Lead Variability in Repeat at-the-tap Samples in NYC

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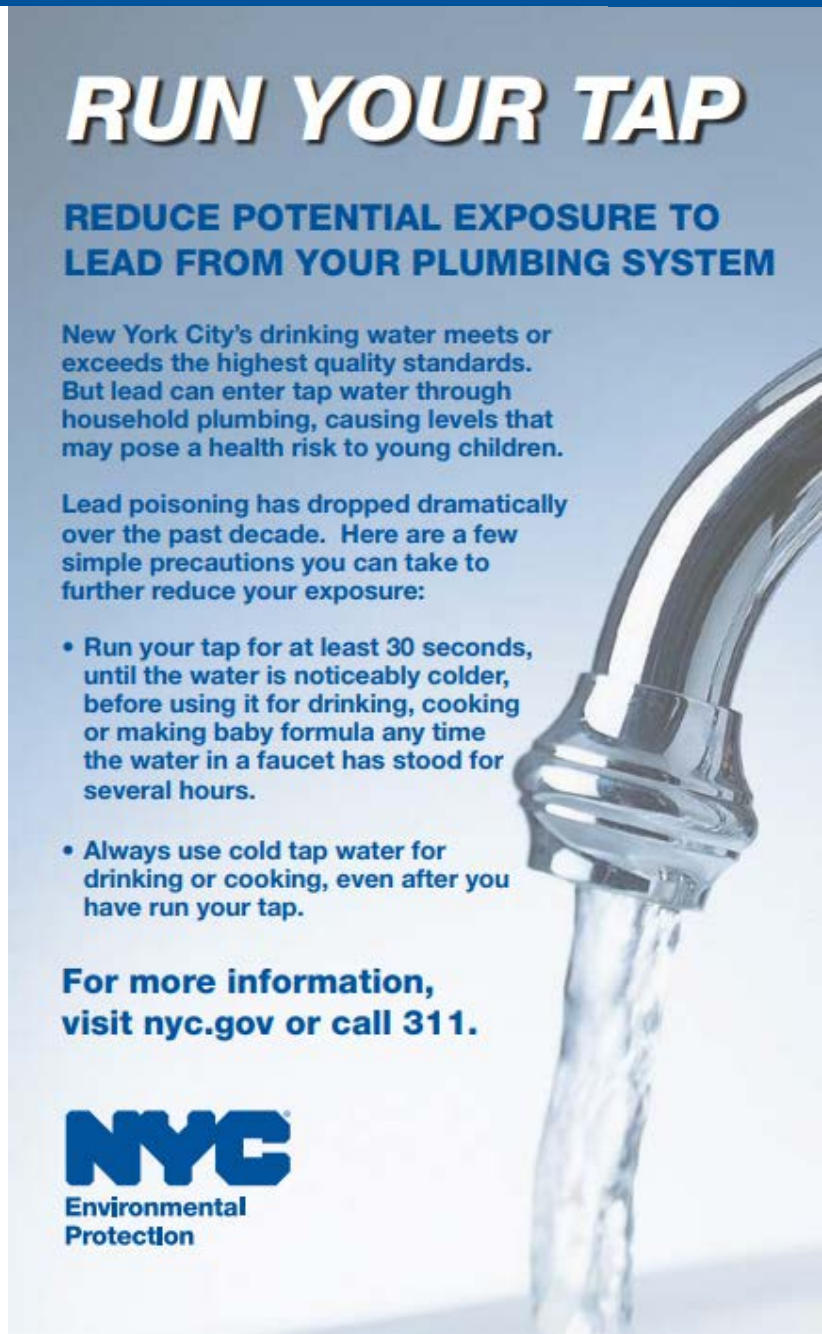
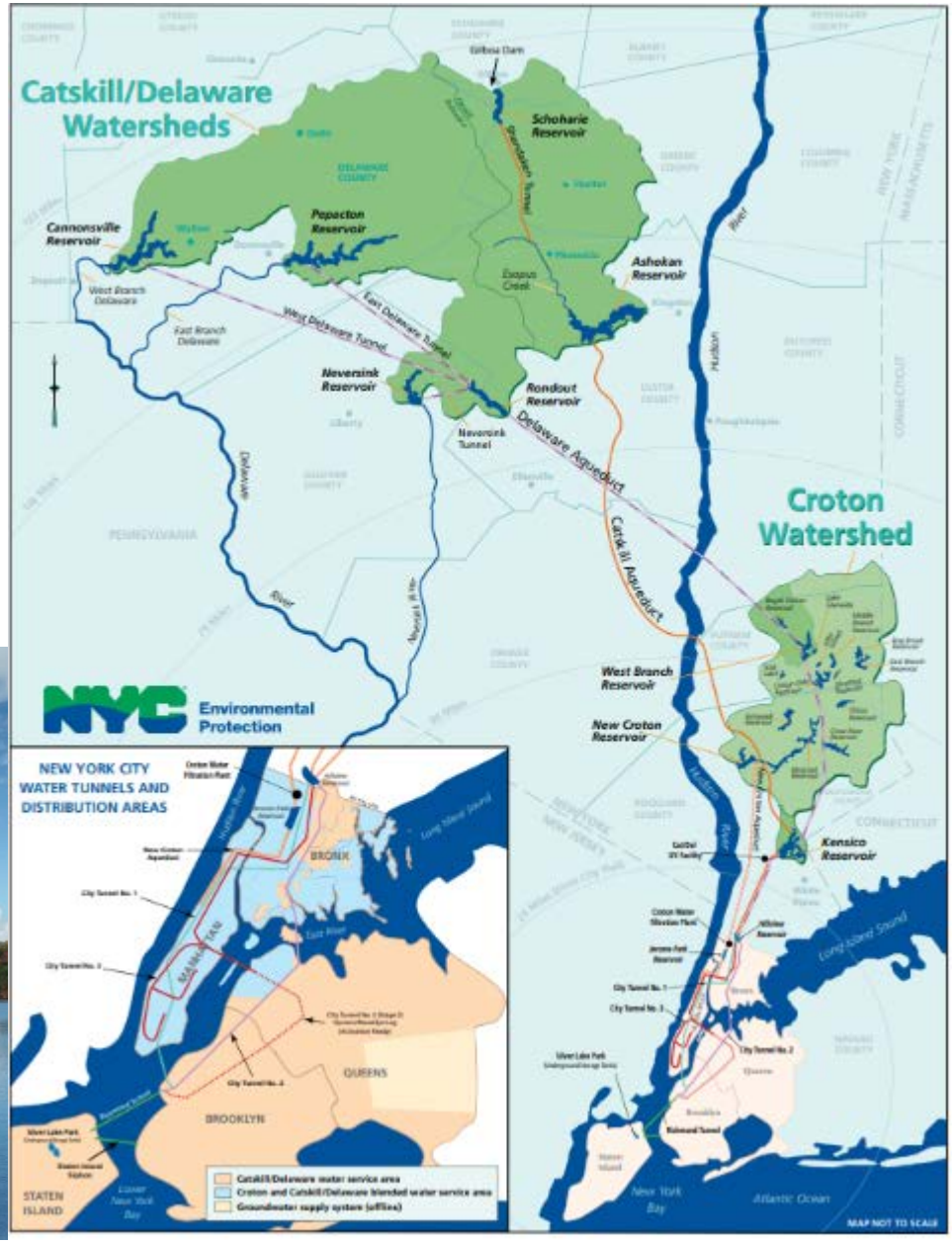
Motivation

- NYC DEP analyzes and provides thousands of results for lead kits to customers each year (3621 kits in 2017)
- Lead levels fluctuate not only from residence to residence, but also within a single residence
- How can DEP better explain results to customers?
  - How likely is it that my lead levels will be the same if I sample again?
  - Will my lead levels decrease if I flush my water?
  - Does housing type play a role in either of the above?



