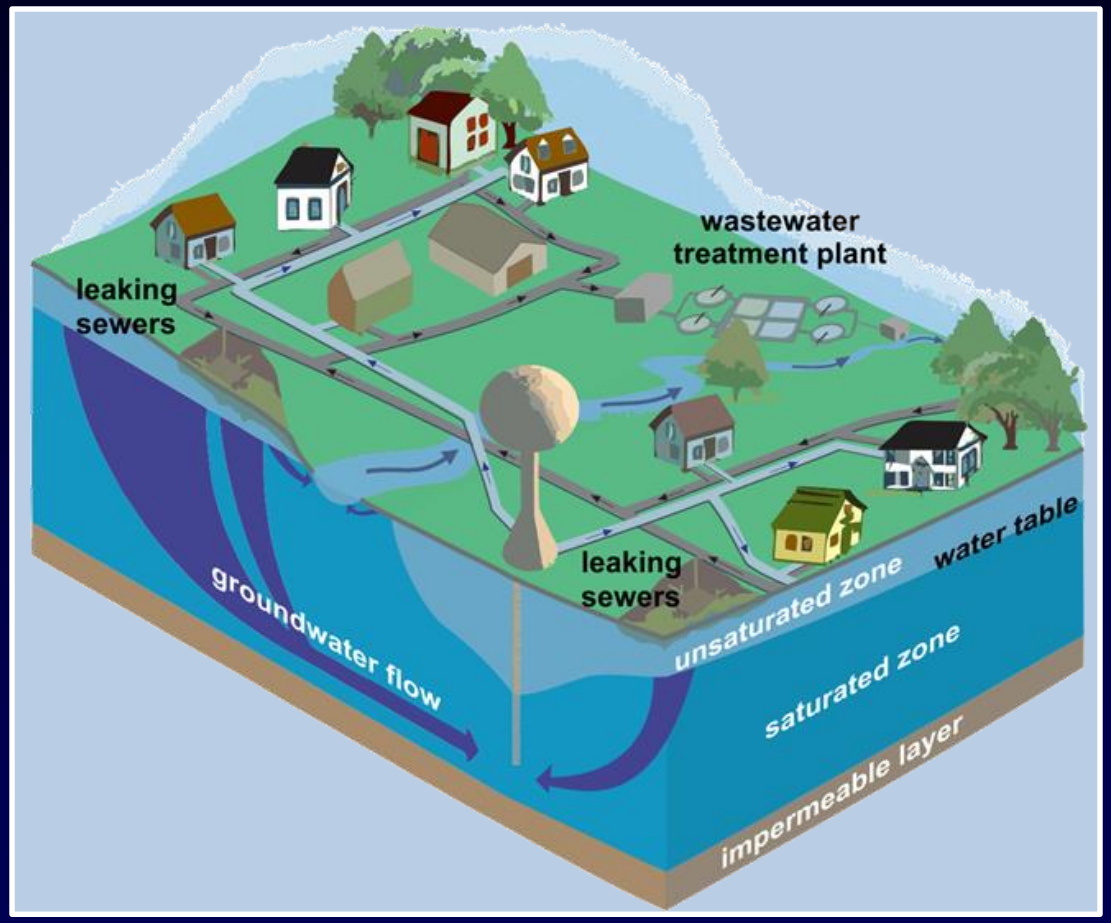
Effects of Precipitation on Virus Presence in Groundwater



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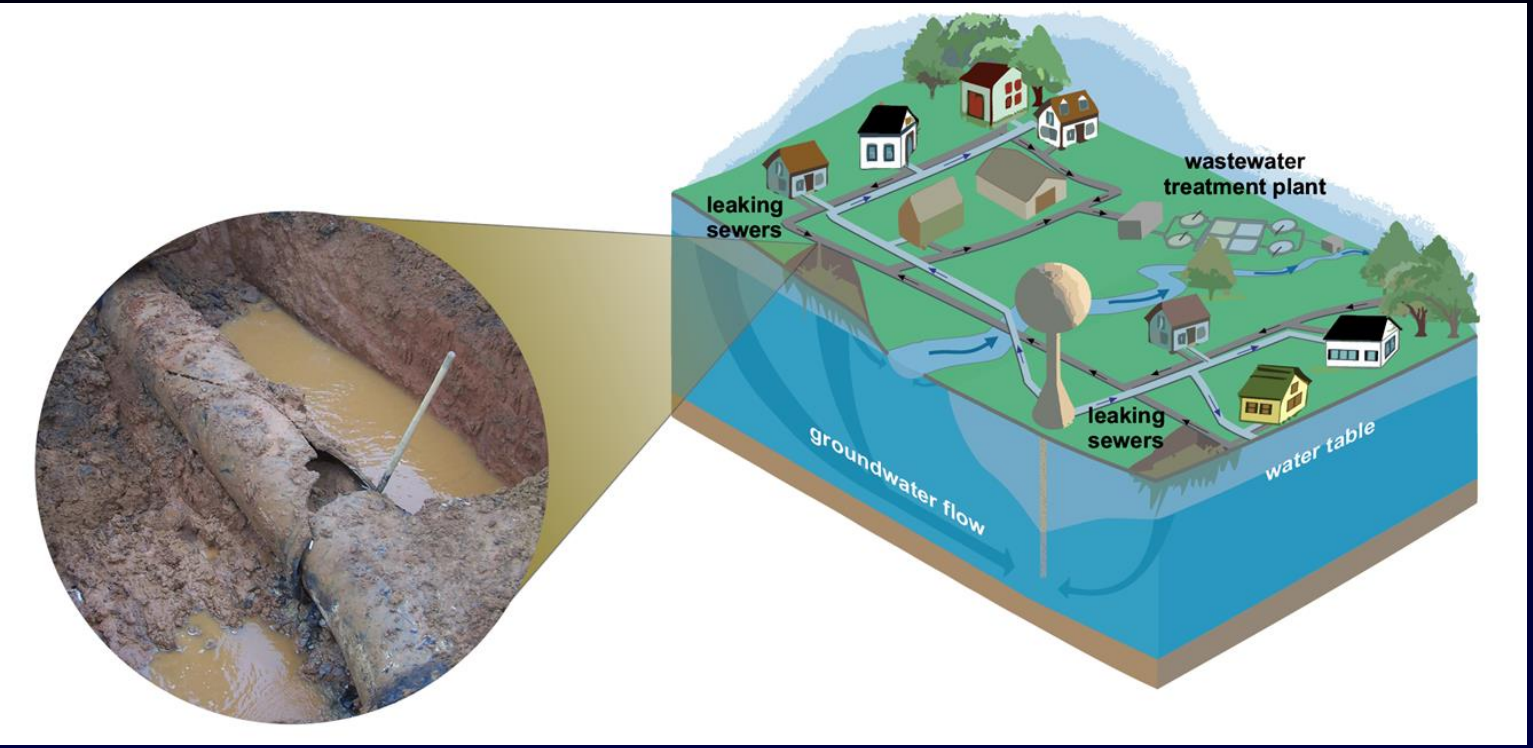
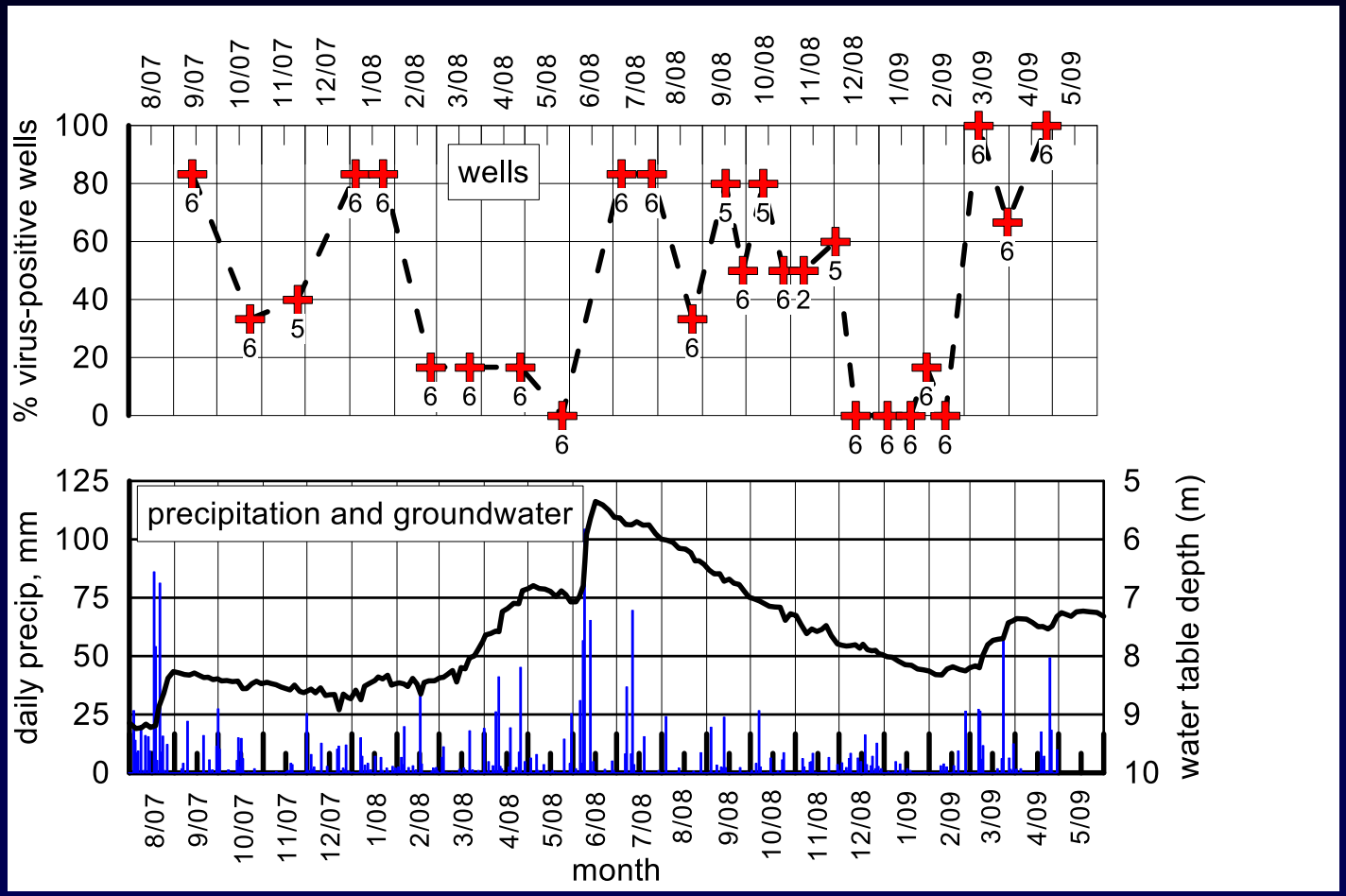


