Groundwater Impacts of Stormwater Infiltration: Considerations for Low Impact Development

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Presentation Overview

- Groundwater modeling applications to green, or low impact development design
- Philadelphia's "Green Streets" Program
  - Hydraulic influences – groundwater mounding and potential for basement flooding
    - 12th Street Infiltration Trench System
- Washington State Infiltration Trench
  - Water quality – infiltration trench upgradient of community public supply wells
- Future Considerations

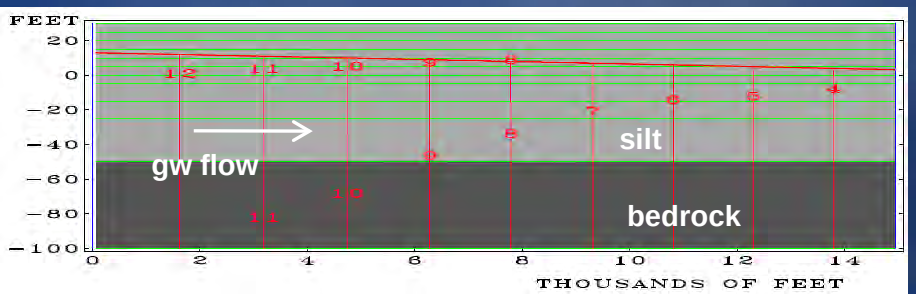
Philadelphia “Green Streets” Project

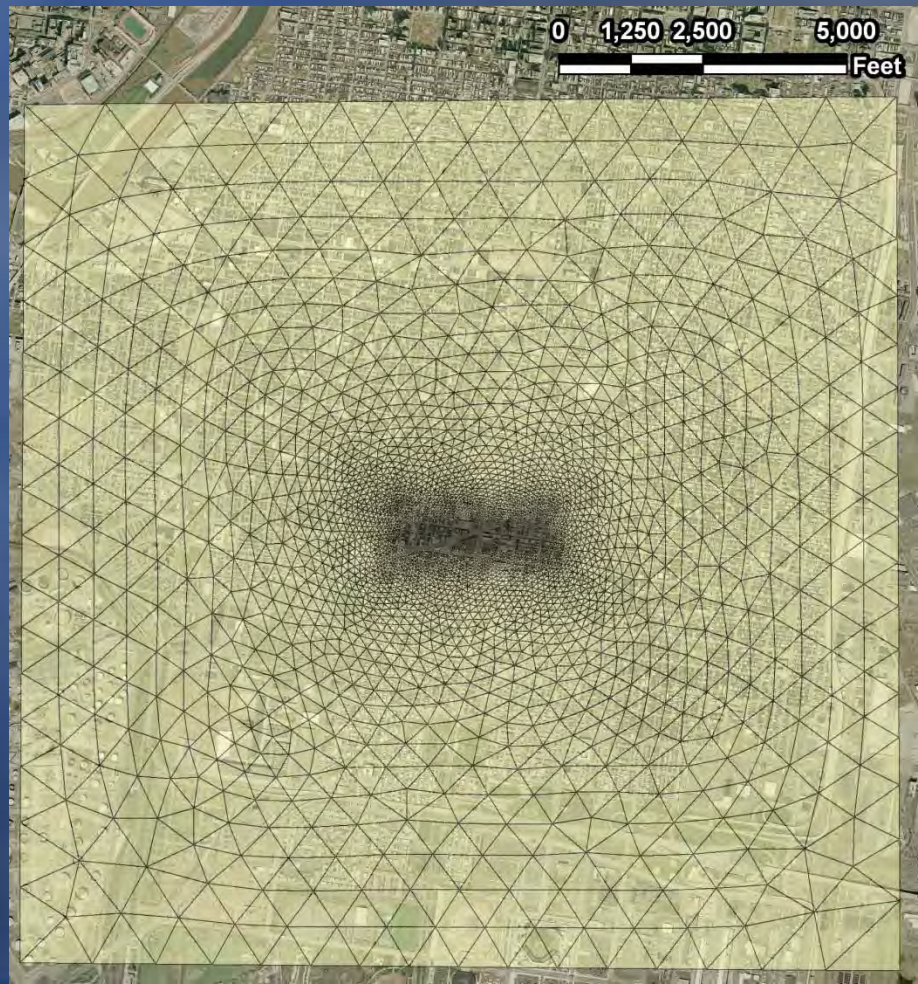
- Site-scale and regional models developed
- DYNFLOW (www.dynsystem.com)
  - Fully 3D, finite element groundwater flow model
  - Used on over 300 projects worldwide
  - Vetted by the International Groundwater Modeling Center
  - GIS compatible

Site Specific Applications

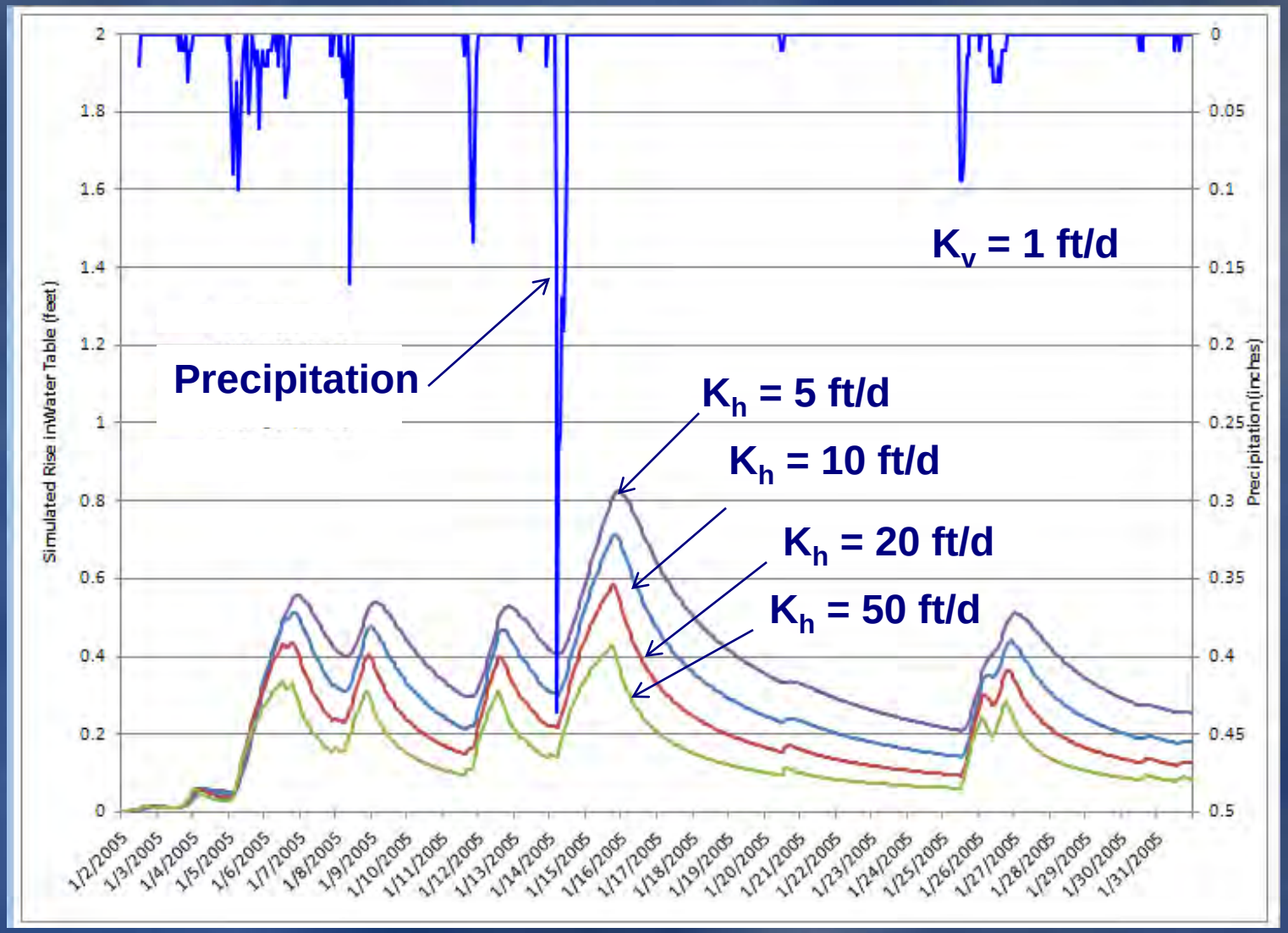
- Initial evaluations considered “box model” with fixed hydraulic conductivities