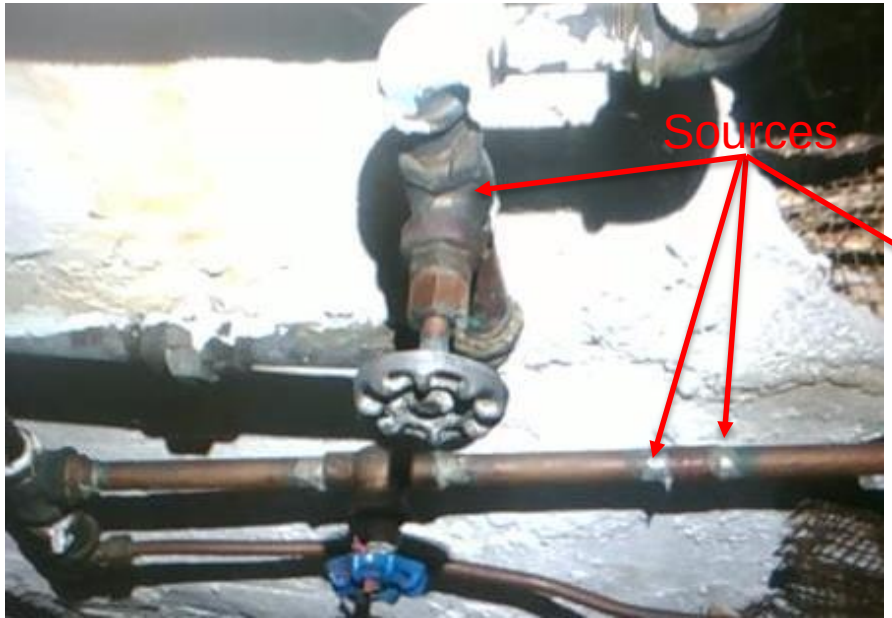
NYC Water Supply & Distribution System

- **Surface Water System –** 19 reservoirs and 3 lakes
- **9.6 million customers** – 8.6 million in NYC and 1 million people upstate
- **1.1 BGD**
- **Phosphoric Acid** corrosion inhibitor
- Estimated **50,000 Lead Service Lines**
- **LSL** installation ceased in 1961



Factors Affecting Lead in Drinking Water

- Plumbing Materials – lead service lines, lead solder, and brass components & faucets
  - Type, age, diameter, alloy composition (brass)
- Interior plumbing design – branches and dead ends, length of pipes
- Water Use – frequency, duration, flow rate
- Water chemistry – corrosion inhibitors, pH, disinfectant, water age, temperature
- **Soluble** lead is far more predictable than **particulate** lead



Free Residential Program Overview

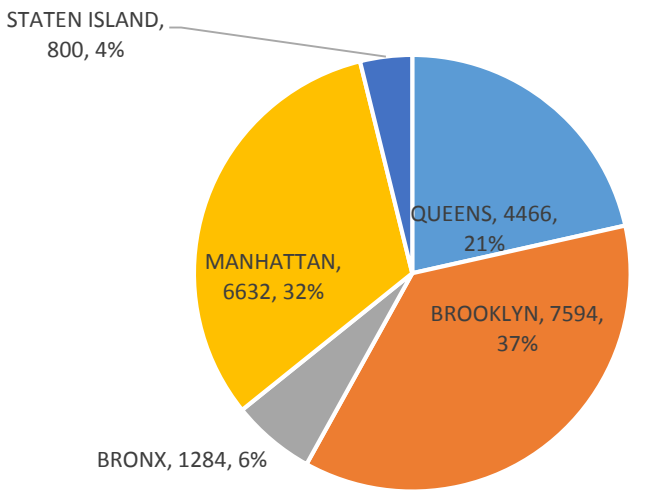
- **1992**: DEP began offering free lead test kits to any customer residing in NYC
- **Purpose:** Inform customers if they have a lead source and provide mitigation recommendations
- Customers can request a kit by calling **311** or going online: https://www1.nyc.gov/311/
- **2-Bottle Kit** is delivered through the mail:
  - 1 L wide-mouth sample bottles
    - First Draw (**FD**) collected after **6+ h stagnation**
    - 1-2 Minute Flush (**1-2MF**)
- Pre-Paid postage to DEP lab, results returned in 3-6 wks
- **3-Bottle Kit** is sent to customers with lead levels ≥15 µg/L in either first kit sample
  - Includes a 5 Minute Flush (**5MF**) sample
- Kit Return Rate = **51%** for 2018 YTD

Year	Number of Requests
2010	11,260
2011	4776
2012	2090
2013	2144
2014	1915
2015	2299
2016	11,737
2017	7947

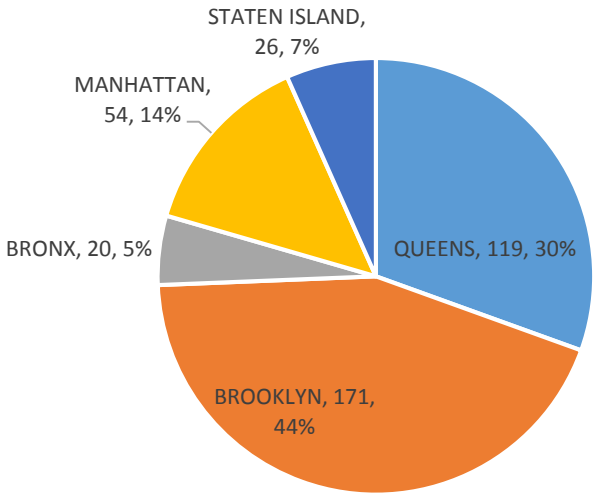
Duplicate Kits are a High Lead Subset

- Duplicate samples occur when more than one kit is sent to a single site, either when a customer is sent a 3-bottle Retest kit or requests a second 2-bottle kit
  - Therefore, **<u>duplicate samples are largely a subset of kits from a residence with a probable lead source</u>**