- *Municipal water supply systems using groundwater are not required to disinfect*
- *Pathogens in drinking water are a risk to human health; AGI incidence is higher for children served by untreated municipal supplies*

Brunkard et al., 2011; Borchardt et al., 2012; Ueijo et al., 2014

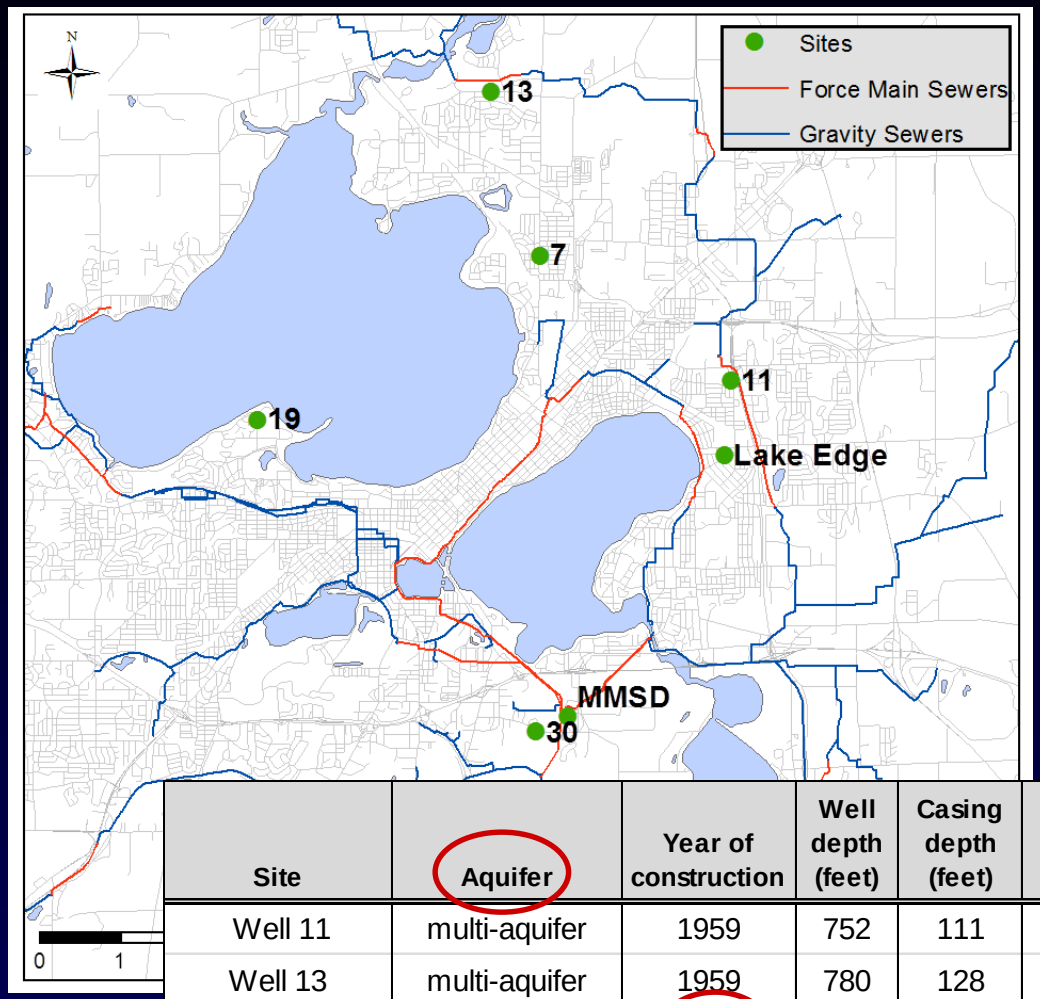
2008 study: 46% of samples from six deep wells were virus positive and temporally correlated



Bradbury et al. 2013, ES&T

2012 study goals

- *Quantify the temporal and spatial distribution of viruses and bacteria in groundwater*
- *Is there a relationship between virus detections and conditions of near-by sewers?*