- Simplified approach
  - Single K
  - Fixed gradient



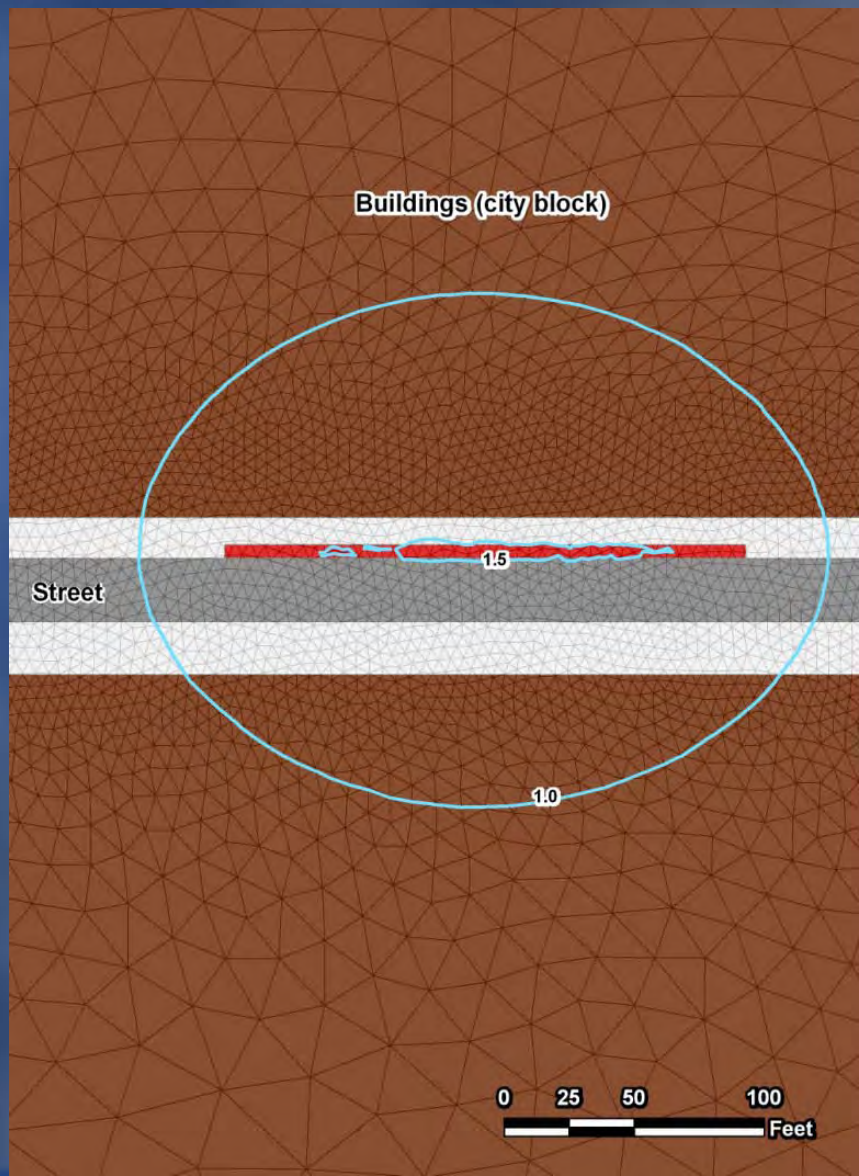


Site-Scale Model Results



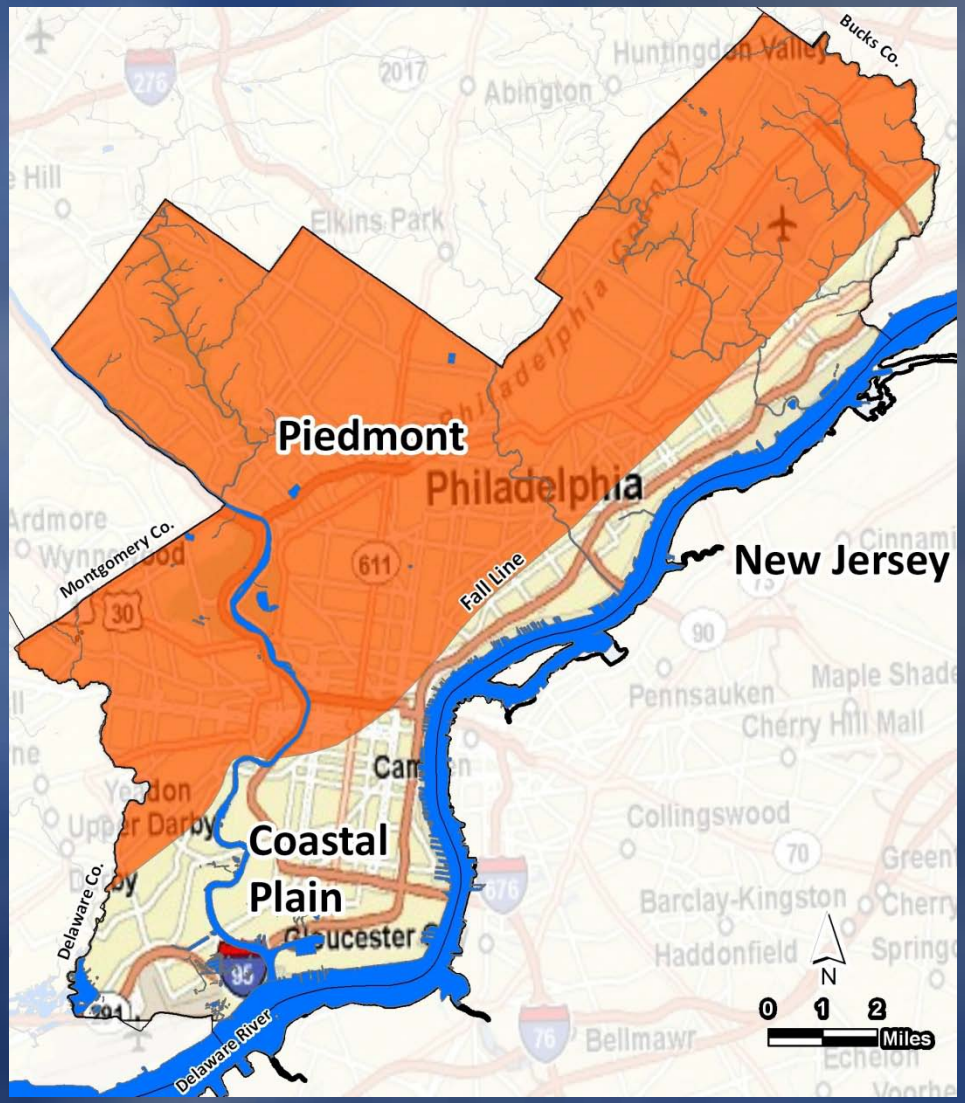
Site-Scale Model Results

- Mounding from the trenches is a localized impact
- Appears to be some local permanent groundwater mounding due to the frequency of storms in Philadelphia
- However, box models not representative of actual hydrogeologic conditions…

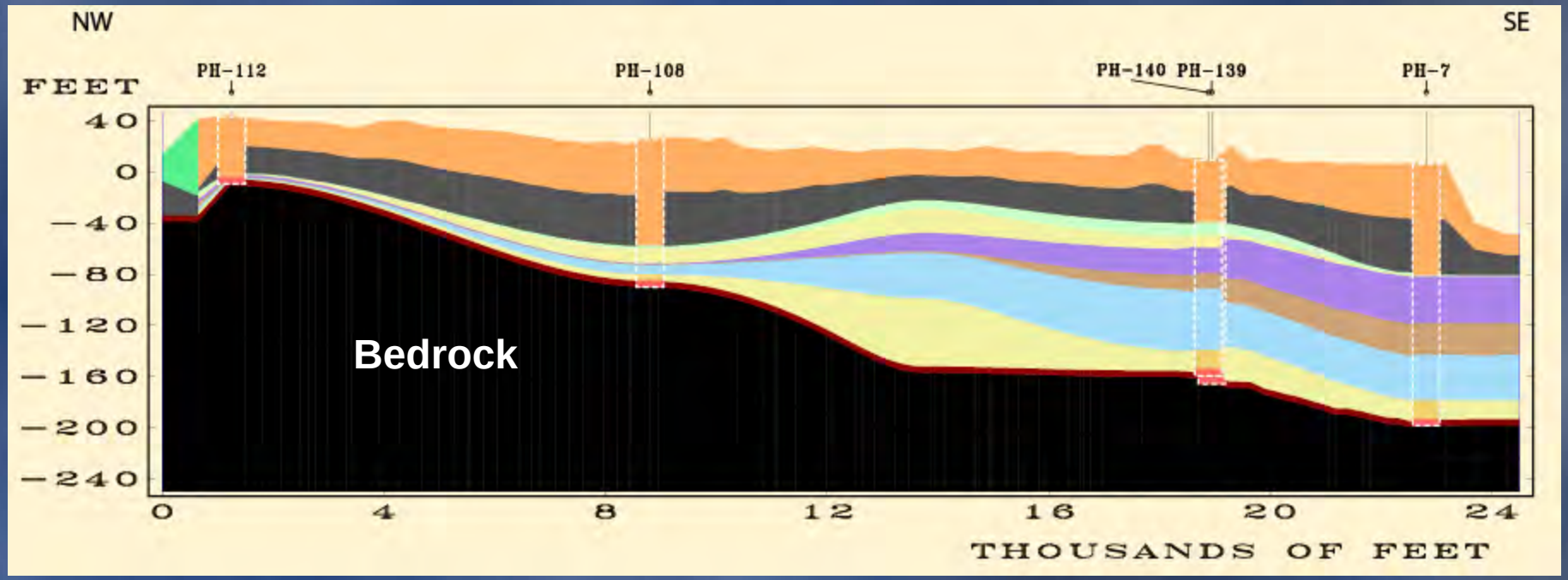


Model Stratigraphy and Hydrogeologic Framework

- Includes both Coastal Plain & Piedmont physiographic provinces
- Divided by Fall Line
- Two very different hydrogeologic environments
- Stratigraphy from cross-sections in USGS reports