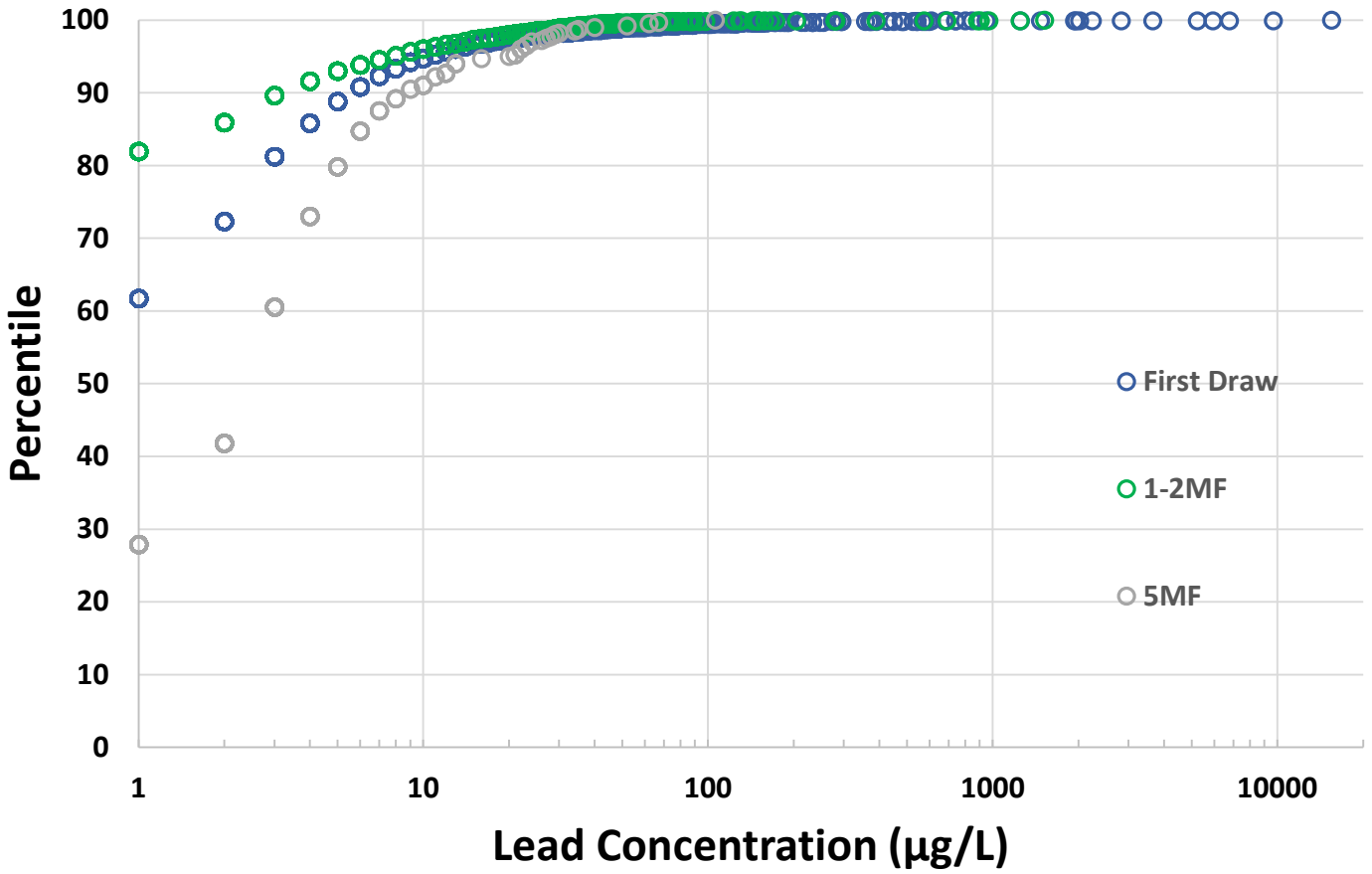
All Analyzed Kits by Borough



Duplicate Analyzed Kits by Borough



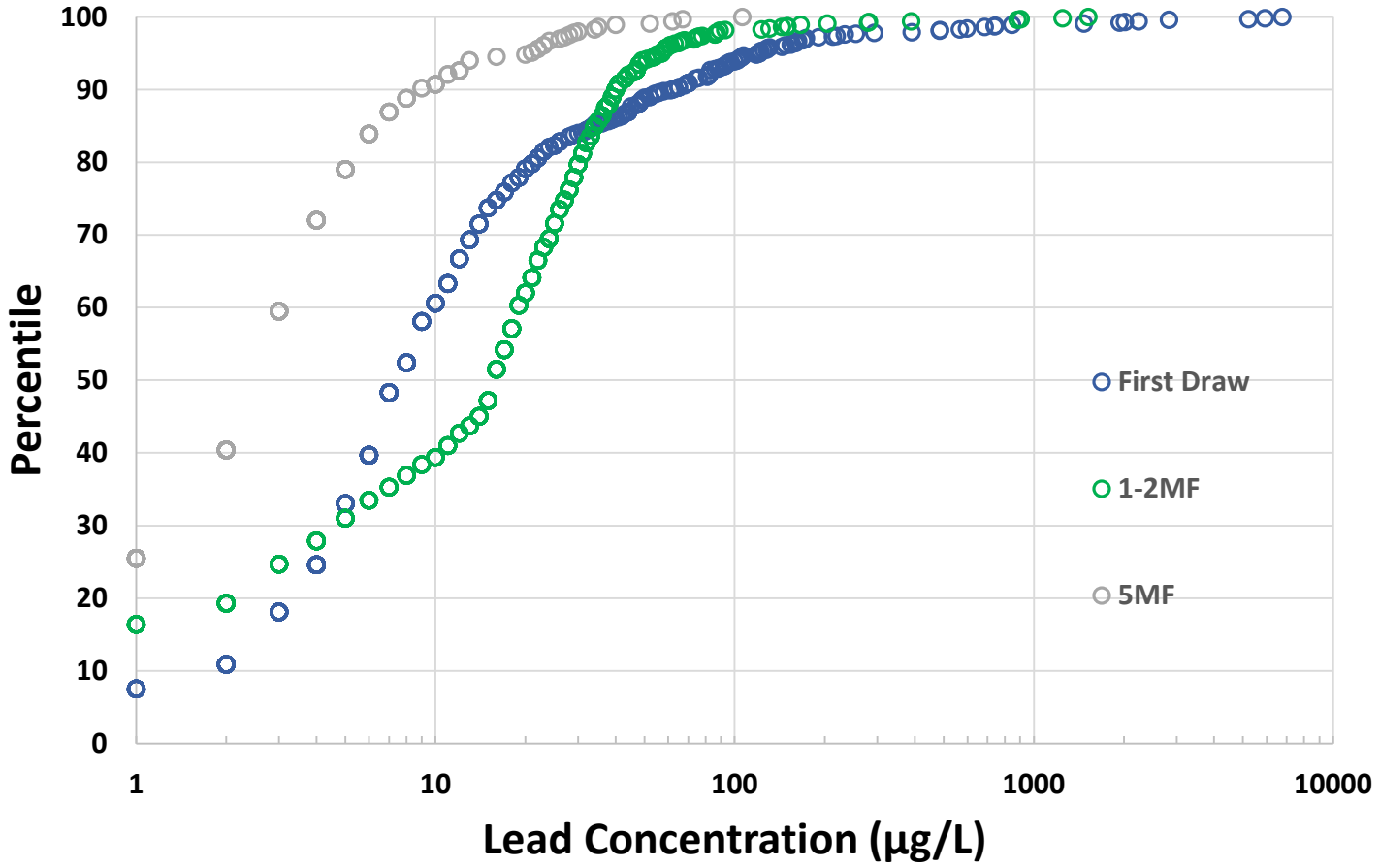
All Free Residential Kits 2010-2018



Sample Type	# Samples	Min Pb (µg/L)	Avg Pb (µg/L)	Max Pb (µg/L)	90th percentile Pb (µg/L)	# Samples >15 µg/L	# Samples ≥50 µg/L	% >15 µg/L	% = 0 µg/L
FD	20754	0	5	9655	5	671	225	3%	62%
1-2MF	20763	0	2	1519	3	515	70	2%	82%
5 MF	397	0	4	106	8	21	4	5%	28%