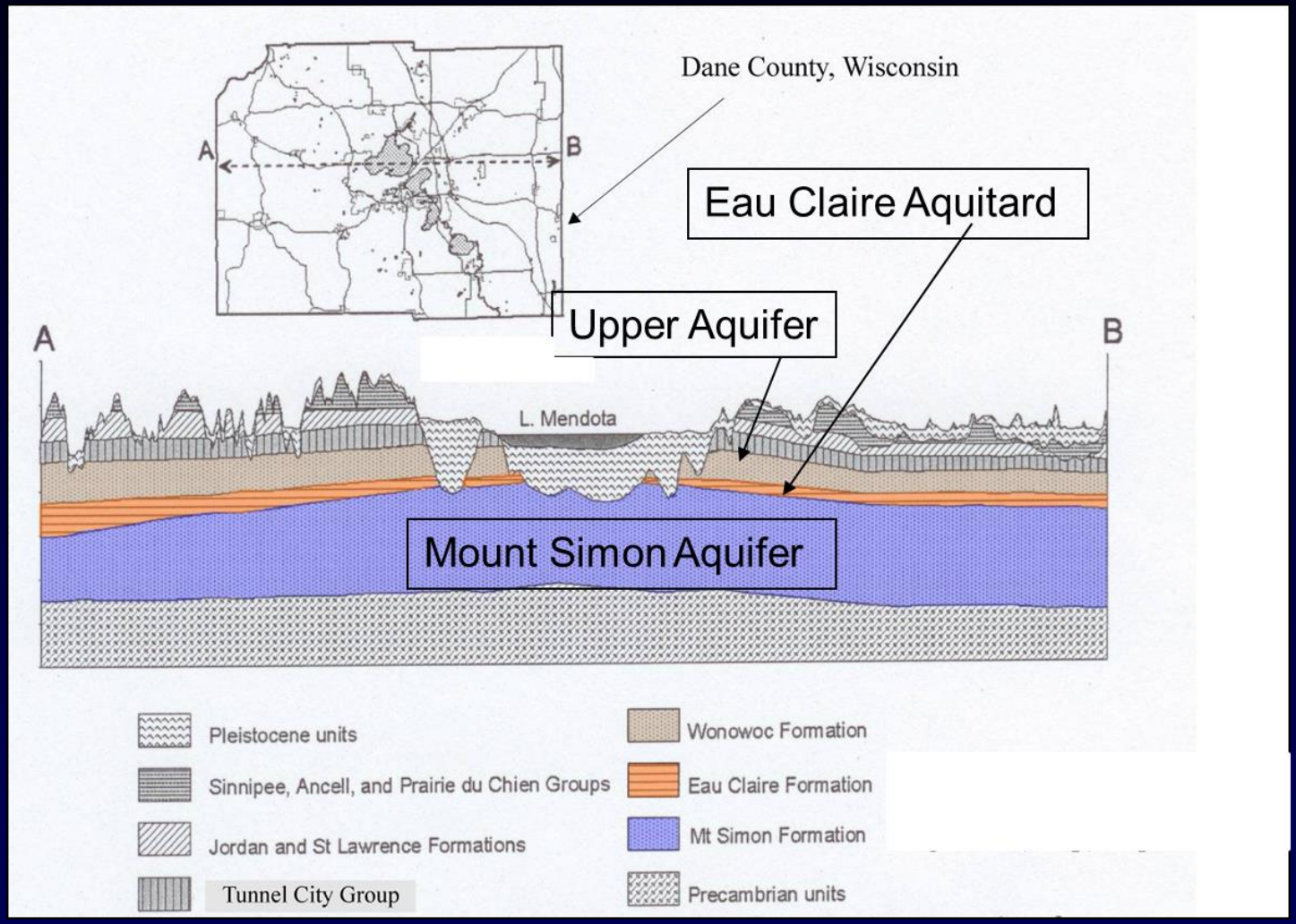


Study design

- *Six sites at public supply wells*
- *Seventh site is a "control" site*

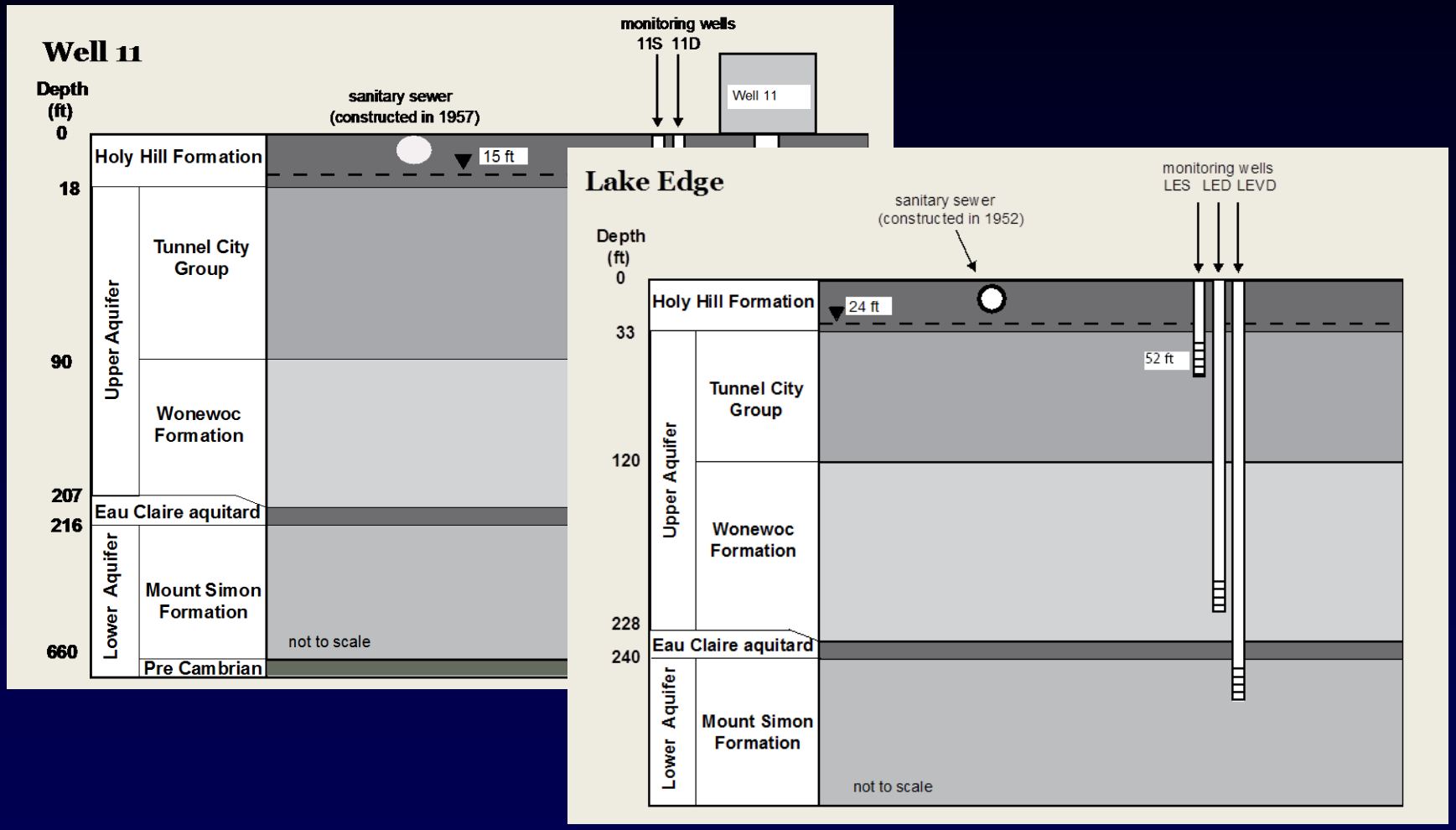
Site	Aquifer	Year of construction	Well depth (feet)	Casing depth (feet)	Sewer Age	Sewer Material	Tritium (TUs)	Chloride (mg/L)	Nitrate (mg/L)
Well 11	multi-aquifer	1959	752	111	1957	clay	5.5	44.2	2.5
Well 13	multi-aquifer	1959	780	128	1958	clay	1.6	7.8	1.7
Well 7	confined	1939	736	238	1939	clay	5.1	11.6	<0.1
Well 19	confined	1970	710	260	1960	clay	3.7	4.4	<0.1
Well 30	confined	2003	800	312	1997	plastic	0.4	3.6	<0.1
FB Well 11	confined	2007	1000	402	2000	plastic	0.04	2.4	<0.1
Lake Edge	NA	NA	NA	NA	1952	clay	6	9.2	1.5