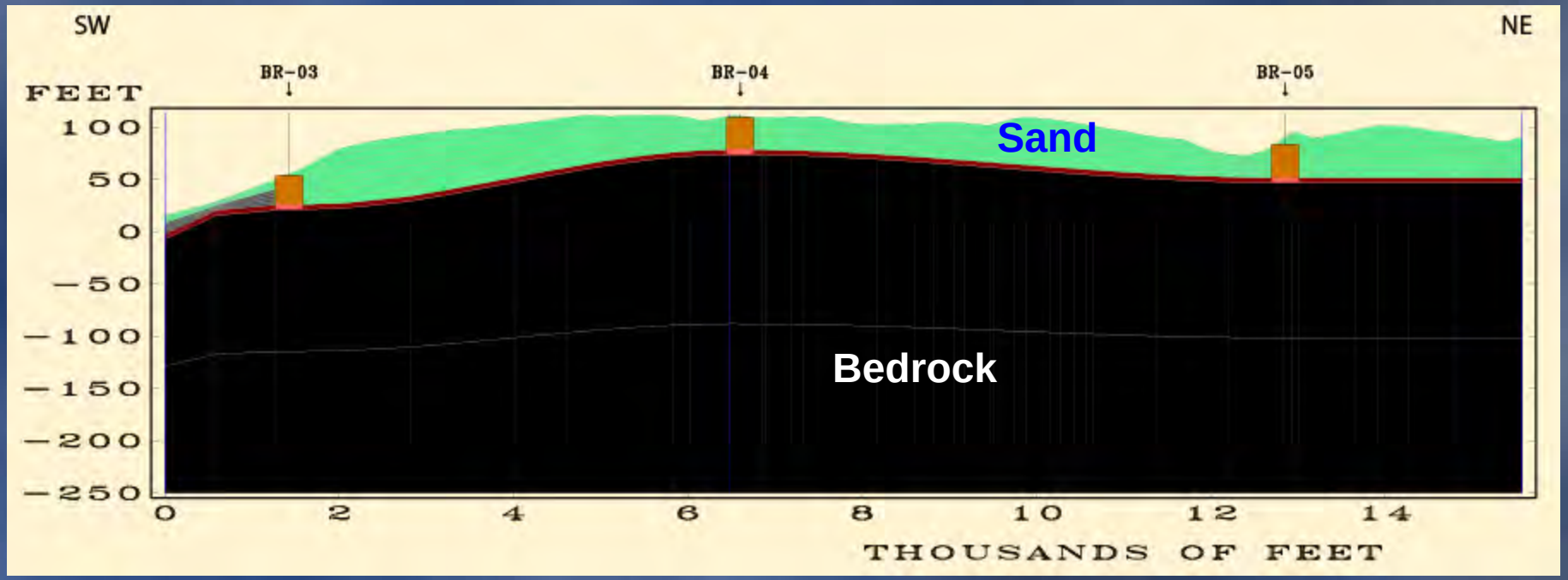
Cross-Section through Coastal Plain



- Layers of permeable aquifer units
- Overlays bedrock

Cross-Section Location

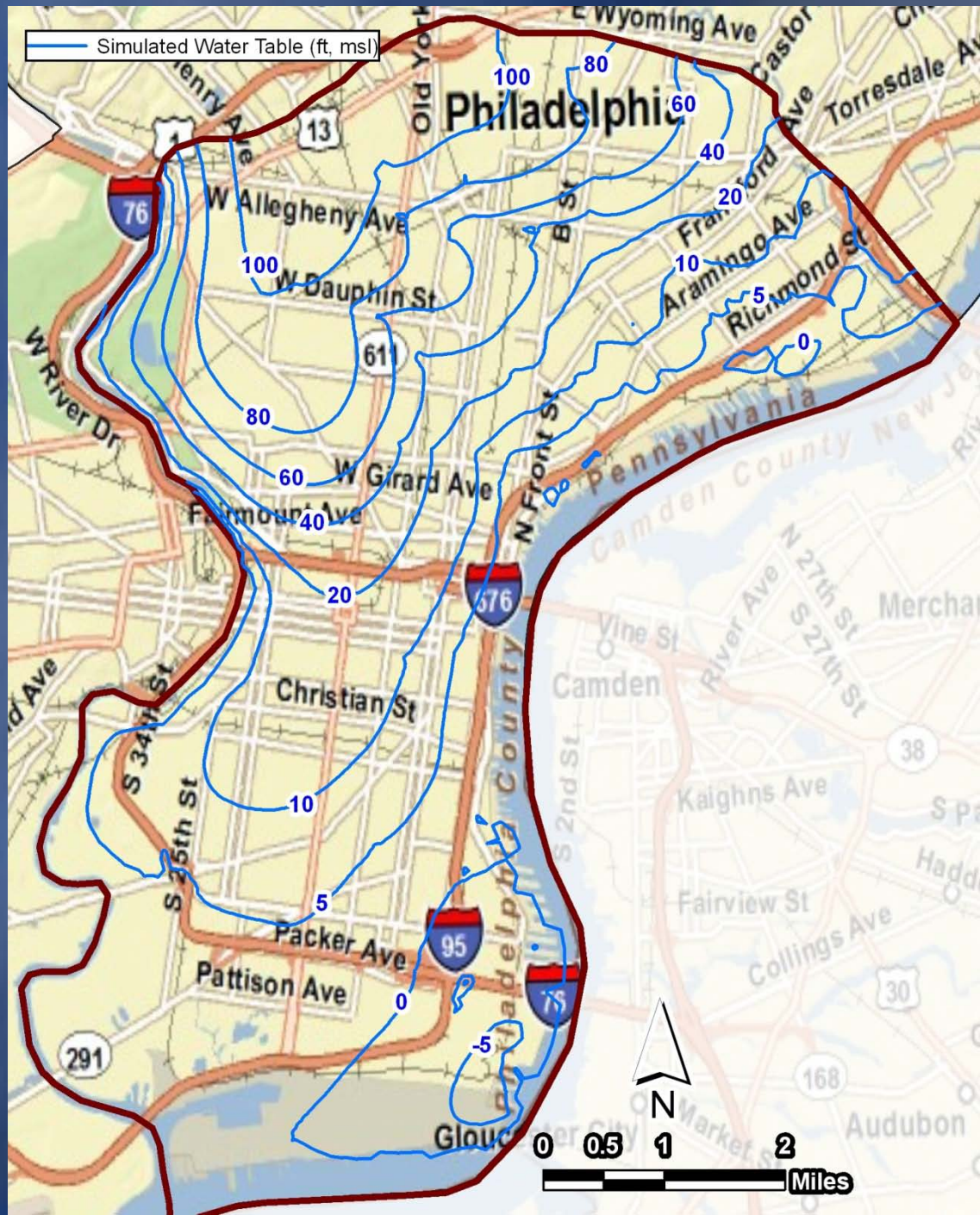
Cross-Section through Piedmont



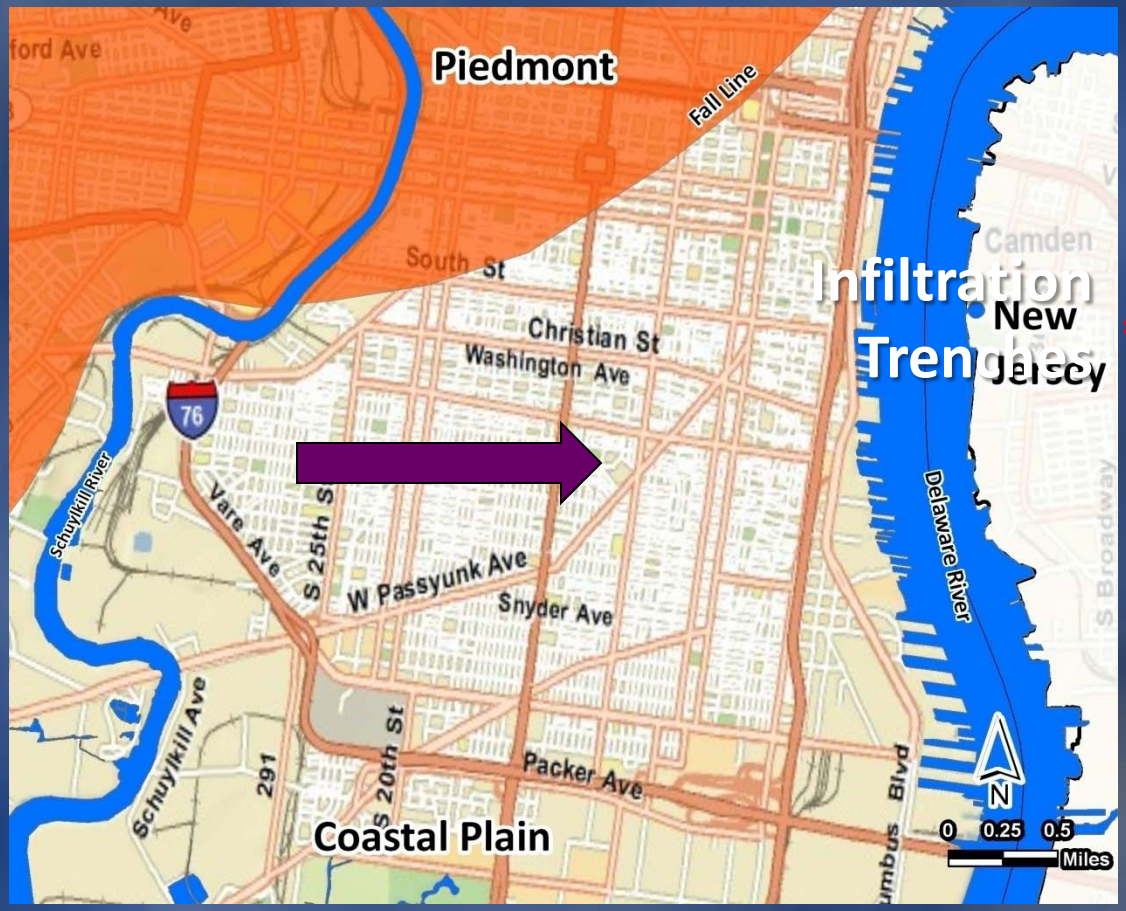
- Sand layer overlaying bedrock
- Transmissivity is limited