Note: Lead values are rounded to the nearest whole number

Data Subset: More than one kit per site



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FD	796	0	60	6768	62	201	88	25%	8%
1-2MF	796	0	25	1519	40	386	47	48%	16%
5MF	369	0	4	106	9	21	4	6%	25%

NYC Housing Stock is Old & Diverse

Borough	% of Population in multi-unit Residences	County Rank Nationwide
Manhattan	96.7%	1
Bronx	87%	2
Brooklyn	82.9%	3
Queens	67.7%	6
Staten Island	< 34.7+%	>30+

+Staten Island is not in the top 30 counties nationwide

Median usage rates per unit by building class and borough, 2014

Major Building Class	Median Use by Borough (gallons/unit/day)				
	Brooklyn	Bronx	Manhattan	Queens	Staten Island
One Family Dwellings	172	168	227	168	164
Two Family Dwellings	133	141	118	139	125
Walk Up Apartments	139	178	131	144	129
Elevator Apartments	174	222	134	153	103

Values in red represent the maximum of each row. Values in green represent the minimum of each row.

Source: Adapted from WRF Project # 4554, 2018

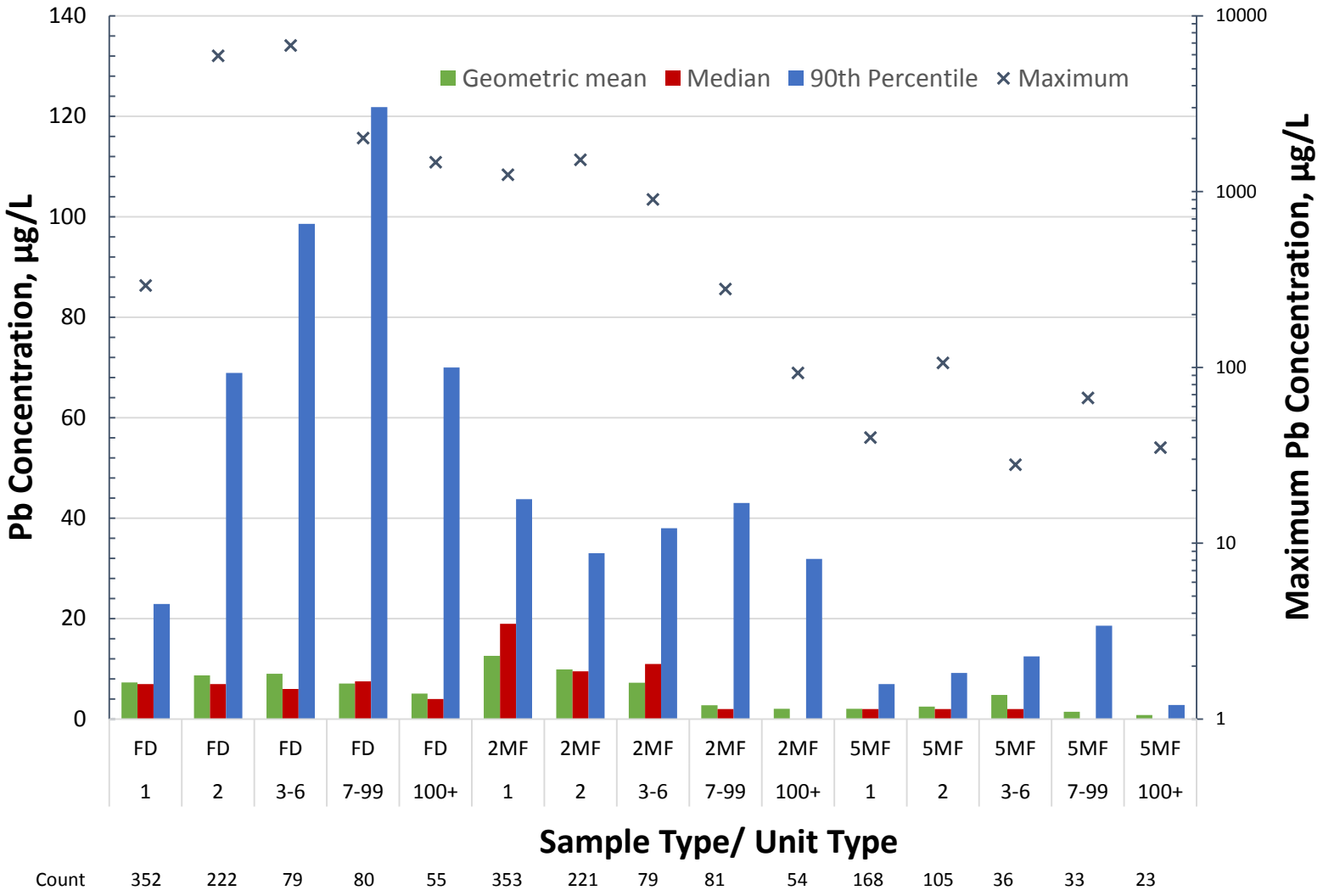
Year Built – Duplicate Samples

Average	Median	5th %ile	25th %ile	75th %ile	95th %ile
1925	1925	1899	1910	1930	1965

Age by House Type – Duplicate Samples

Units per Building	1	2	3-6	7-99	100+
Count	171	108	39	40	27
Median Year Built	1925	1920	1910	1920	1960

Lead Levels by Housing Type



Differences due to Flushing – Housing Type

Sample Type	# Samples	Min Pb (µg/L)	Avg Pb (µg/L)	Median Pb (µg/L)	Max Pb (µg/L)	90th percentile Pb (µg/L)	# Samples >15 µg/L	# Samples >=50 µg/L	% >15 µg/L	% = 0 µg/L
FD	796	0	60	7	6768	62	201	88	25%	8%

FD to 2MF

Units per Building	Count	% of Samples Increased	% of Samples Decreased	% of Samples No Change	Median Increase, µg/L	Median Decrease, µg/L
Overall	794	56%	36%	8%	16	-14
1	353	70%	25%	5%	16	-7
2	222	57%	38%	5%	15	-12
3-6	79	47%	40%	13%	14	-35.5
7-99	81	26%	55%	17%	15	-17
100+	55	16%	55%	27%	22	-12

FD to 5MF

Units per Building	Count	% of Samples Increased	% of Samples Decreased	% of Samples No Change	Median Increase, µg/L	Median Decrease, µg/L
Overall	368	7%	84%	9%	6.5	-4
1	168	6%	88%	5%	10	-4
2	105	10%	84%	6%	6	-4
3-6	36	0%	94%	6%	N/A	-4
7-99	33	12%	70%	18%	3	-7
100+	23	4%	57%	39%	7	-8

Will Flushing Always Work?