Hydrogeology



From Massie-Ferch 1997

Sites and monitoring network

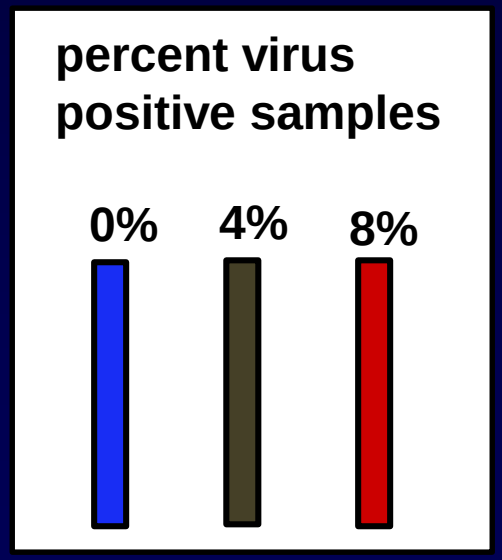


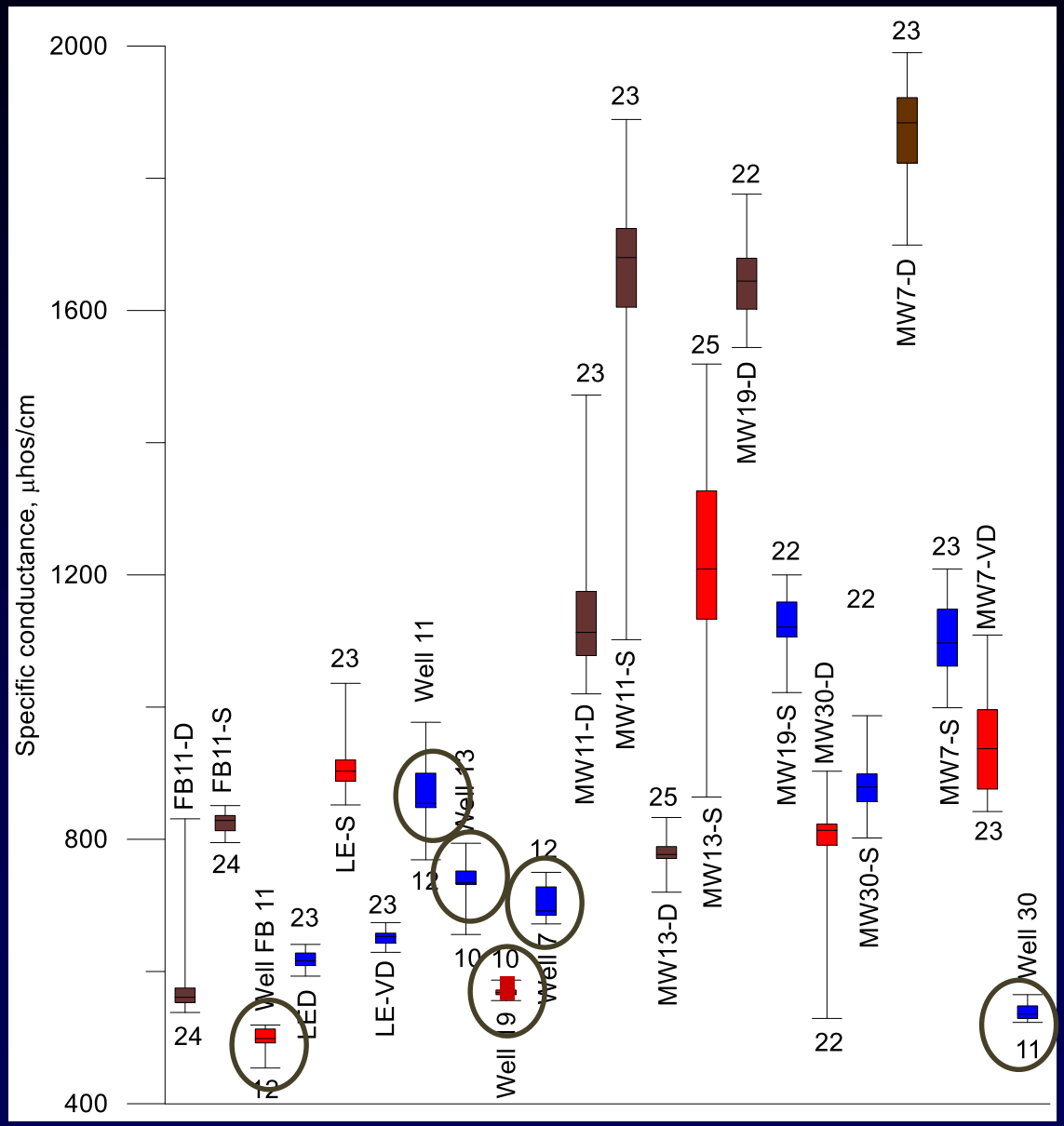
Urban and suburban locations

Results: seven sites have similar virus detection rates

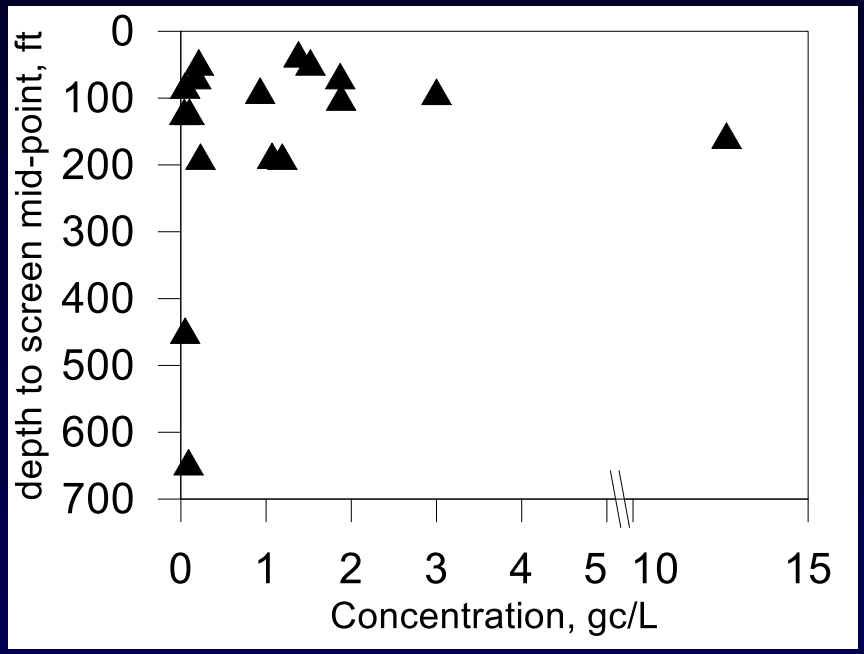
Site name	Virus positive samples, percent	Number of virus positive samples	Number of samples	Sanitary sewer density in 1-year capture zone
Lake Edge	3	2	72	0.004
11	3	2	60	0.003
13	5	3	59	0.003
19	3	2	60	0.001
30	3	2	60	0.001
7	4	3	84	0.003
FB11*	5	3	60	0.001

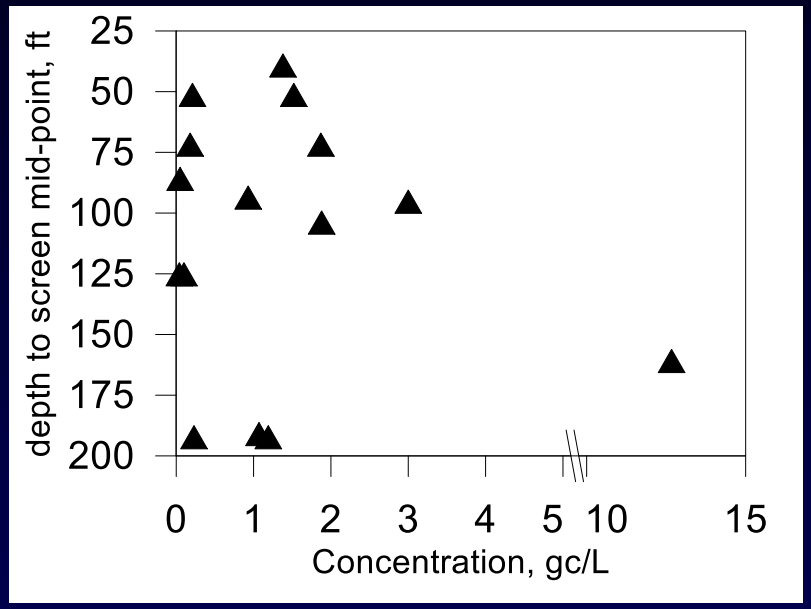
Wells with elevated conductivity were virus positive