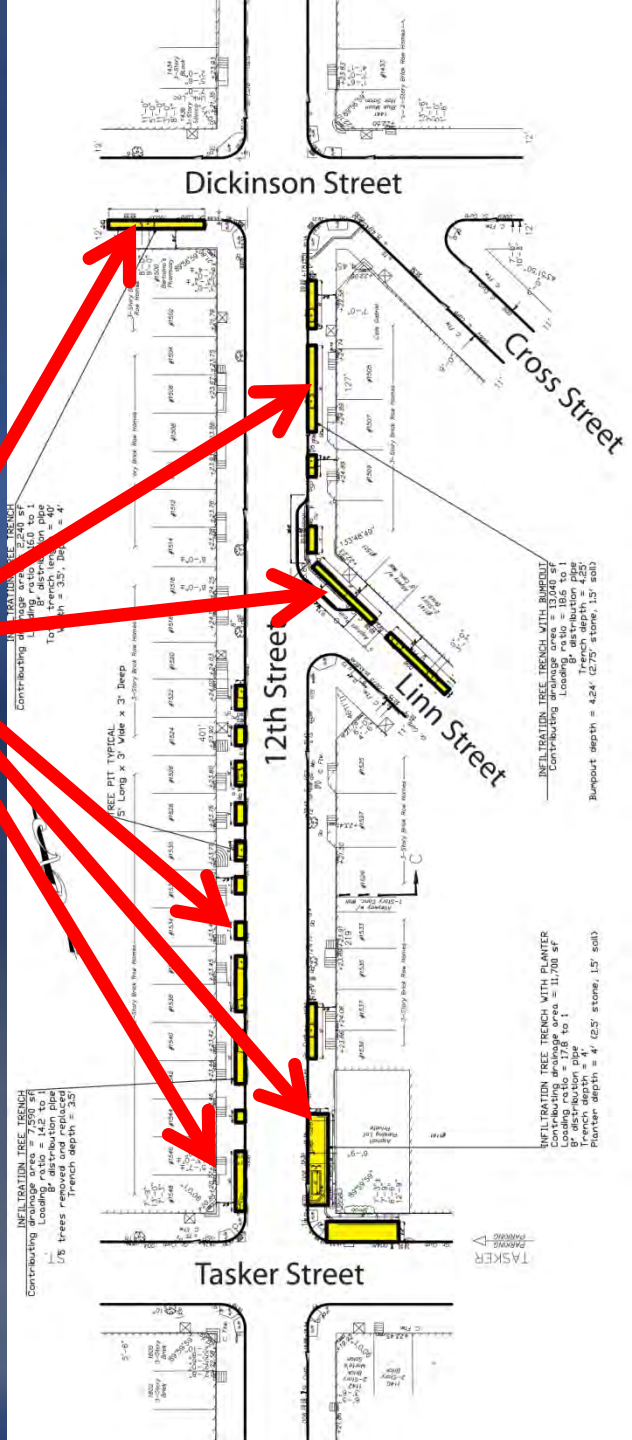
Cross-Section Location

- General flow consistent with published maps



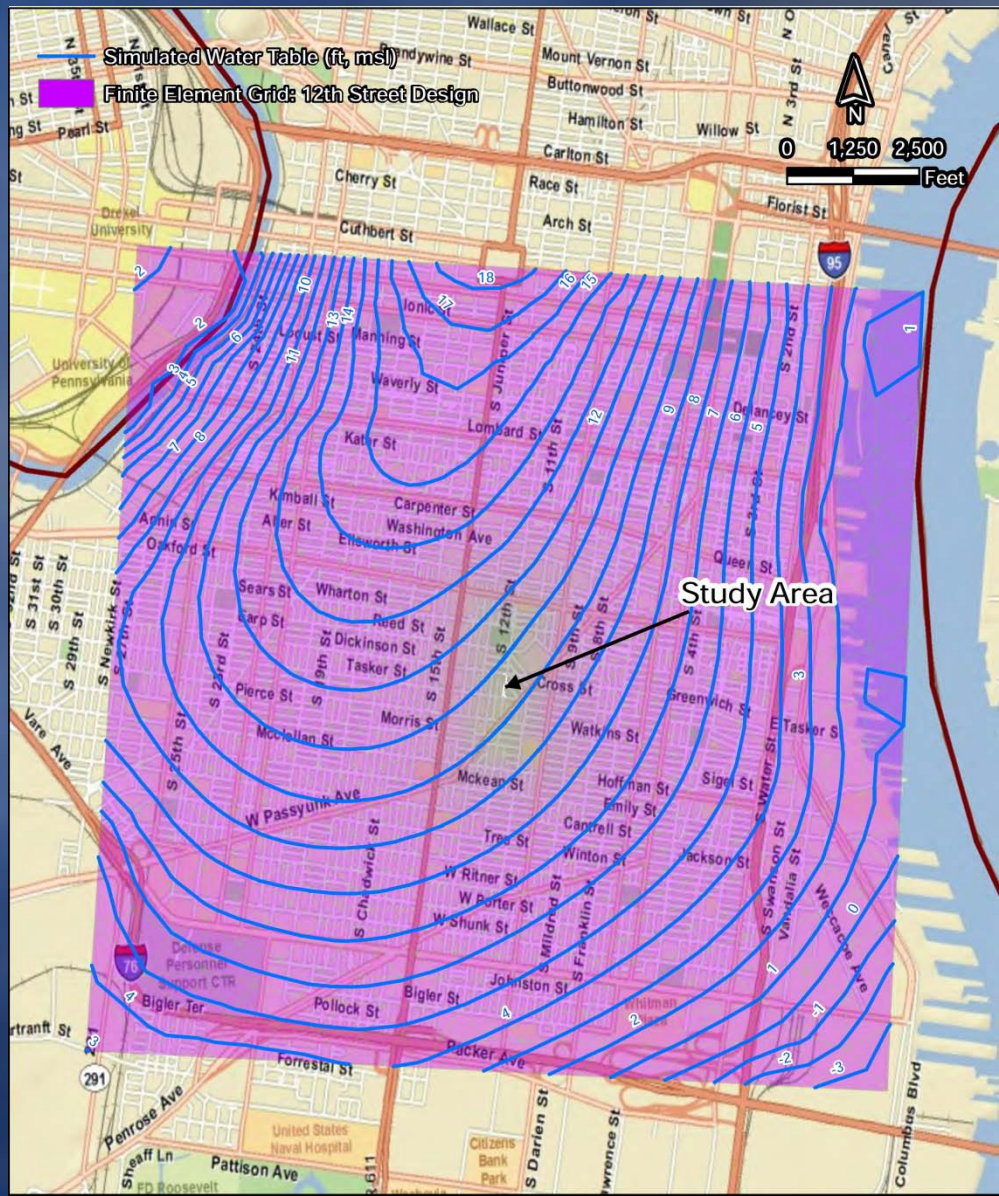
12th Street Infiltration Design



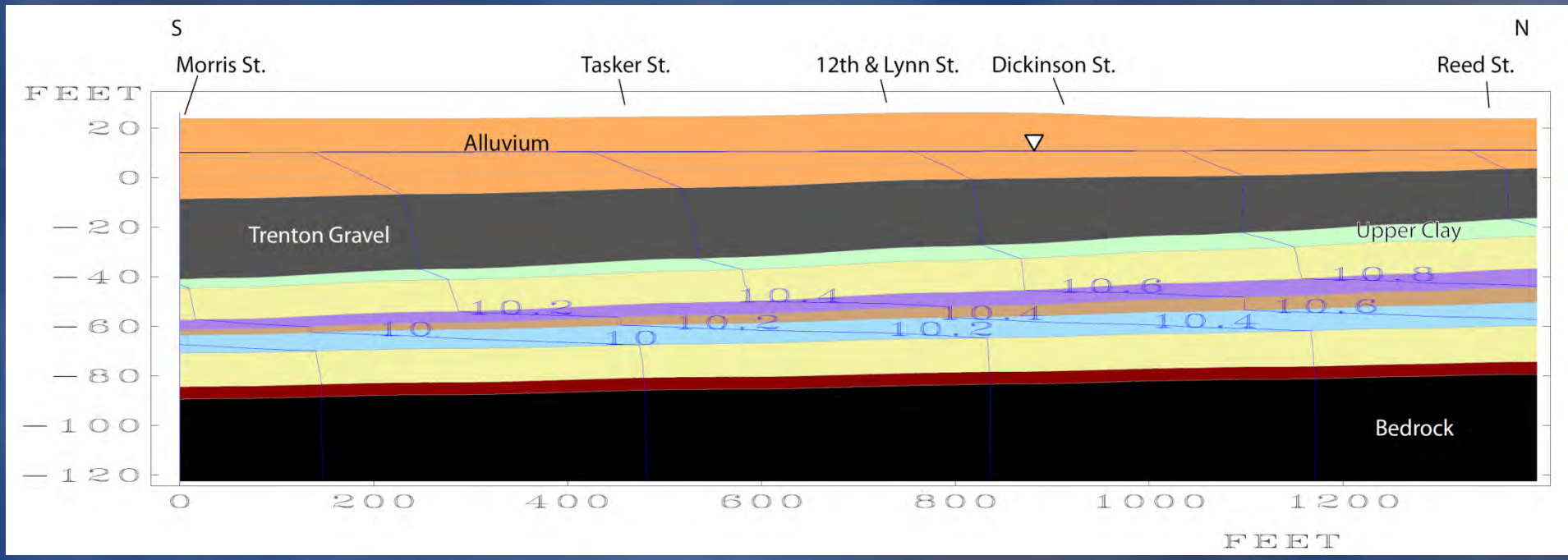


Incorporate Regional Model

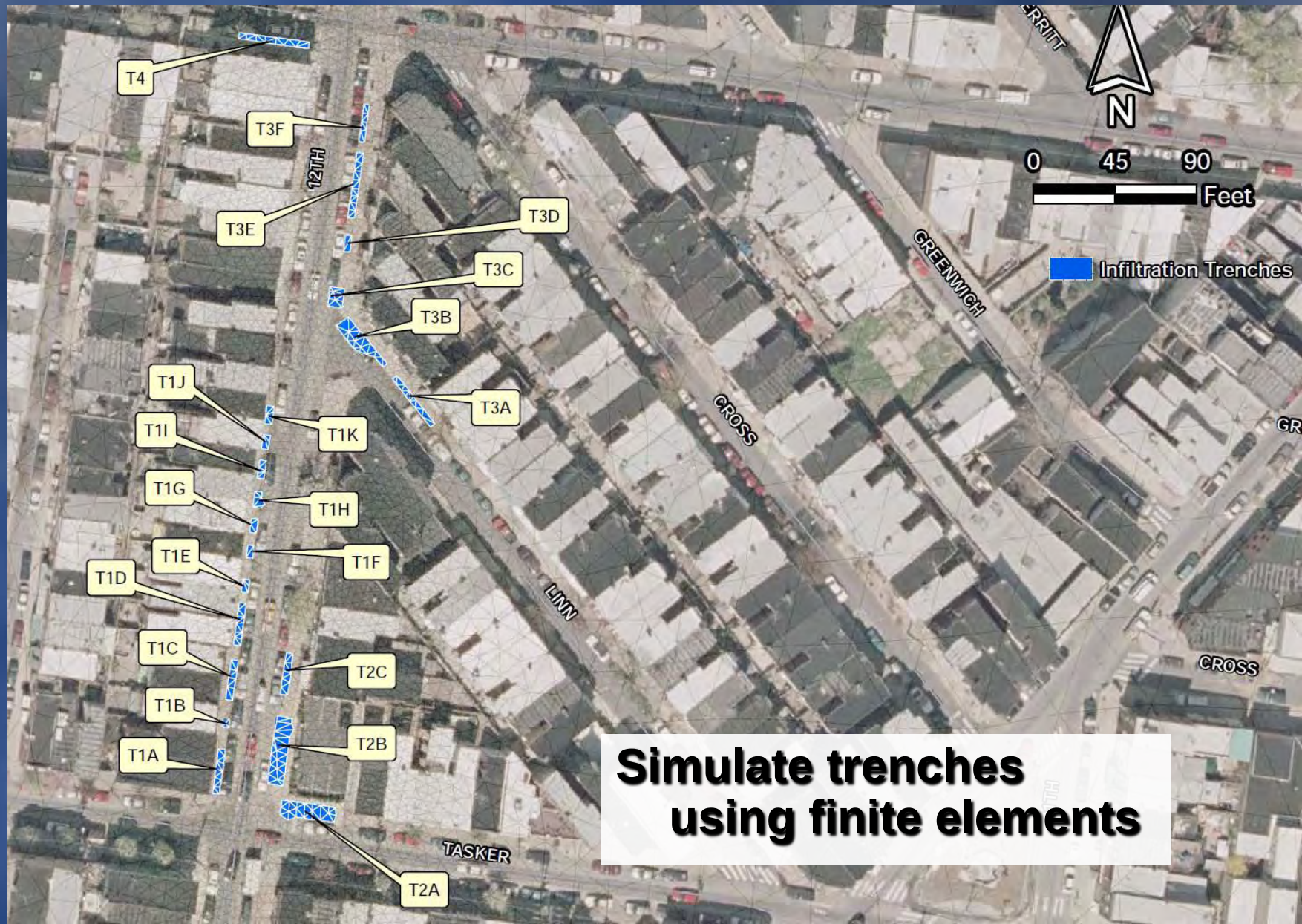
- Create sub-regional model utilizing regional model stratigraphy and boundary conditions