- 1-2MF can increase lead levels, possibly due to a LSL
- Flushing will not always reduce Pb enough in residences with a probable lead source:
  - Out of 89 FD samples ≥ 50 µg/L, only 58% reduced to ≤15 µg/L in the 1-2 MF
  - Out of 34 3-btl kits with FD samples ≥ 50 µg/L, 84% reduced to ≤15 µg/L after 5MF
- FD samples that likely contain particulate lead do not always fully reduce after flushing

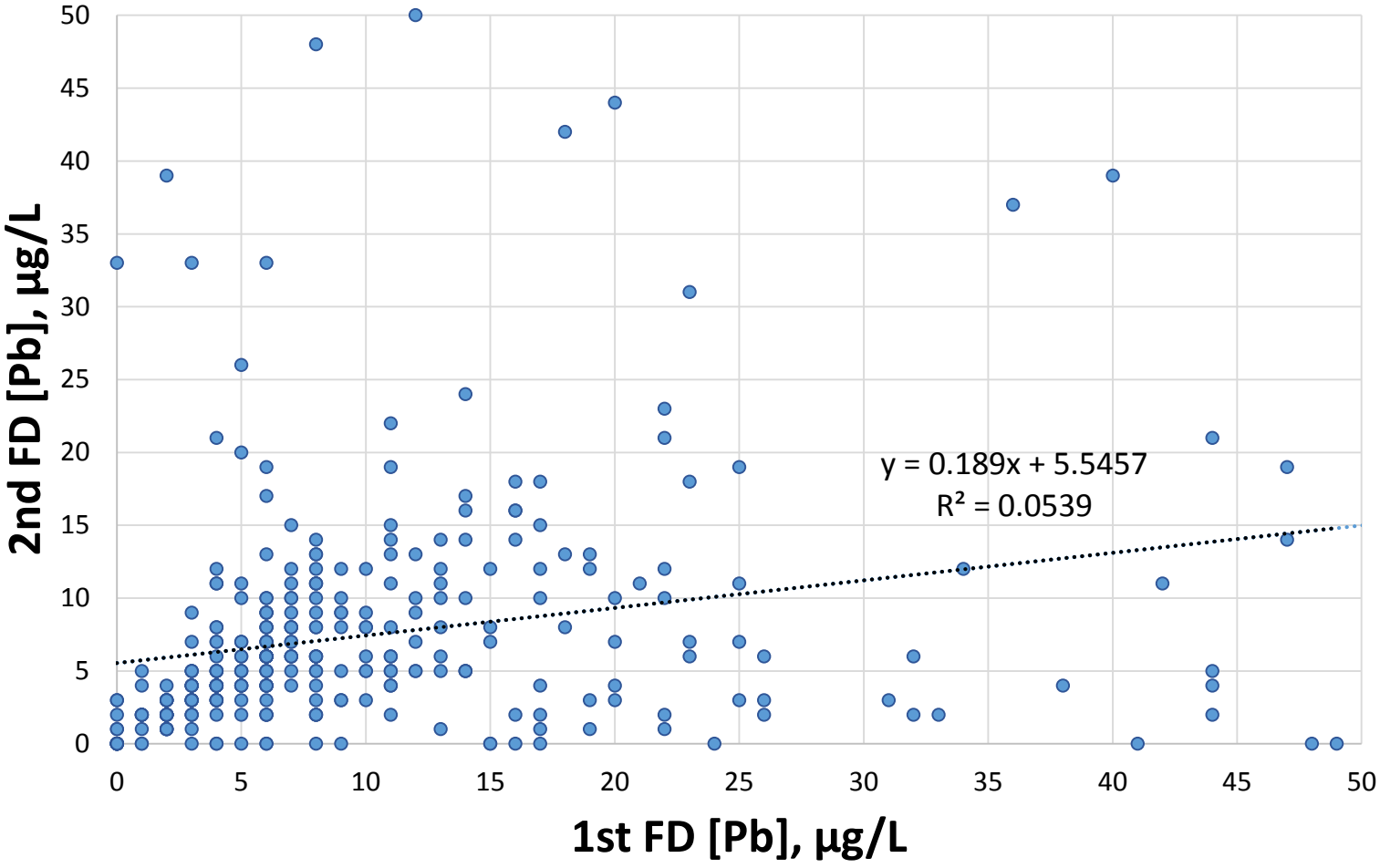
FD (µg/L)	1-2 MF (µg/L)	5MF (µg/L)
213	20	
219	11	4
233	0	1
254	36	
293	10	
391	1	0
484	75	
486	8	3
566	48	
597	33	
685	904	27
739	1	
742	8	
845	2	
1469	5	
1936	10	
2015	47	
2237	13	5
2826	15	12
5219	1519	
5924	1	
6768	389	

Conditions May Differ Between Duplicates

- Hours Unused (Median difference = 1 hr)
- Sample tap location
- Days/Months/Years between repeat samples (avg=68 d, median=34 d, max=6.5 y)
- Season/daily temperature during sampling
- Exact length of flush time & flow rate
- Customer sampling errors
- Possible interior plumbing changes
- Water main work/other disturbances between sampling events
- Differences in analysis

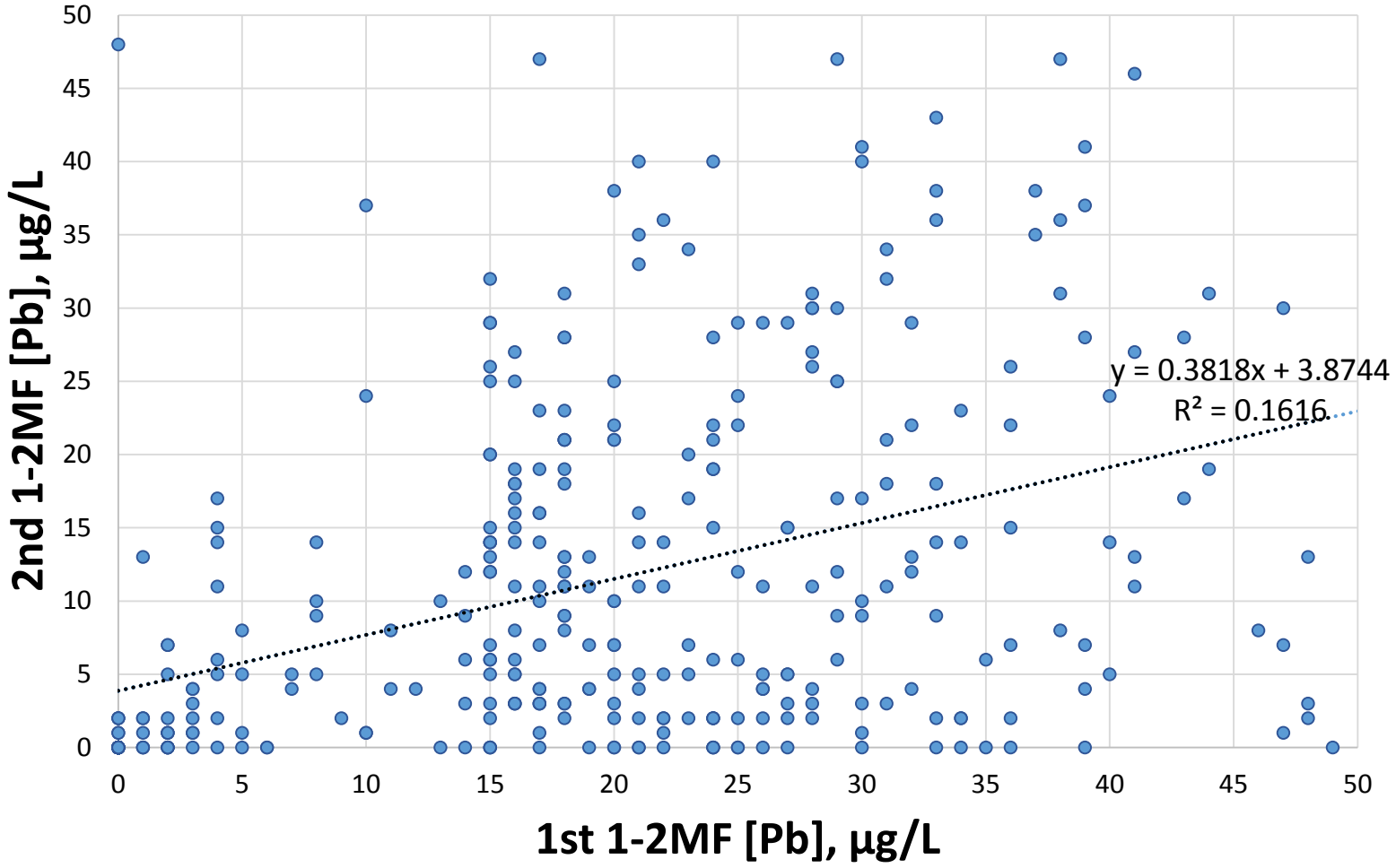
However, these are the differences in lead levels that the customer actually experienced in their own residence at different points in time.