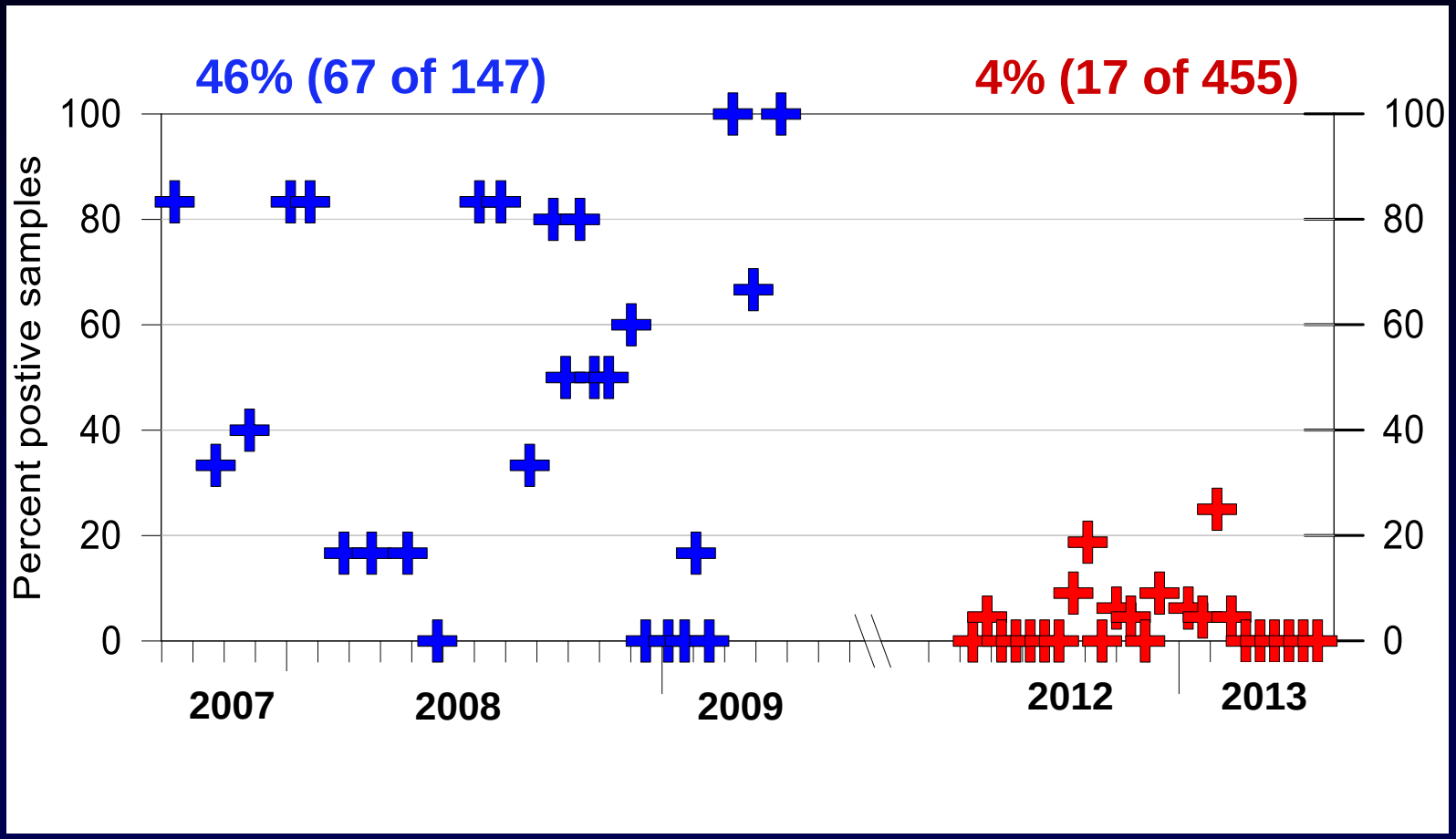
Shallow wells have higher virus concentrations



