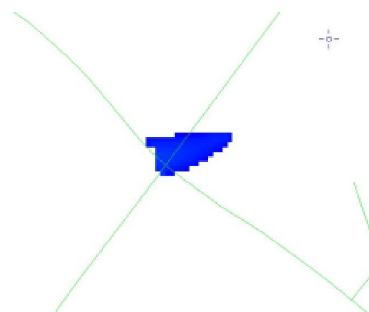
25 years from Present



50 years from Present



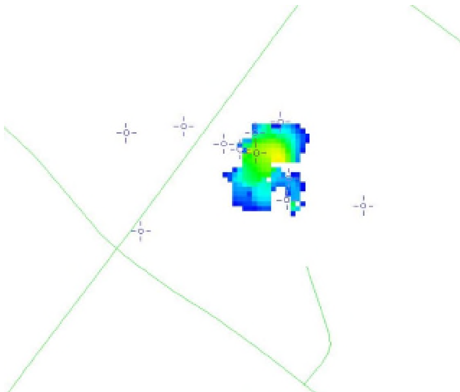
75 years from Present



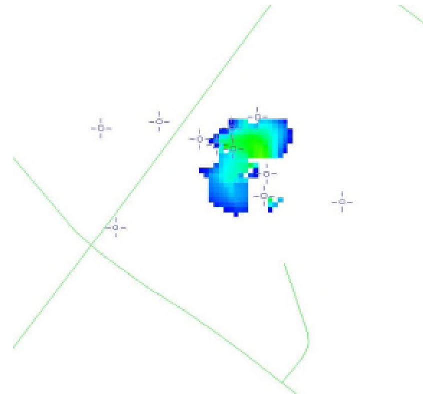
100 years from Present

Modeled 1,4-DIOX Concentrations – Model Layer 4

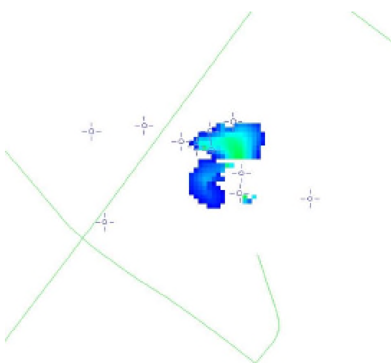
- 1 ug/L
- 5 ug/L
- 25 ug/L
- 250 ug/L
- 500 ug/L
- > 1500 ug/L