FD Duplicates



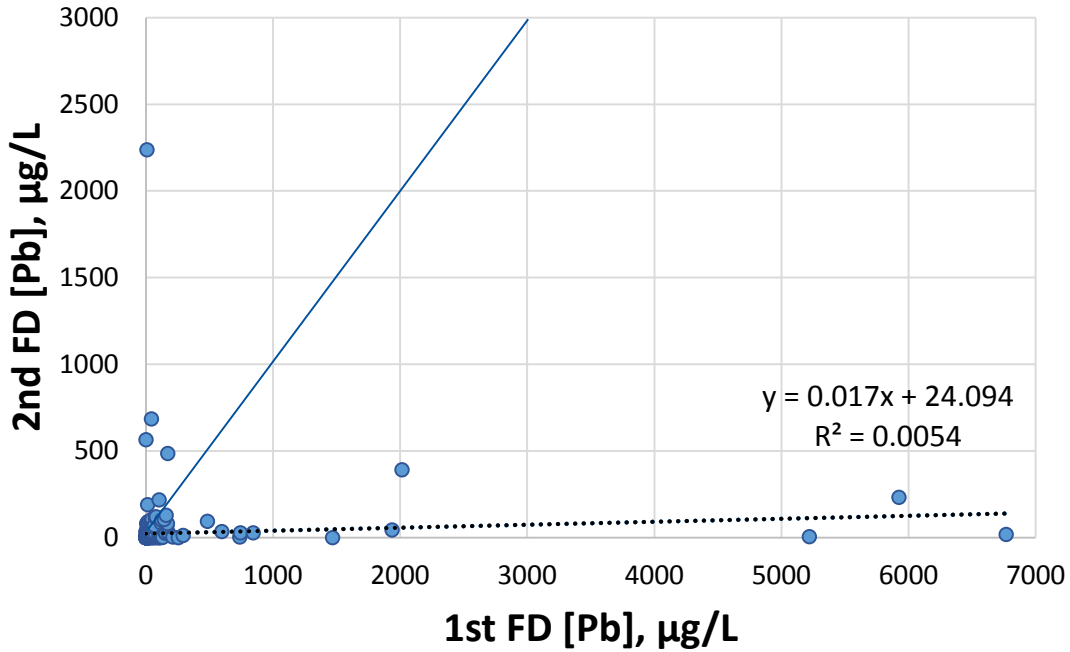
320 pairs, limited to both values ≤50 µg/L

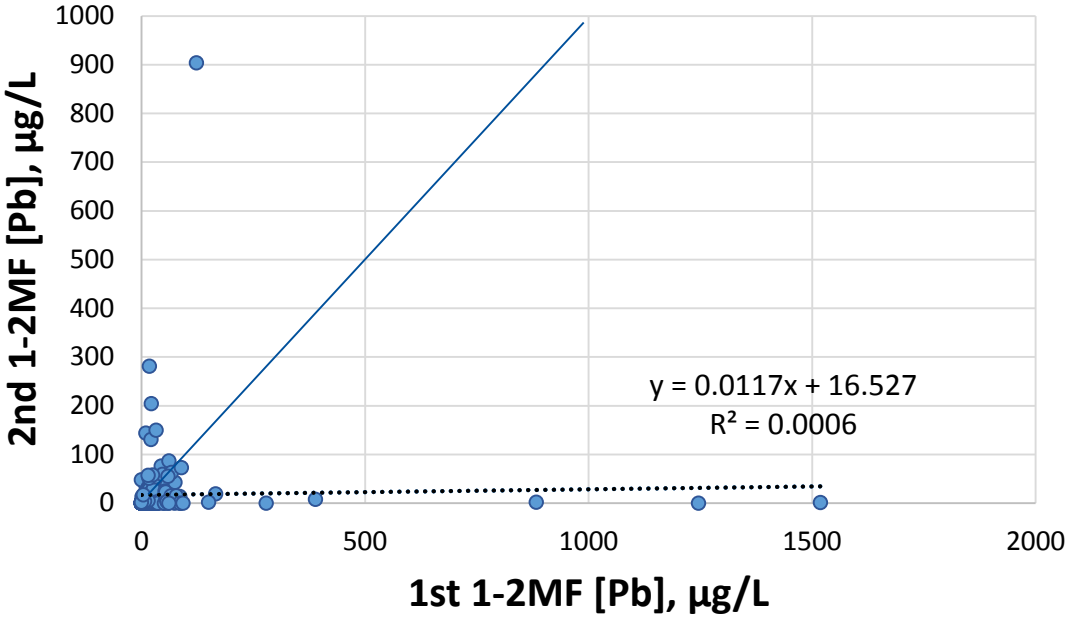
1-2MF Duplicates



347 pairs, limited to both values ≤50 µg/L

Outliers Are Not Reproducible





Sites Sampled More Than 2x

First Draw

Site	FD 1 (µg/L)	FD 2 (µg/L)	FD 3 (µg/L)	FD 4 (µg/L)	Std. Dev.
A	1	1	0		0.47
B	8	8	7	5	1.22
C	1	0	0		0.47
D	5	0	1		2.16
E	6	7	1		2.62
F	11	15	4		4.55
G	6	6	6		0.00
H	47	14	0		19.70
I	6	0	0	0	2.60
J	10	9	8	7	1.12
K	4	0	0		1.89
L	65	70	148		38.00
M	17	18	13	5	5.12
N	4		4		
O	44	5	5		18.38
P	56	63	2826		1304.14