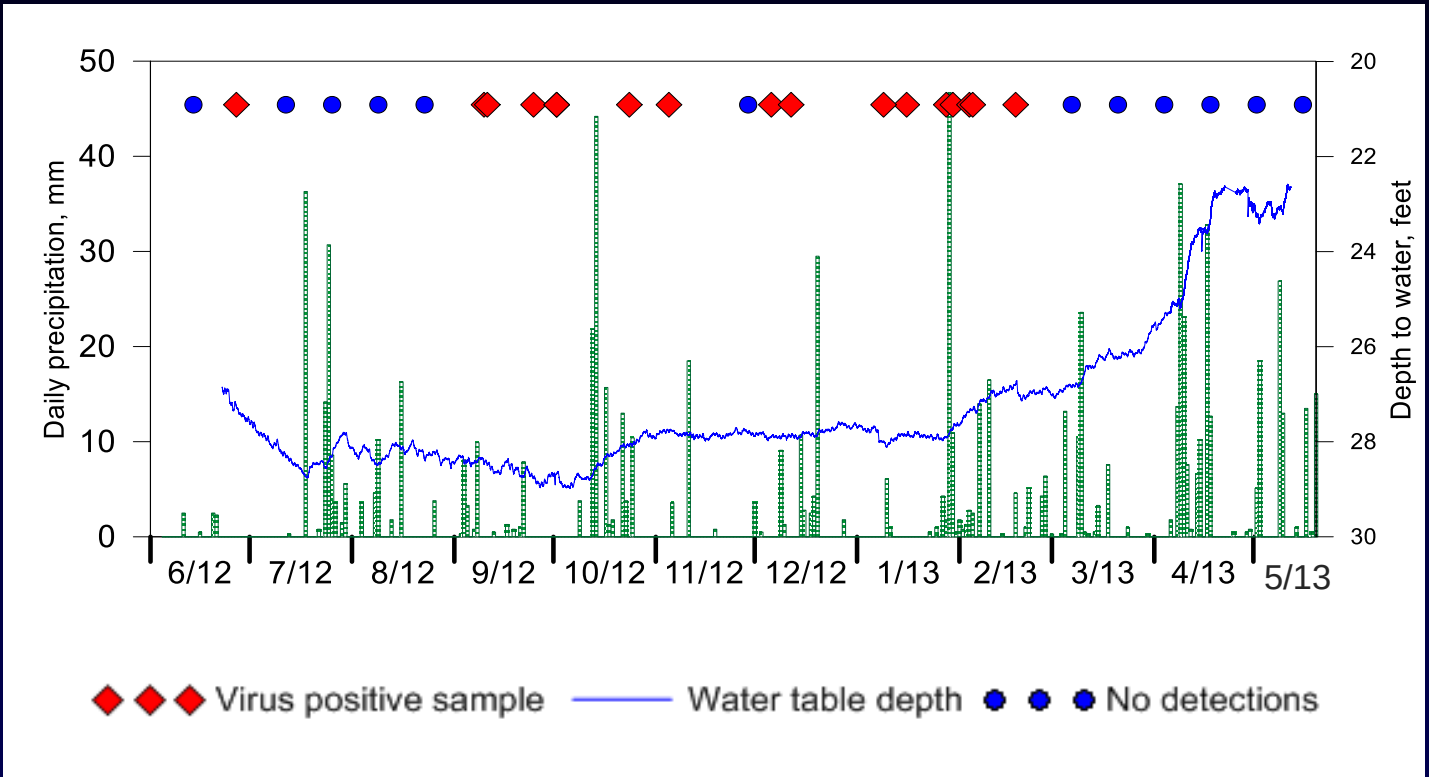


Graphs show virus-positive samples only

2012 virus detection rate was low

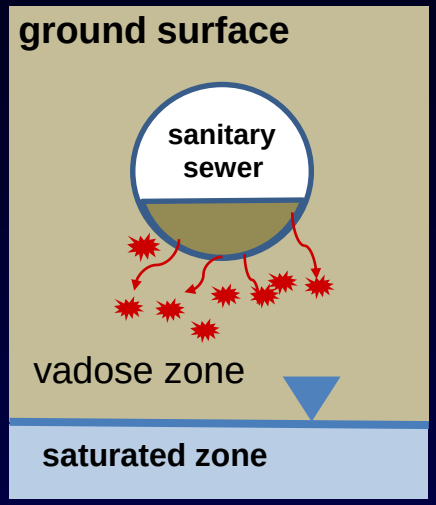


Climate affects virus transport from sewers to groundwater

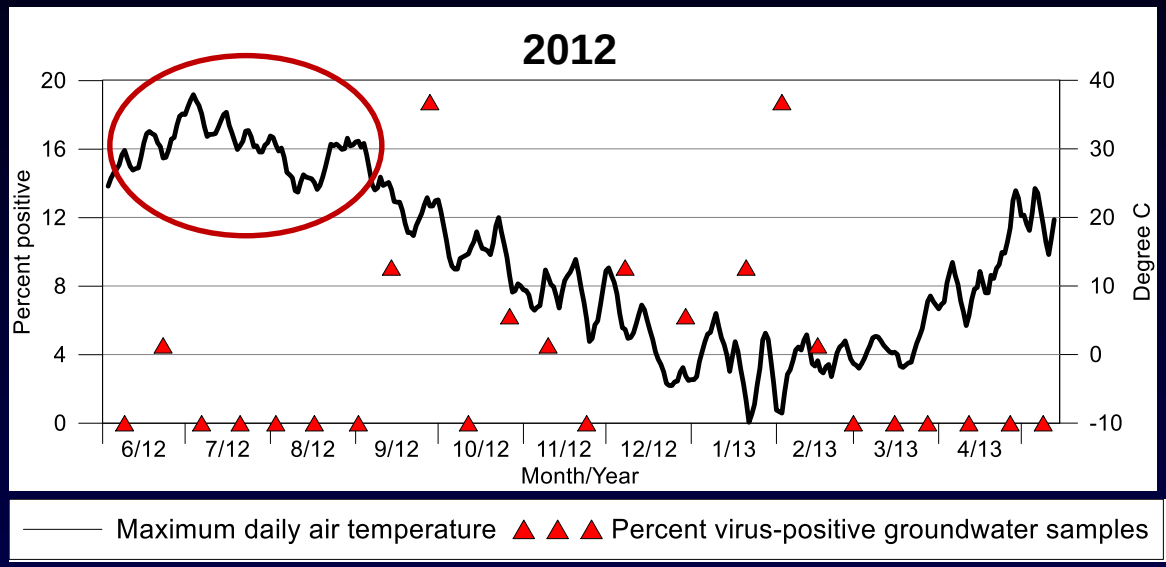


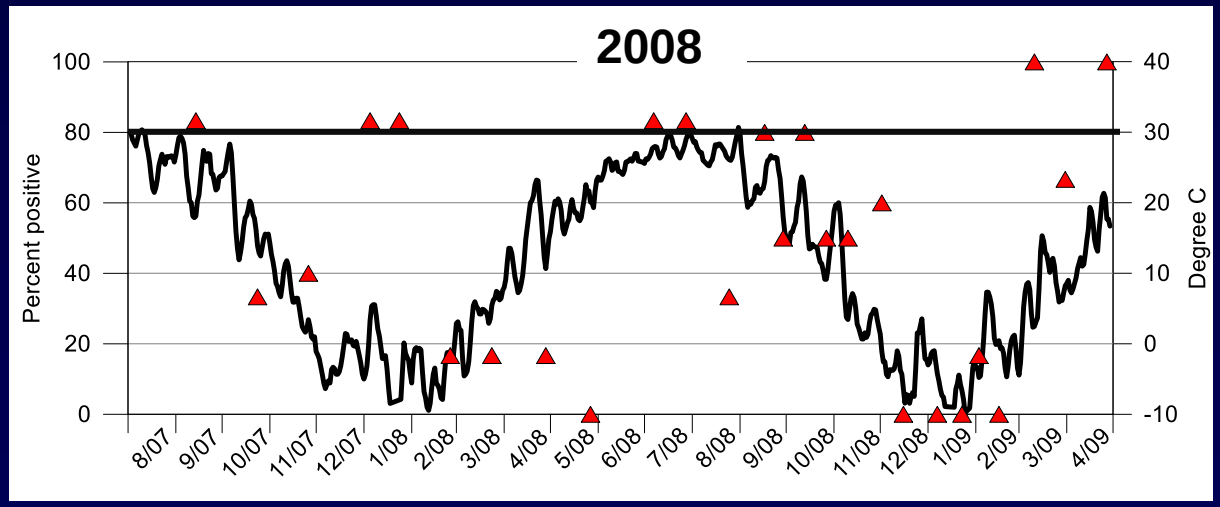
1. Why are there no detects after the drought, in July - August?
2. Why do the detects occur in September – February?
3. Why are there no detects during heavy spring recharge?