Stratigraphic Framework



12th Street Infiltration Trenches



Simulate trenches using finite elements

Create Model Input – Recharge File

PWDInfiltration_12thStreet_v1.xlsm - Microsoft Excel

Home Insert Page Layout Formulas Data Review View Acrobat

A2

Infiltration Rate Time Series for PWD Groundwater Model

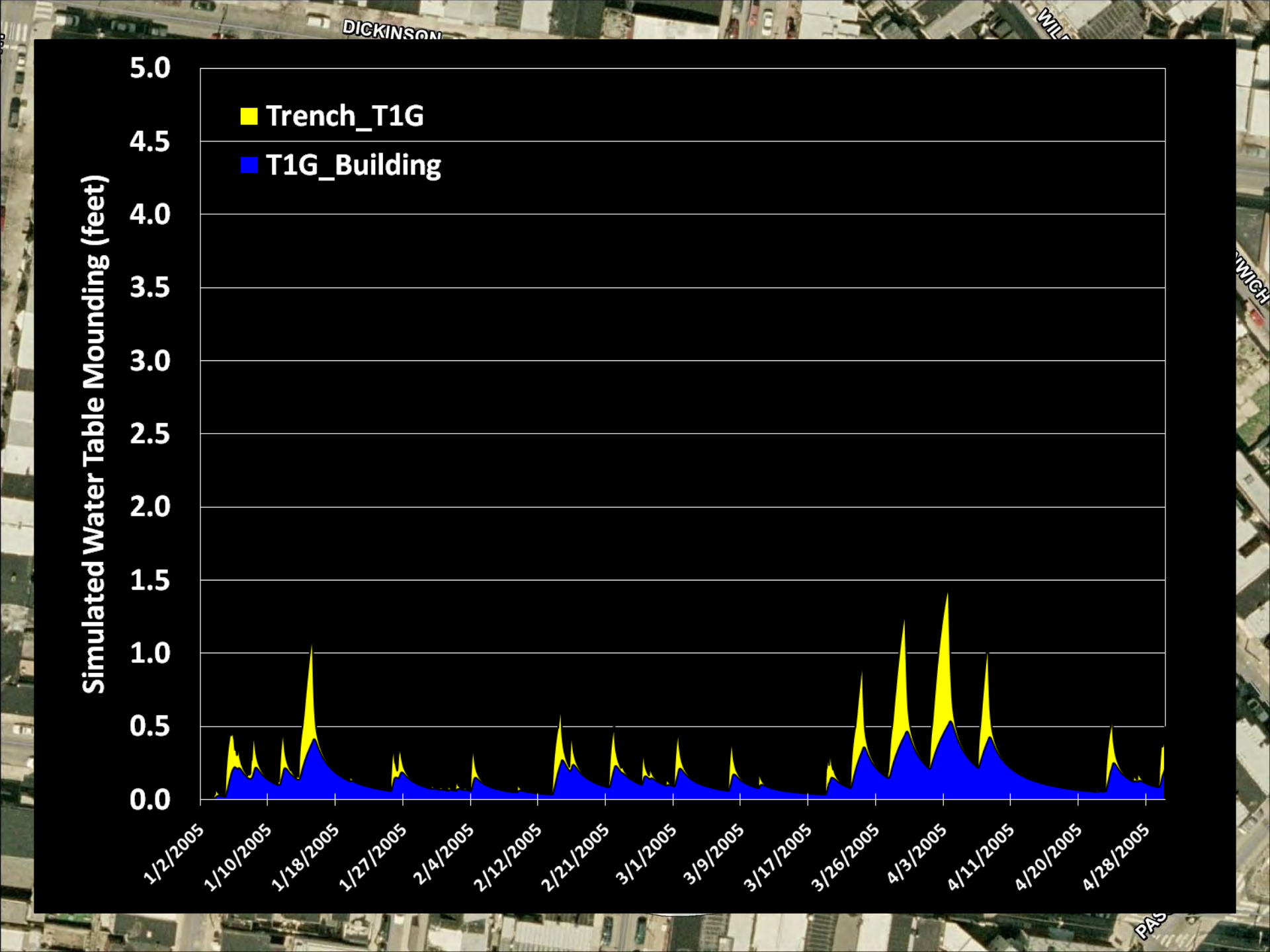
Green Infrastructure Input Data

Required Trench Volume (ft^3)	632.5	Infiltration Area (ft^2)	534.507	Trench volume (ft^3)	748.3099
Impermeable area served (ft^2)	7590	Trench Depth (ft)	3.5	Area Ratio	14.2
Vertical Hydraulic Conductivity (ft/d)	1	Infiltration Amount (ft3/time step)	5.568	Porosity	0.4

Red text is % area of each sub trench

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	
6				Trench System 1					0.186567	0.037313	0.1641791	0.171642	0.052239	0.052239	0.059701	0.067164	0.07
7	Actual Date & Tim	Time Step (hours)	**Input: Rainfall during time step (inches)**	Rainfall Volume in time step (ft^3)	Potential Volume water in trench (ft^3)	Actual Volume water in trench (ft^3)	**Model Input: Actual Infiltration Amount (ft^3/time step)**	Spill-Over (ft^3)	T1a (ft3/time step)	T1b (ft3/time step)	T1c (ft3/time step)	T1d (ft3/time step)	T1e (ft3/time step)	T1f (ft3/time step)	T1g (ft3/time step)	T1h (ft3/time step)	T1i (ft3/ step
1144	1/14/2005 9:00	284.25	0.05	31.63	644.49	644.49	5.568	0.000	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1145	1/14/2005 9:15	284.5	0.069	43.64	682.57	682.57	5.568	0.000	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1146	1/14/2005 9:30	284.75	0.03	18.98	695.97	695.97	5.568	0.000	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1147	1/14/2005 9:45	285	0.02	12.65	703.05	703.05	5.568	0.000	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1148	1/14/2005 10:00	285.25	0.03	18.98	716.46	716.46	5.568	0.000	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1149	1/14/2005 10:15	285.5	0.04	25.30	736.19	736.19	5.568	0.000	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1150	1/14/2005 10:30	285.75	0.06	37.95	748.31	748.31	5.568	20.267	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1151	1/14/2005 10:45	286	0.06	37.95	748.31	748.31	5.568	32.382	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1152	1/14/2005 11:00	286.25	0.04	25.30	748.31	748.31	5.568	19.732	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1153	1/14/2005 11:15	286.5	0.04	25.30	748.31	748.31	5.568	19.732	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1154	1/14/2005 11:30	286.75	0.04	25.30	748.31	748.31	5.568	19.732	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1155	1/14/2005 11:45	287	0.02	12.65	748.31	748.31	5.568	7.082	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1156	1/14/2005 12:00	287.25	0.02	12.65	748.31	748.31	5.568	7.082	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1157	1/14/2005 12:15	287.5	0.03	18.98	748.31	748.31	5.568	13.407	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1158	1/14/2005 12:30	287.75	0.02	12.65	748.31	748.31	5.568	7.082	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1159	1/14/2005 12:45	288	0	0.00	742.74	742.74	5.568	0.000	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1160	1/14/2005 13:00	288.25	0	0.00	737.17	737.17	5.568	0.000	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1161	1/14/2005 13:15	288.5	0	0.00	731.61	731.61	5.568	0.000	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1162	1/14/2005 13:30	288.75	0	0.00	726.04	726.04	5.568	0.000	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0
1163	1/14/2005 13:45	289	0	0.00	720.47	720.47	5.568	0.000	1.0388	0.2078	0.9141	0.9557	0.2909	0.2909	0.3324	0.3740	0