RSD = 0.74

1-2MF

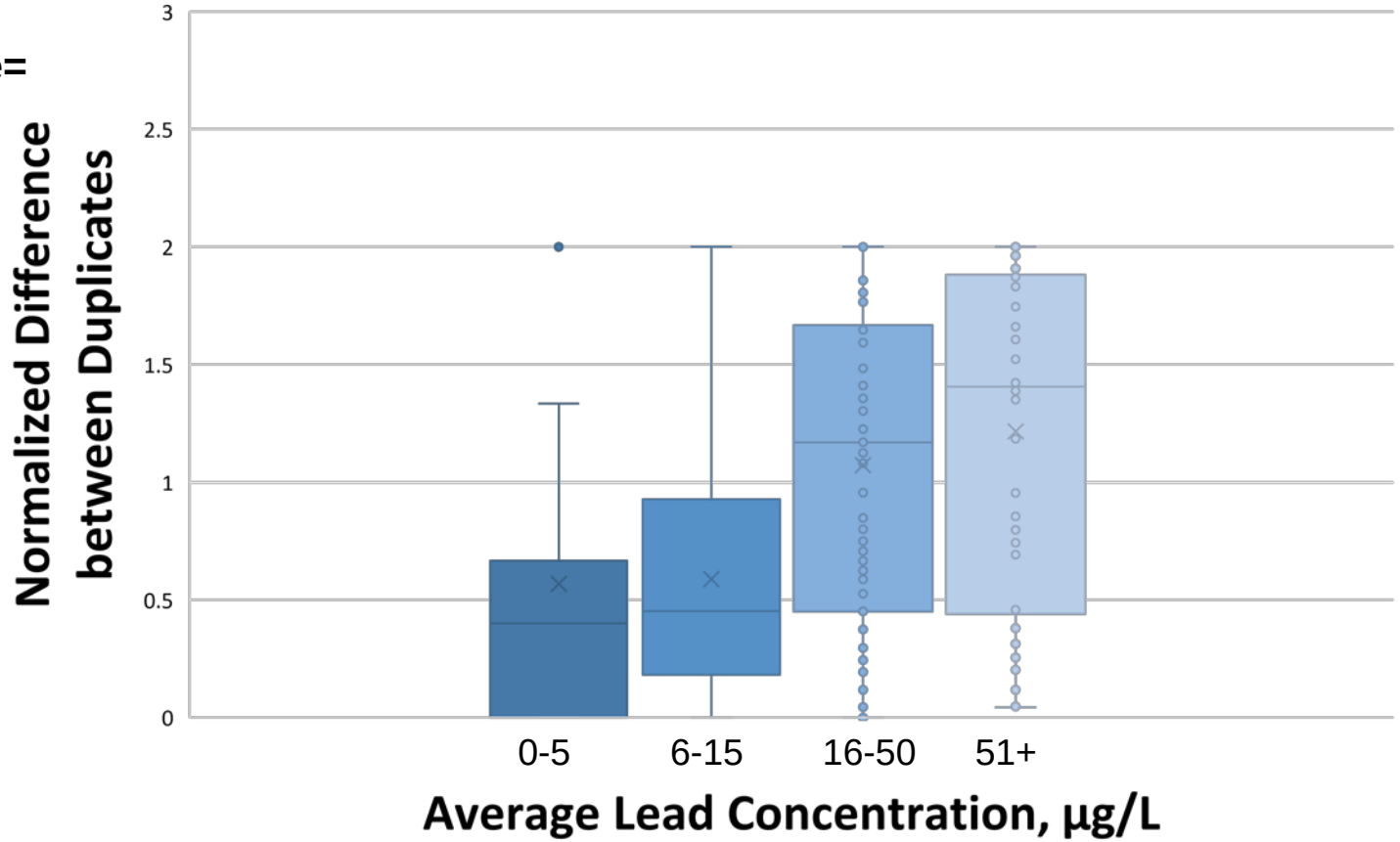
1-2MF 1 (µg/L)	1-2MF 2 (µg/L)	1-2MF 3 (µg/L)	1-2MF 4 (µg/L)	Std. Dev
2	0	0		0.94
37	35	0	0	18.01
0	0	0		0.00
18	9	0		7.35
41	13	0		17.11
25	12	0		10.21
31	3	0		13.96
24	0	0		11.31
4	11	6	6	2.59
55	10	39	31	16.21
14	0	0		6.60
19	7	8		5.44
47	30	0	6	18.86
28	30	35		2.94
25	0	0		11.79
2	7	15		5.35

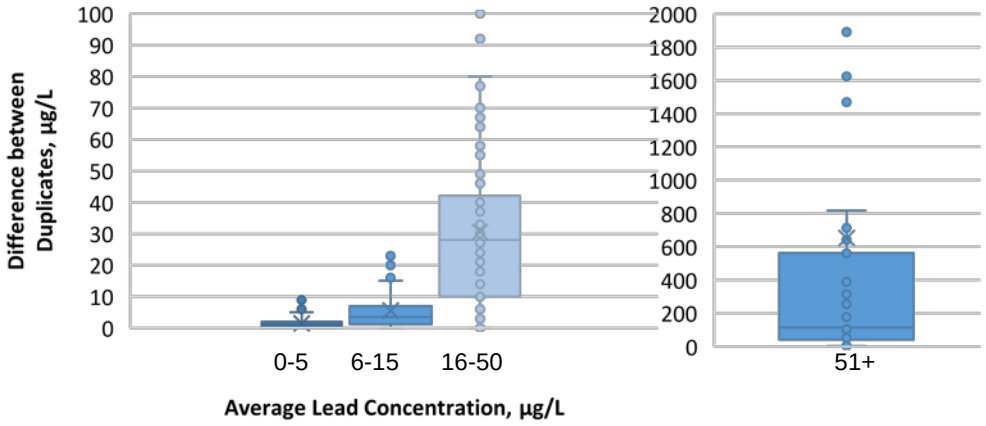
RSD = 0.90

First Draw Repeatability

Normalized Difference= $|([Pb]_{dup1} - [Pb]_{dup2})|$/ Average Lead Concentration