1. Transport through vadose zone

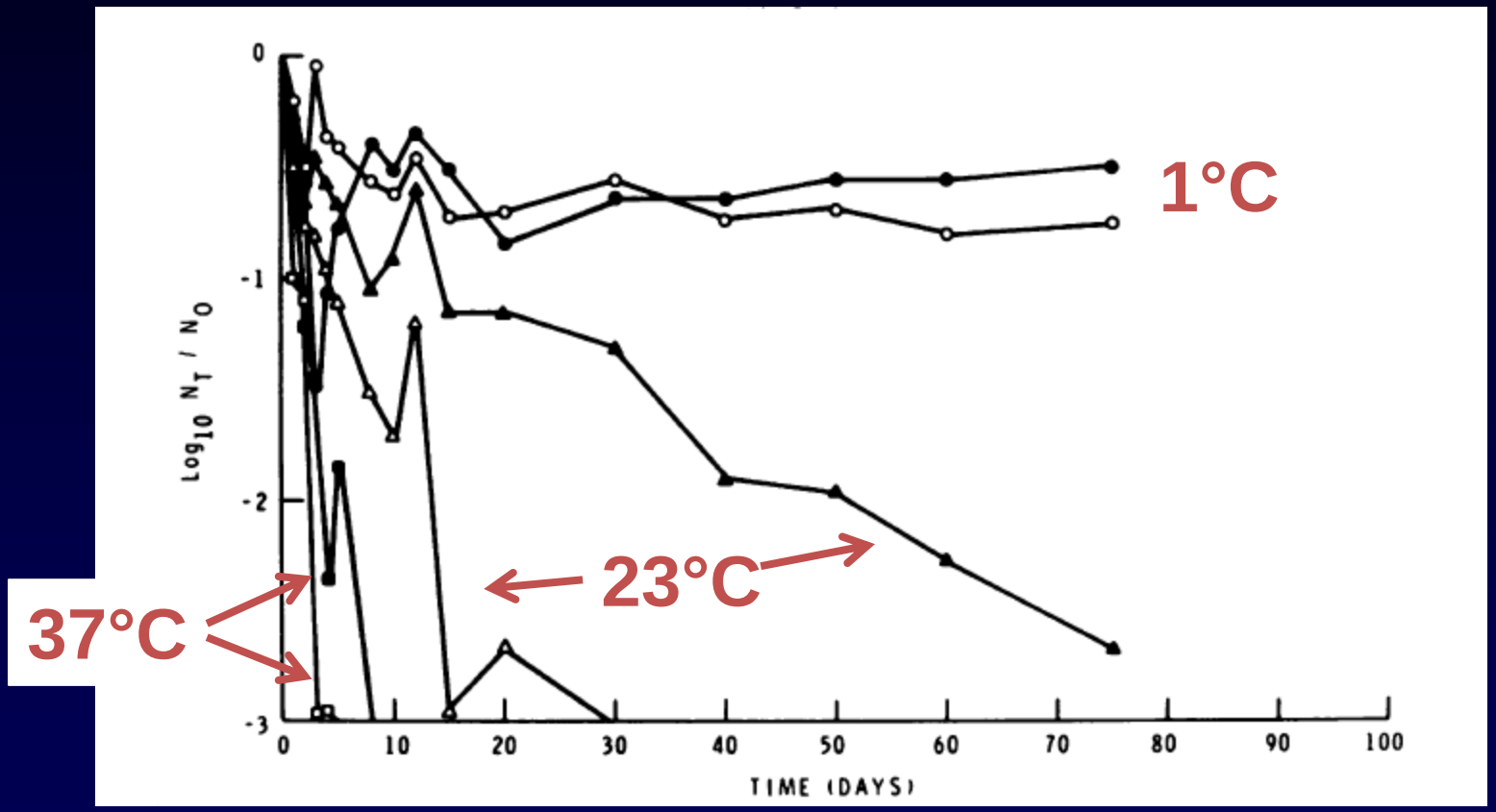


Transport time through vadose zone increases during drought



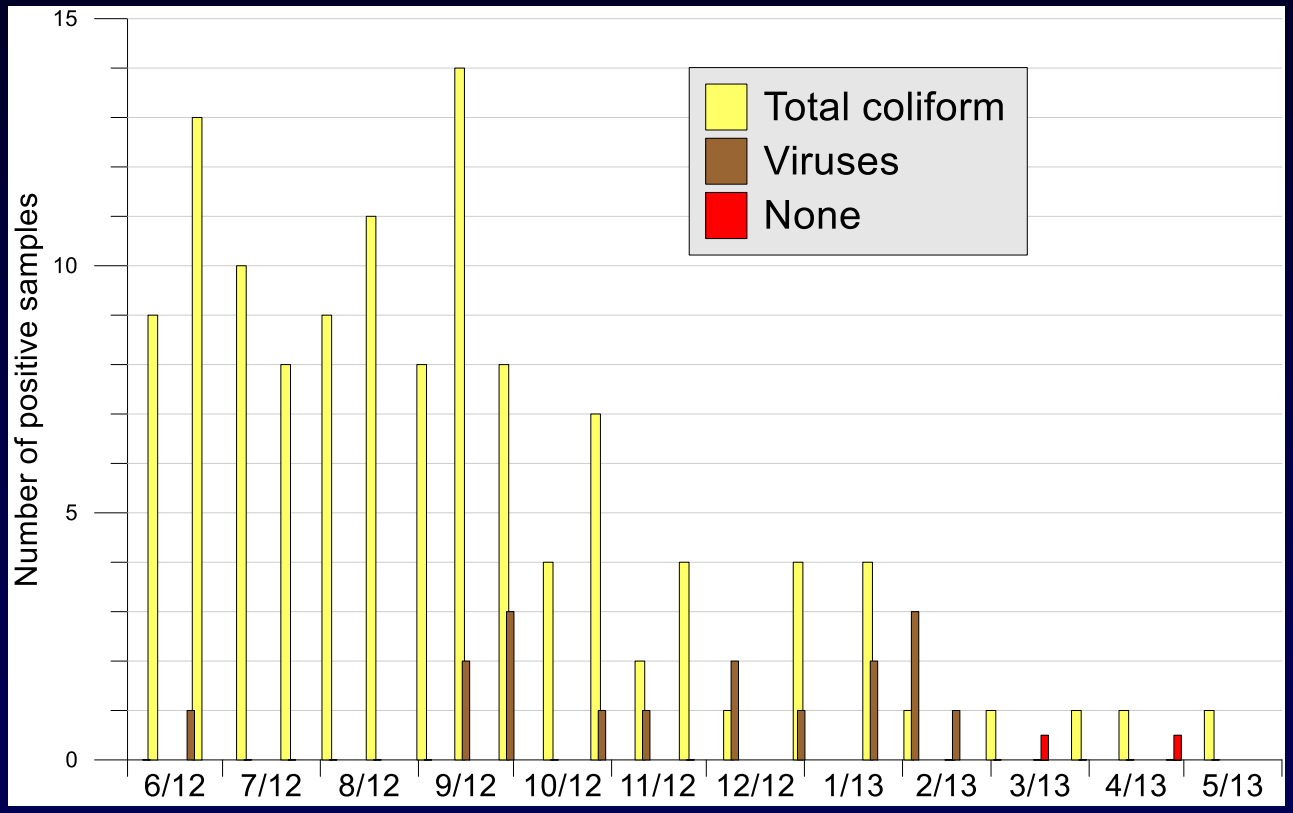


Virus survival in soil decreases as temperature increases



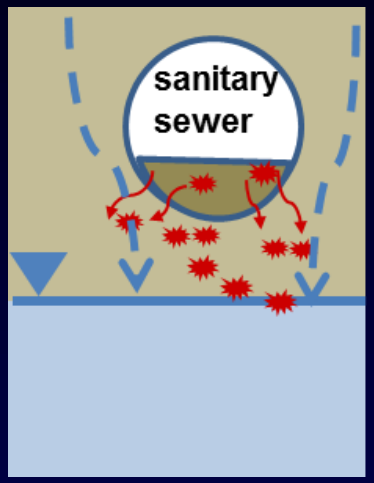
Hurst et al., 1980

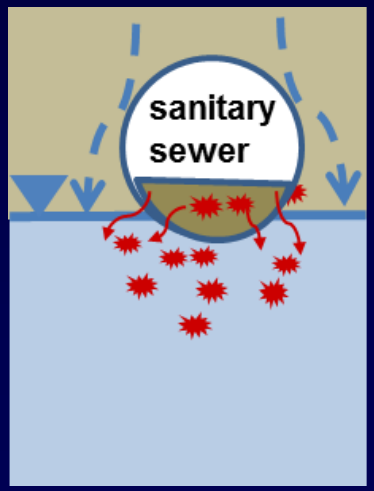
Total coliform detections are not correlated to presence of viruses; warming temperatures increase bacterial populations