Data_T1 Data_T2 Data_T3 Data_T4 Sheet1 GAGE


Trench_T1G
T1G_Building
Simulated Water Table Mounding (feet)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1/2/2005
1/10/2005
1/18/2005
1/27/2005
2/4/2005
2/12/2005
2/21/2005
3/1/2005
3/9/2005
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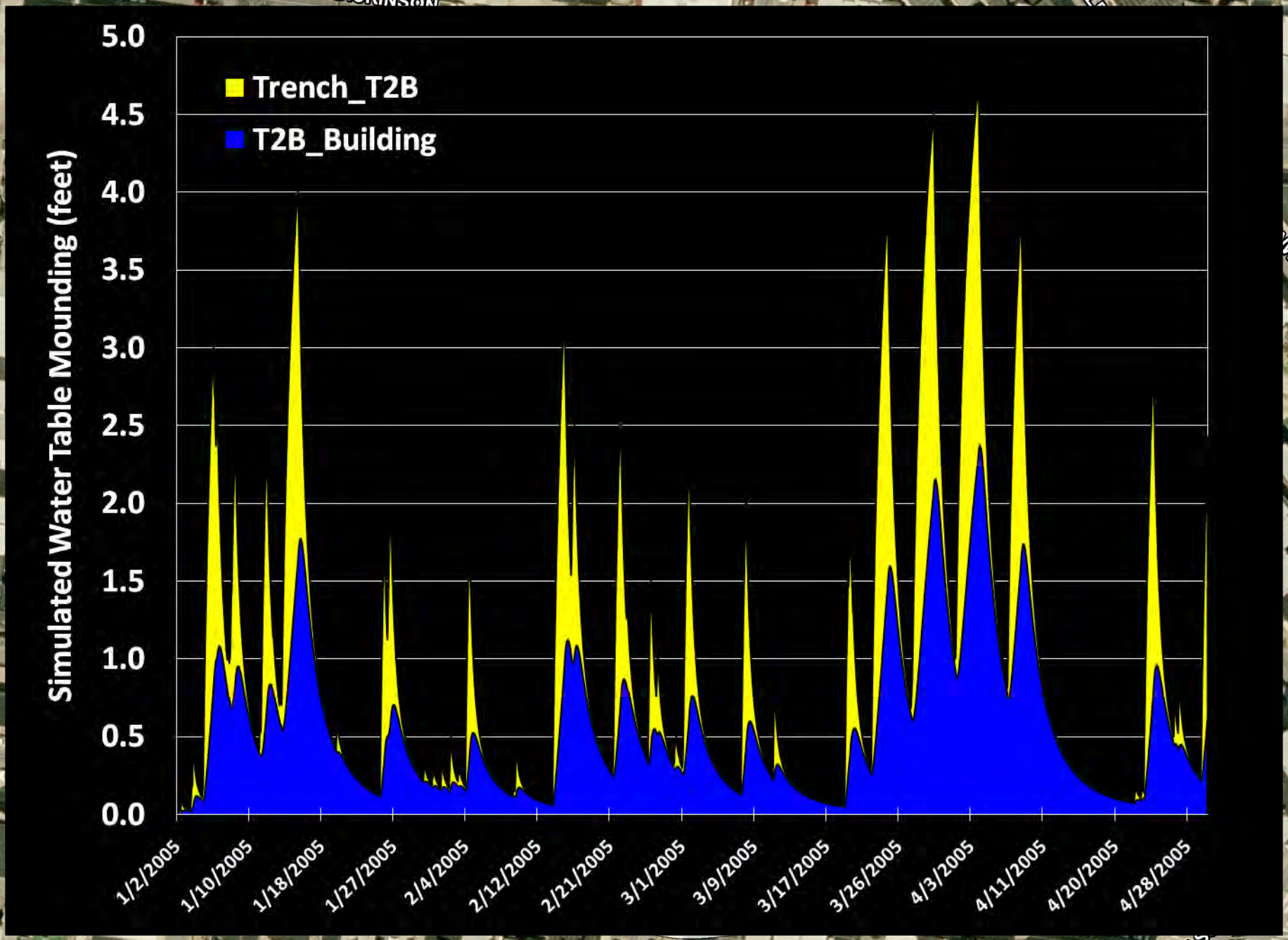
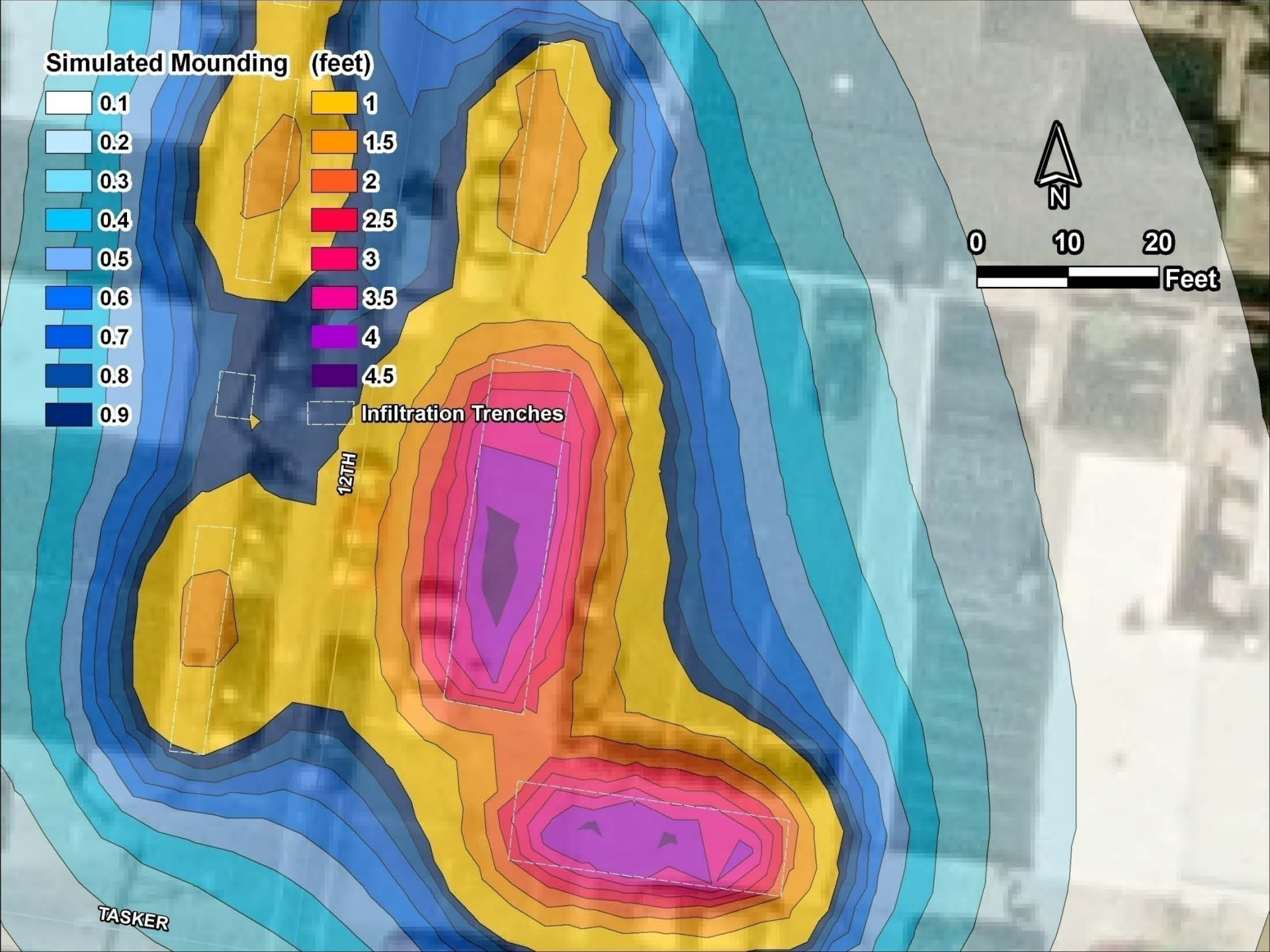
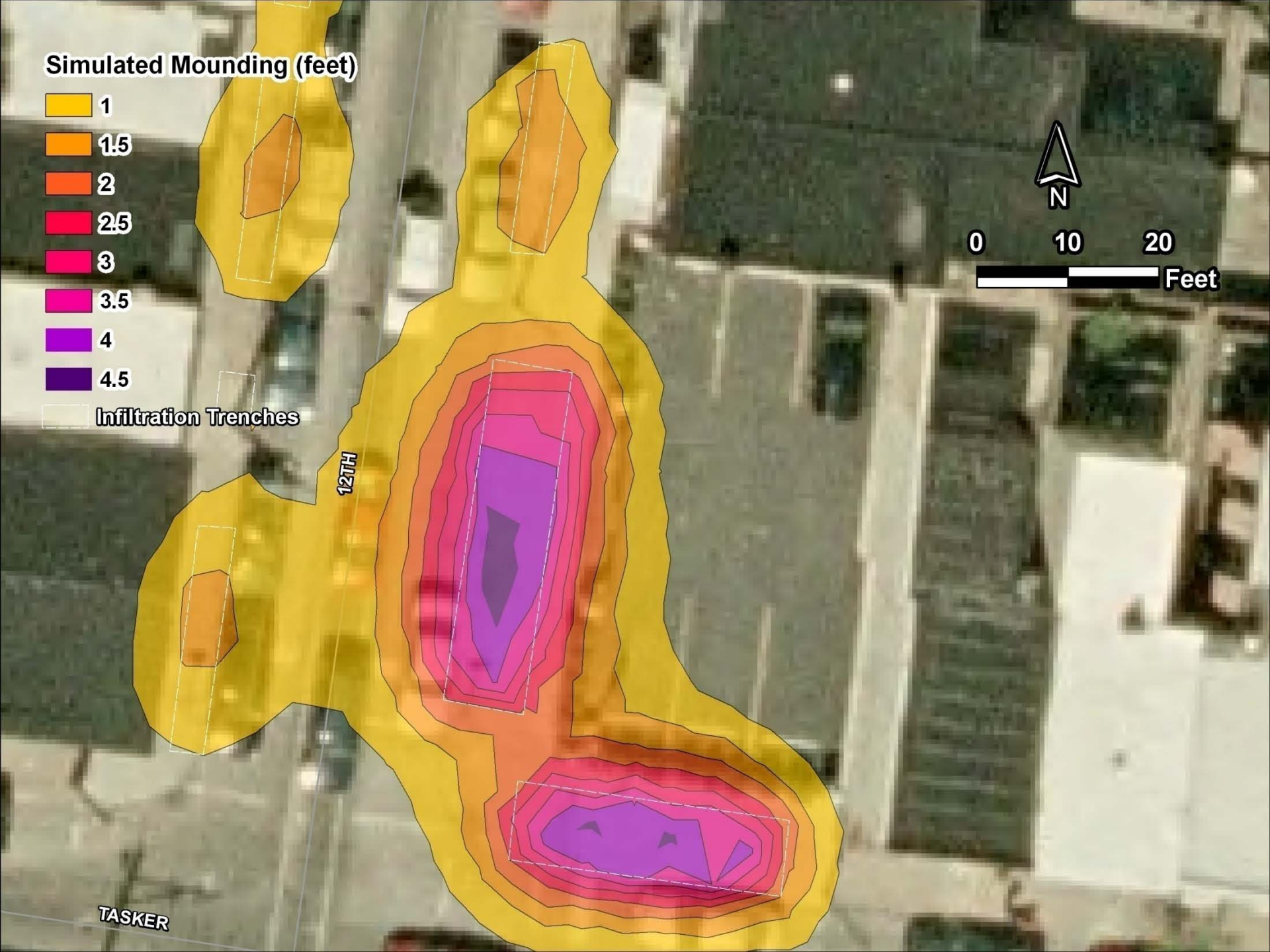
4/3/2005
4/11/2005
4/20/2005
4/28/2005


Trench_T2B
T2B_Building
Simulated Water Table Mounding (feet)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1/2/2005
1/10/2005
1/18/2005
1/27/2005
2/4/2005
2/12/2005
2/21/2005
3/1/2005
3/9/2005
3/17/2005
3/26/2005
4/3/2005
4/11/2005
4/20/2005
4/28/2005


Simulated Mounding (feet)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.5
2
2.5
3
3.5
4
4.5
Infiltration Trenches
DICKINSON
WILDER
GREENWICH
CROSS
CAMAC
12TH
TASKER
PASSYUNK
N
0
50
100
Feet
Trench_T1G
T1G_Building
Simulated Water Table Mounding (feet)
Trench_T2B
T2B_Building
Simulated Water Table Mounding (feet)

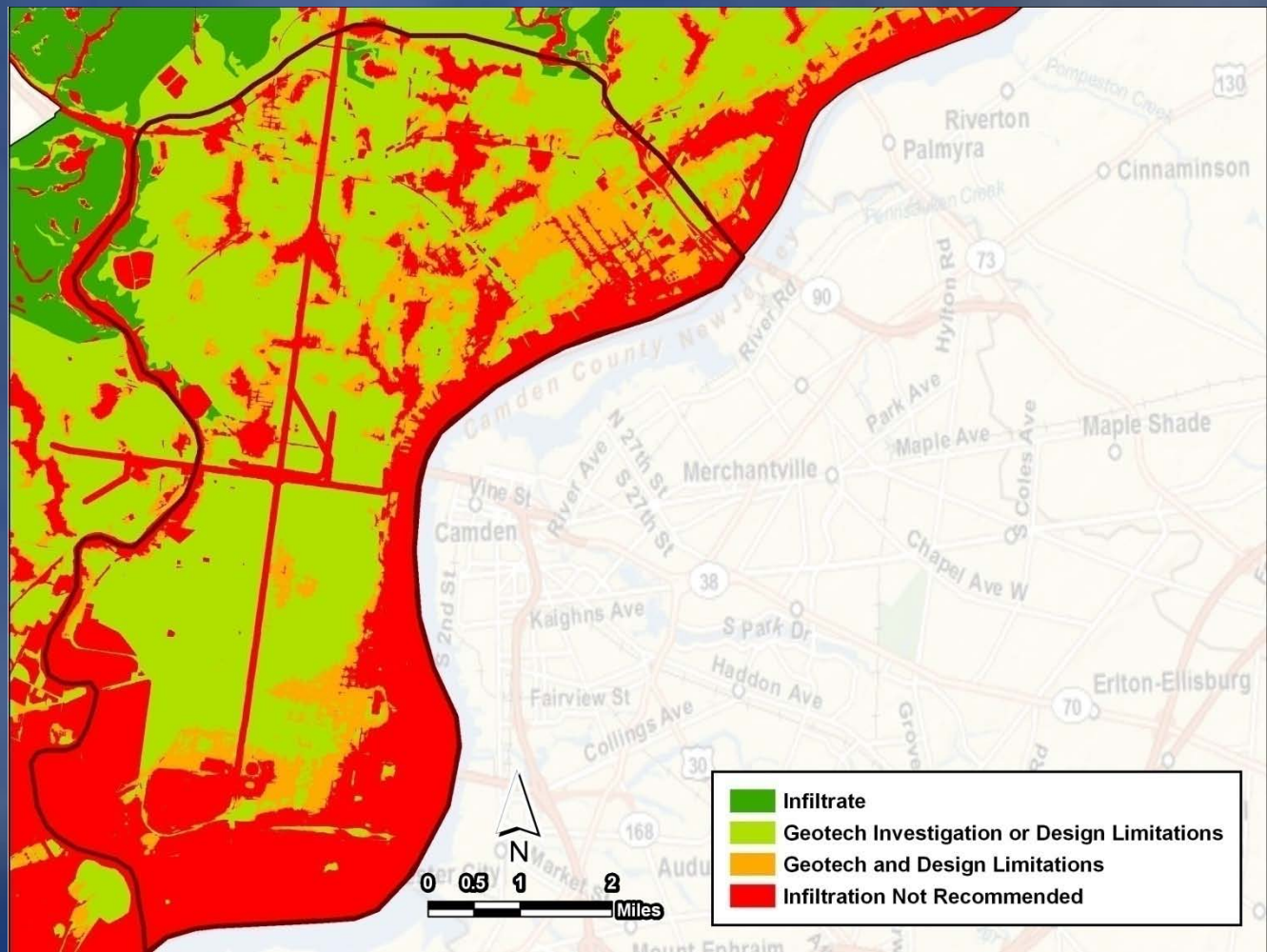

Simulated Mounding (feet)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.5
2
2.5
3
3.5
4
4.5
Infiltration Trenches
12TH
TASKER
N
0
10
20
Feet