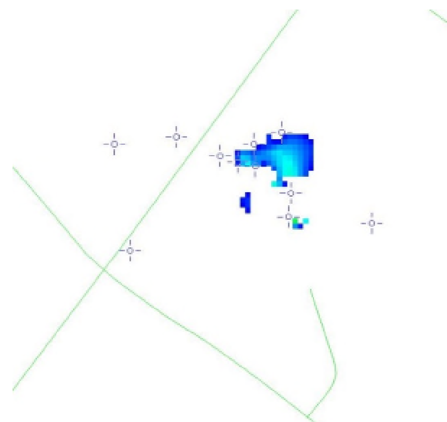
25 years from Present



50 years from Present

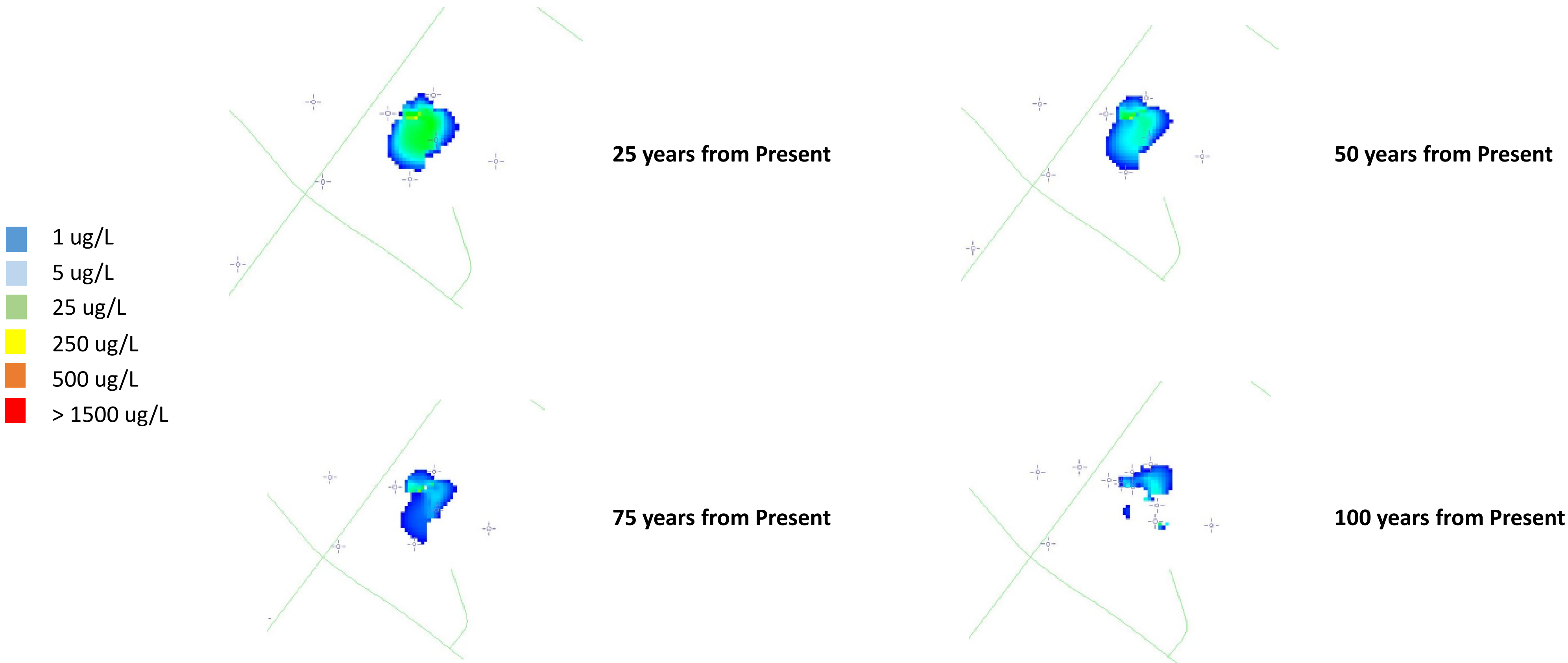


75 years from Present



100 years from Present

Modeled MTBE Concentrations – Model Layer 1



Modeled MTBE Concentrations – Model Layer 2

Modeled MTBE Concentrations – Model Layer 3

Summary of Fate and Transport Analysis – Future Predictions by Chemical and Layer

- TCE
  - Minor advancement of plume in Layers 1 and 2 (across Hoffmansville Road in Layer 2)
- 1,2-Dicholorbenzene
  - Minor advancement of plume noted in Layers 3 across Hoffmansville Road and migration into Layer 4 on Hoff VC Site
- 1,4-Dioxane
  - No advancement of plume however downward migration to Layer 4 is predicted
- MTBE
  - No advancement of plume however downward migration to Layers 2 and 3 is predicted

Summary of PADEP Hoff VC Site Groundwater Modeling and Fate and Transport Analysis

- Groundwater Model
  - Constructed accurate representation of the hydrogeological system at the Hoff VC Site and adjacent Gibraltar Rock Quarry
  - MODFLOW model has “upward” mobility for more advanced and typical model application

- Fate and Transport Model
  - Most contaminants only show minor advancement in future years to on or offsite locations and migration into lower groundwater zones

- Future Work?
  - Translation of MODFLOW model into model not based on boundary conditions
  - Evaluation of additional fate and transport output based on ranges in contaminant and geochemistry input