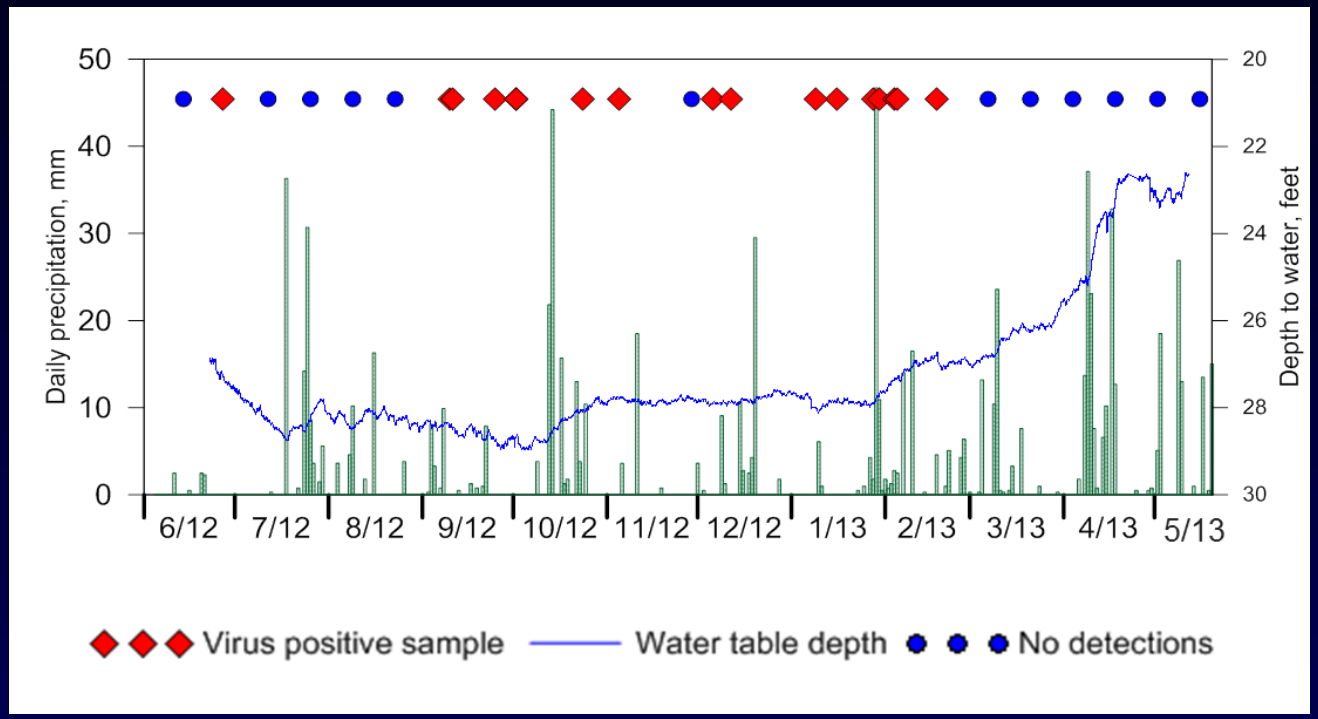


1 of 17 virus positive samples was also TC positive

2. Precipitation and low temperatures are conducive to survival and transport

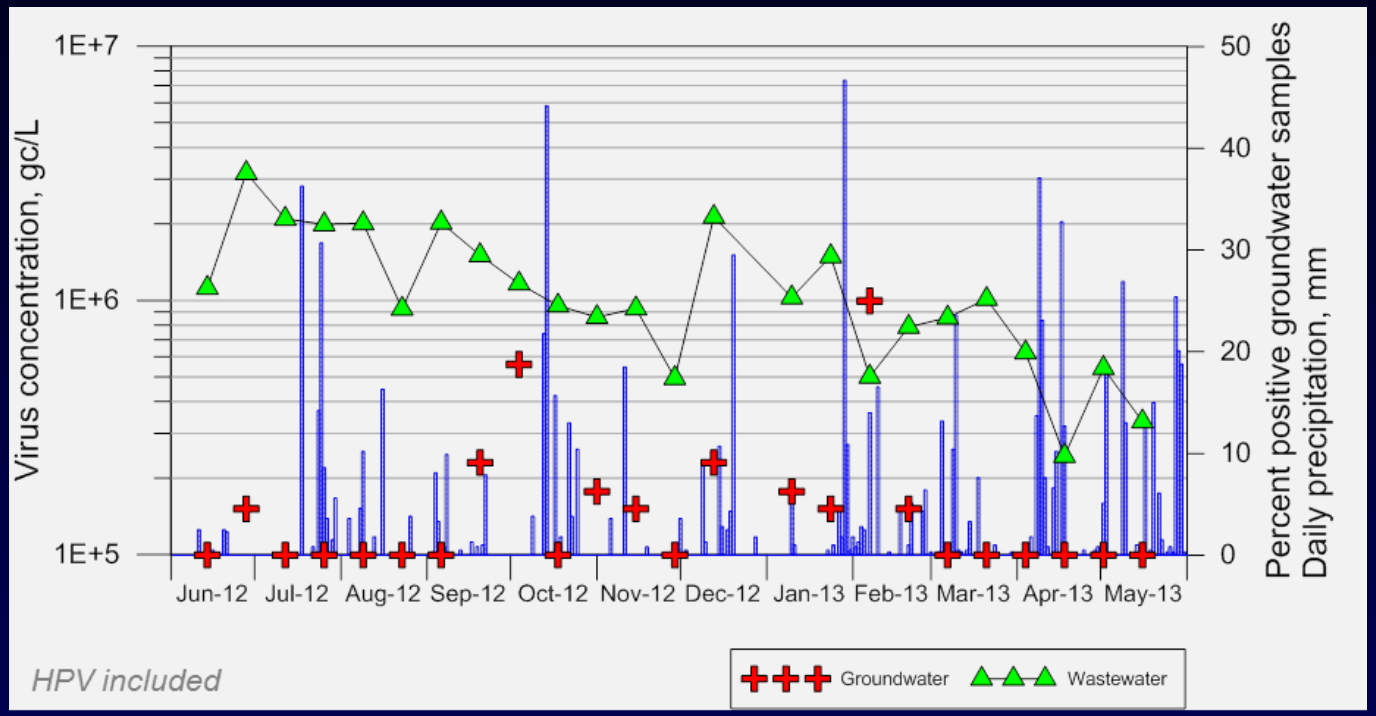






3. Why do the detections stop during heavy spring recharge?

3. Elevated water table causes inflow to sewers and dilutes virus concentrations



Some observations

- *Virus detections occur at similar rates across urban and suburban environments, near old and new sewer systems*
- *The temporal distribution of viruses in groundwater is affected by climate: temperature, precipitation and source concentration (dilution)*
- *Results support disinfection of groundwater sourced municipal systems*

Help from:

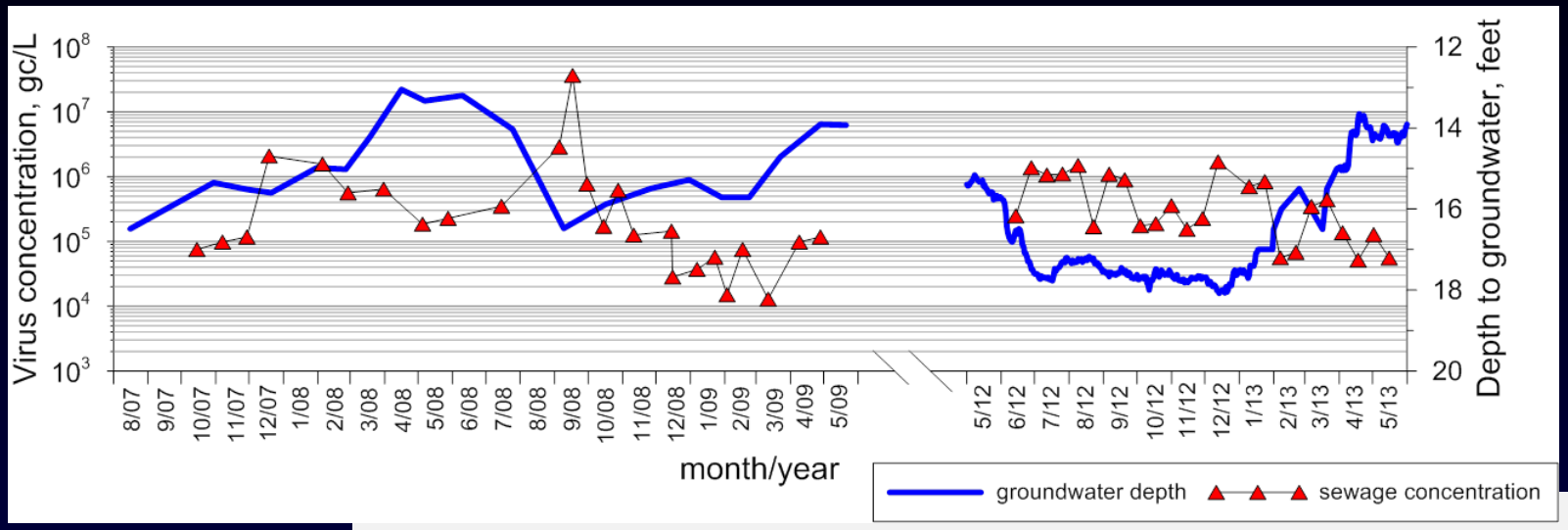
R. Bradbury and J. Borchardt

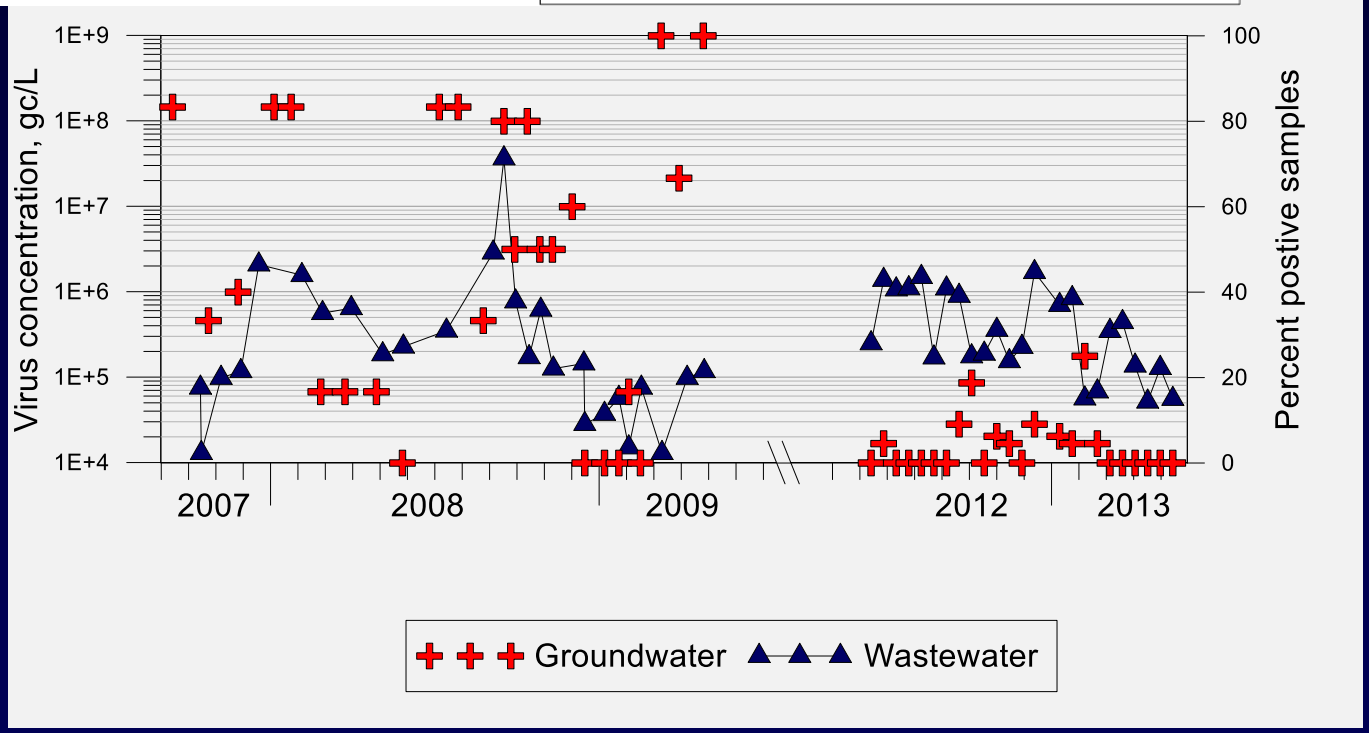
Madison and Fitchburg Water Utilities

Madison Metropolitan Sewer District

EPA Science to Achieve Results (STAR) Program

Bureau of Drinking Water and Groundwater, WDNR


Virus concentration, gc/L
10^8
10^7
10^6
10^5
10^4
10^3
12
14
16
18
20
Depth to groundwater, feet
8/07
9/07
10/07
11/07
12/07
1/08
2/08
3/08
4/08
5/08
6/08
7/08
8/08
9/08
10/08
11/08
12/08
1/09
2/09
3/09
4/09
5/09
5/12
6/12
7/12
8/12
9/12
10/12
11/12
12/12
1/13
2/13
3/13
4/13
5/13
month/year
groundwater depth
sewage concentration


Virus concentration, gc/L
1E+9
1E+8
1E+7
1E+6
1E+5
1E+4
100
80
60
40
20
0
Percent postive samples
2007
2008
2009
2012
2013
Groundwater
Wastewater

Climate control on virus transport is not precipitation alone