Simulated Mounding (feet)
1
1.5
2
2.5
3
3.5
4
4.5
Infiltration Trenches
N
0
10
20
Feet
12TH
TASKER

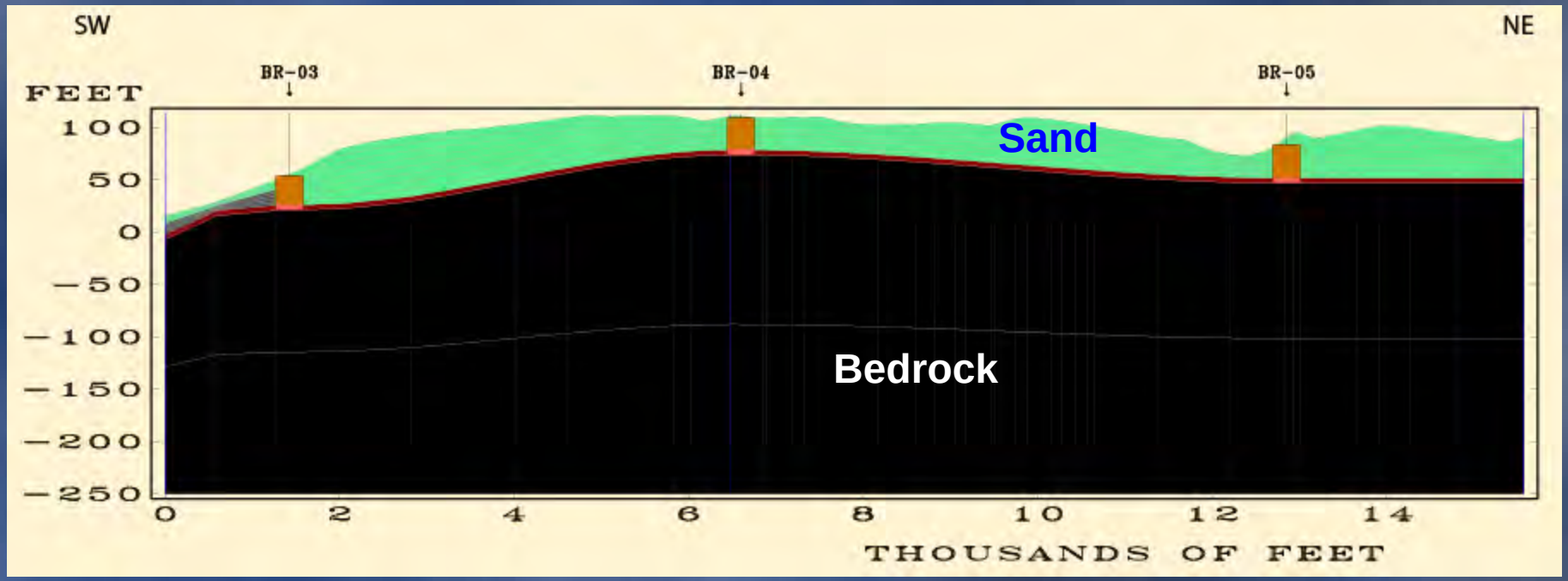

N
0
10
20
Feet
Infiltration Trenches
12TH
TASKER

Hydraulic Impacts

- Site specific



Cross-Section through Piedmont



- Sand layer overlaying bedrock
- Transmissivity is limited
- Mounding may be more problematic

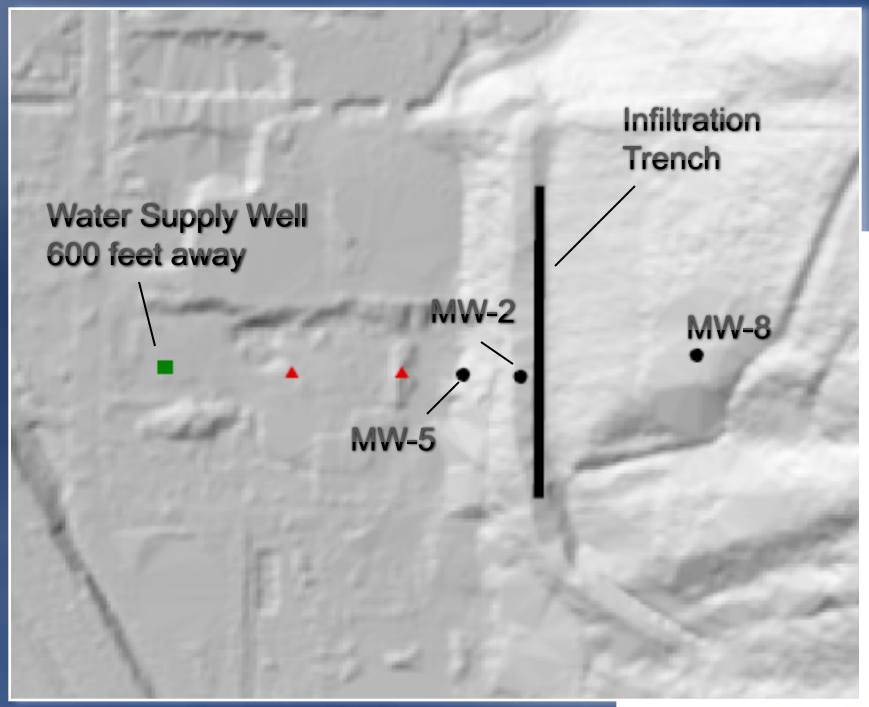
Hydraulic Impacts

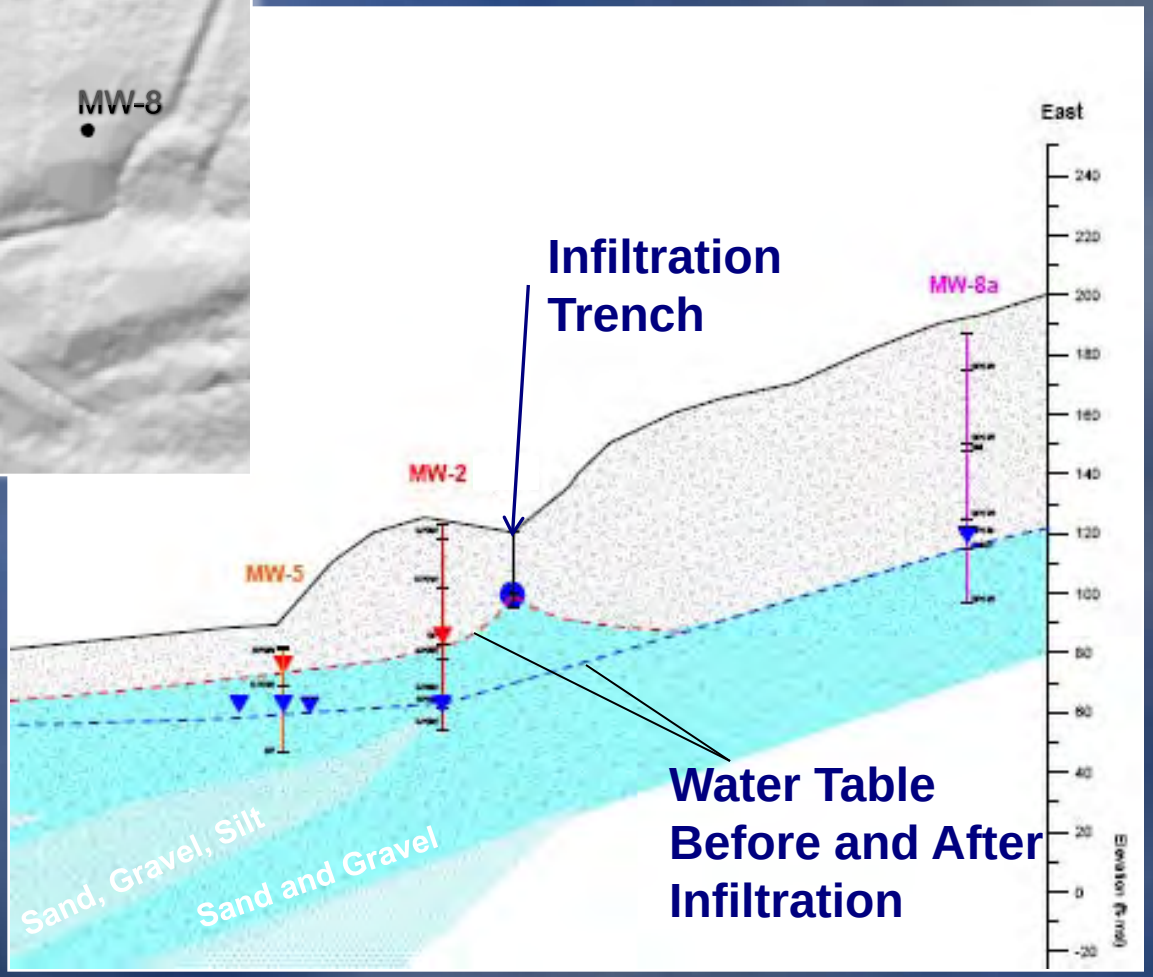
- Site specific
- Need more detailed information on stratigraphic framework, groundwater head and pumpage throughout Philadelphia
- Model results indicate that mounding not a major issue, in general, but need to be careful how basins are designed as mounding overlap may be an issue locally

Storm Water Infiltration – Groundwater Quality Considerations

- Case Study – Washington State
- Infiltration trench used for stormwater capture
- Sand and gravel aquifer (Kh = 200 – 500 f/d)
- Inflow rates as high as 10 CFS
- Water supply well 600 feet away
- Concerns about downgradient water quality impacts
  - Particularly pathogens
- Groundwater modeling to evaluate mounding and travel time to supply well

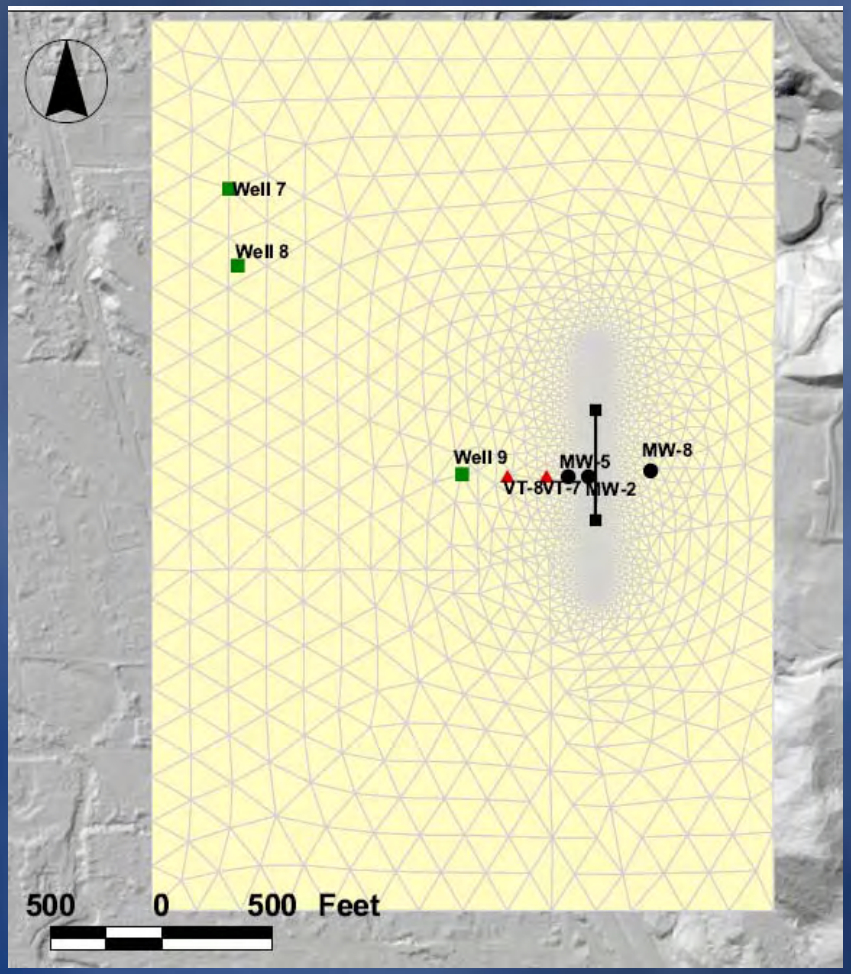
Site Conditions



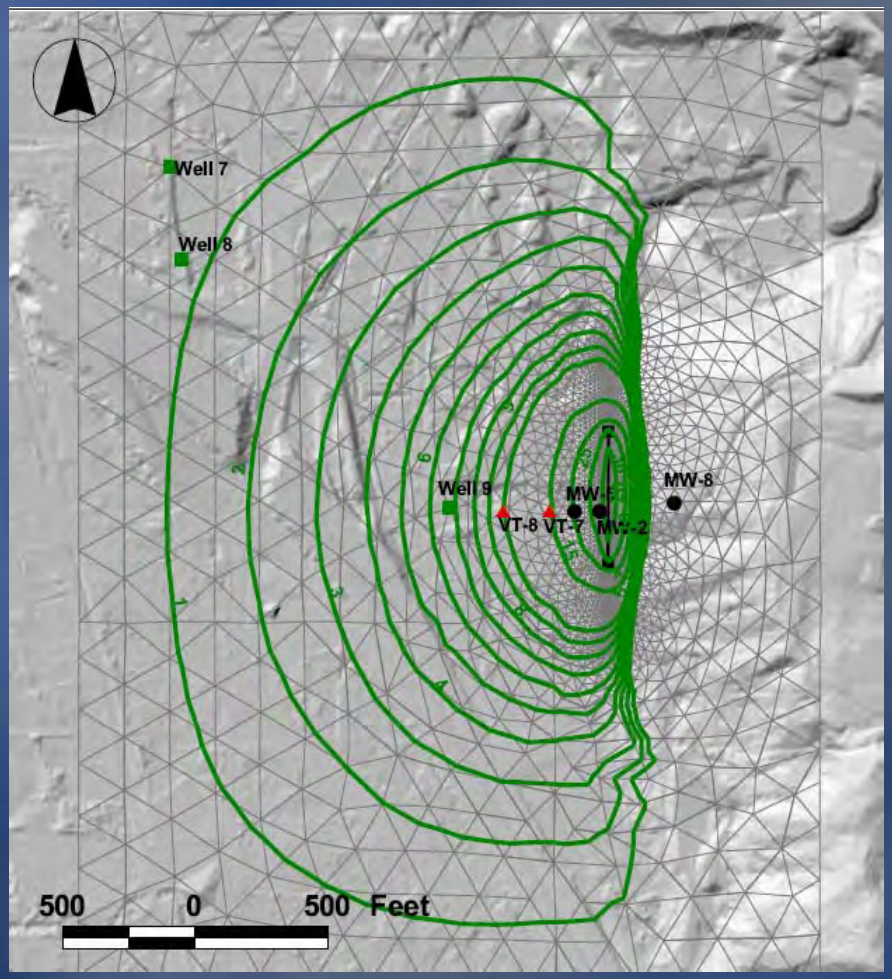


Model Simulation Results - Mounding

Model Grid

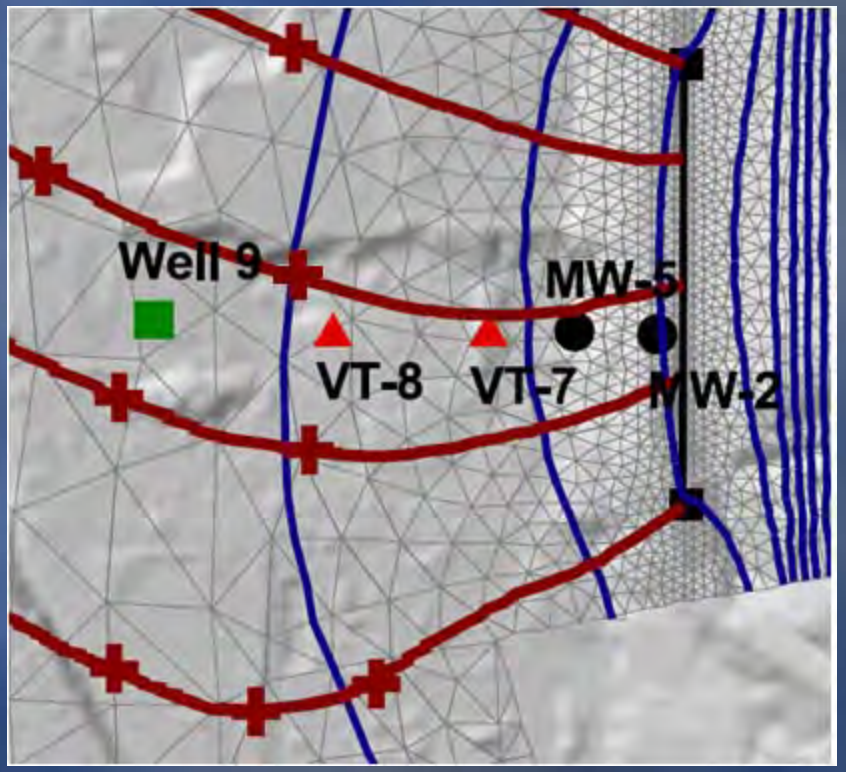


Simulated Head Rise After 7 Days

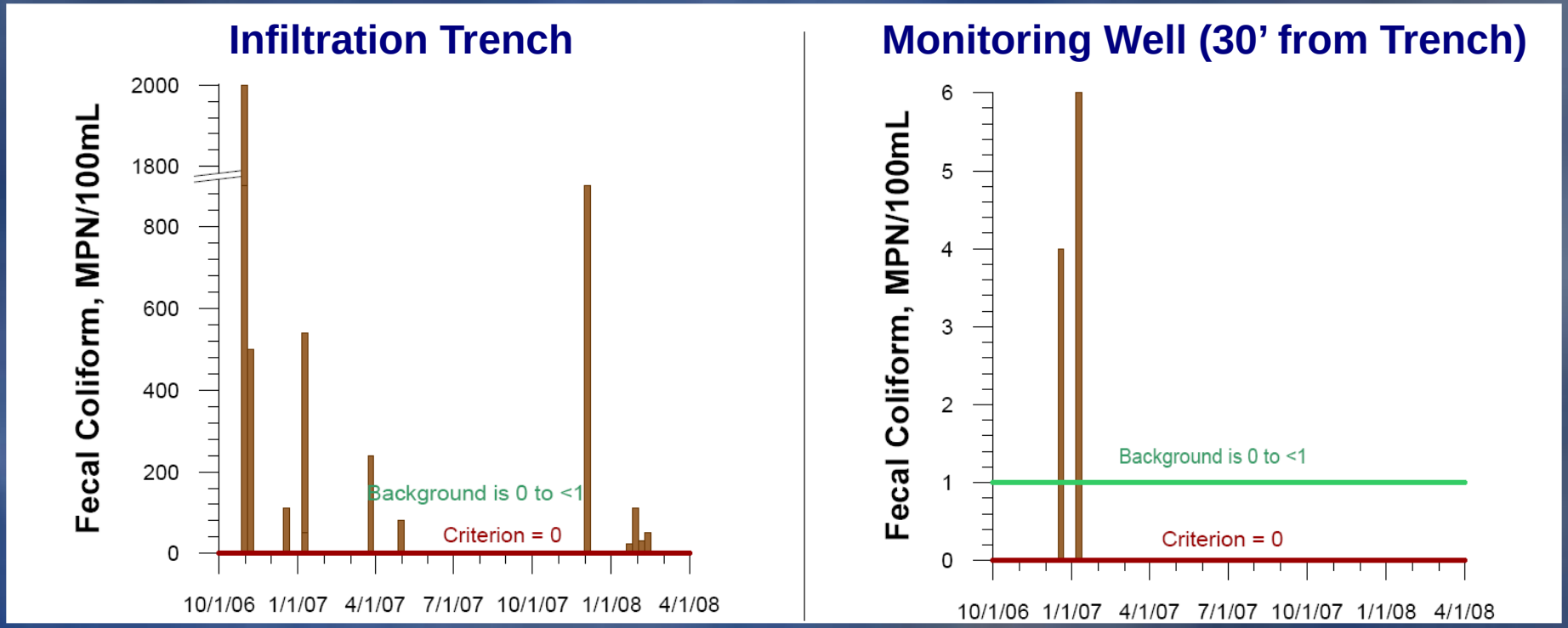


Model Simulation Results - Transport

- Travel time to closest supply well 1-2 months
- Supply well pumps infrequently



Water Quality Impacts



Future Goals

- Parties agreed to:
  - Reduce trench inflows
  - Maintain sufficient unsaturated zone thickness
  - Monitor groundwater quality
- Goals
  - Control of pathogens
  - Sustainable groundwater resource

How the Groundwater Model Helped

- Gain better understanding of the trench/aquifer relationship
- Characterize the vulnerability of receptors
- Guide the design of an effective monitoring program

Future Considerations

- Implementation of stormwater BMP will continue to grow over the coming decades
- Care must be taken on a site-by-site basis to ensure that groundwater sustainability is considered
- Groundwater investigations may be vital to the successful implementation of such a project
  - Geologic borings
  - Long term water level monitoring

Thank You

- Questions?

- Contact Info
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