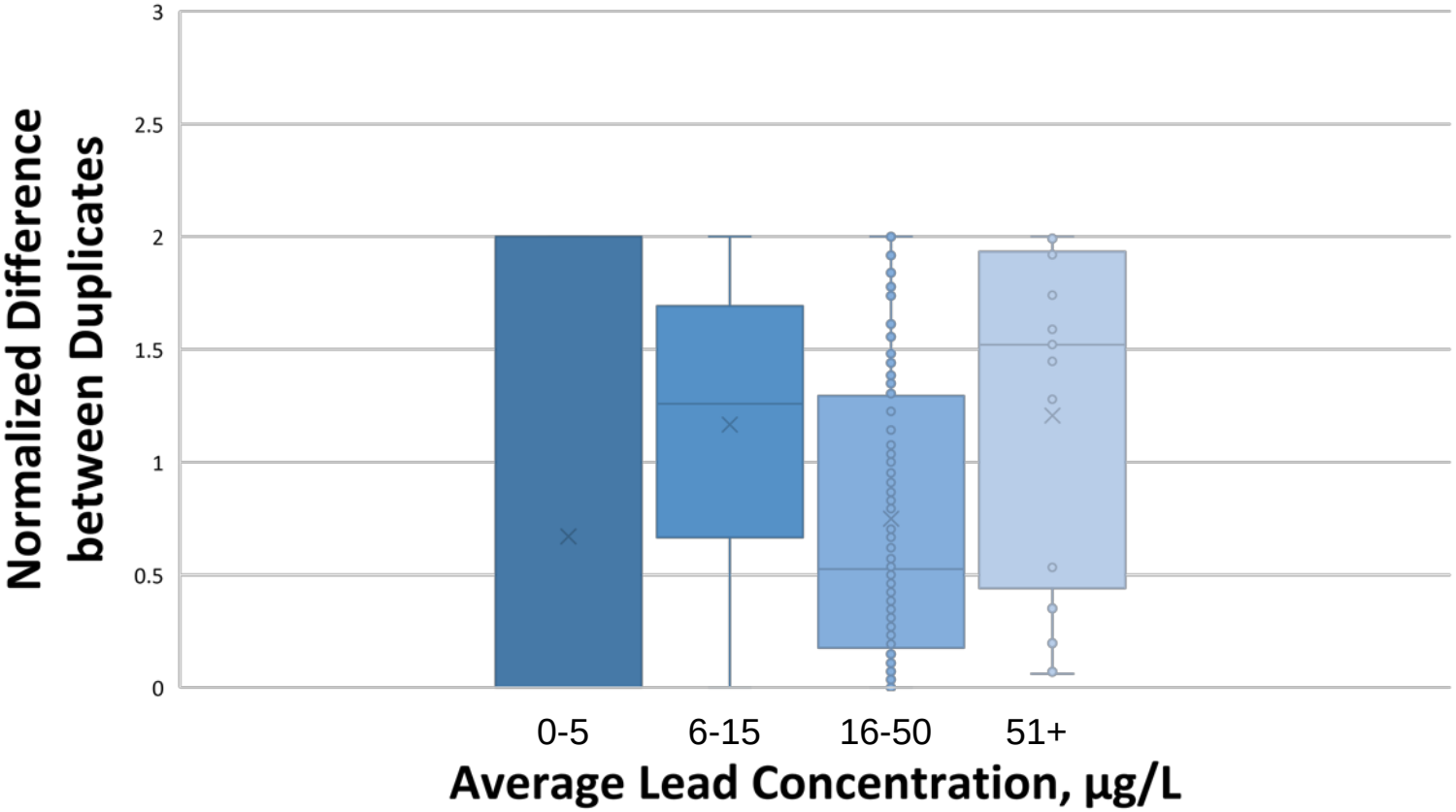
Norm diff=0 if average is zero

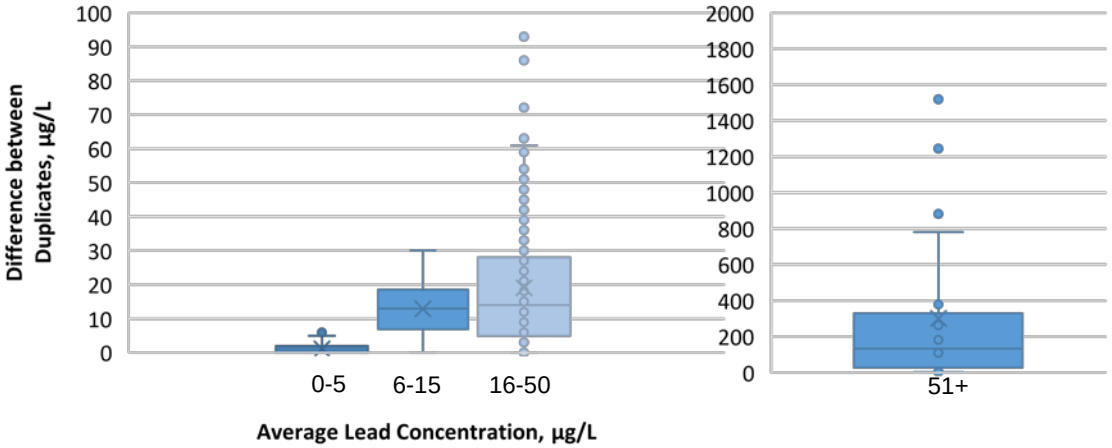




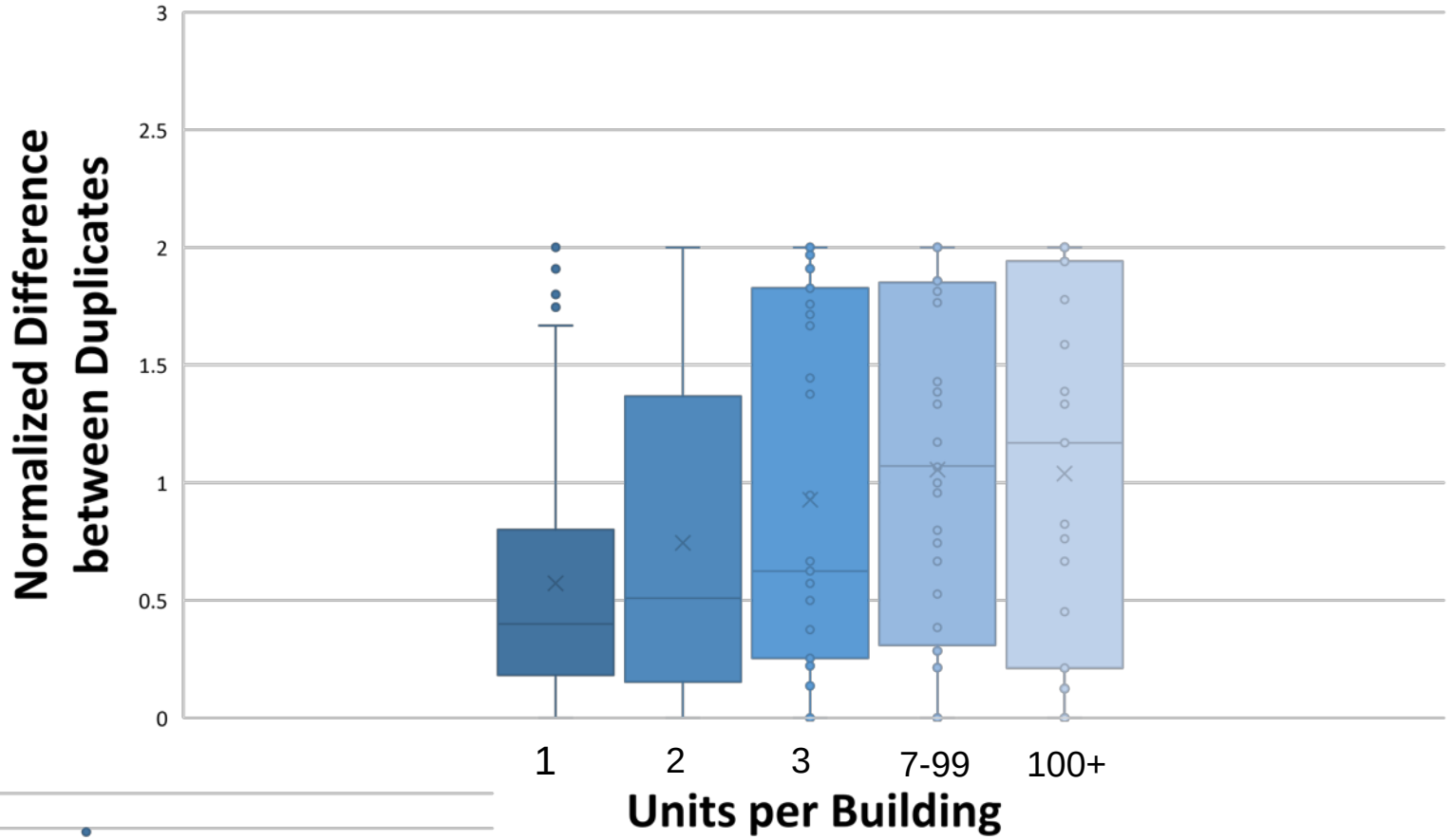
Average Lead Concentration = $([Pb]_{dup1}+[Pb]_{dup2})/2$

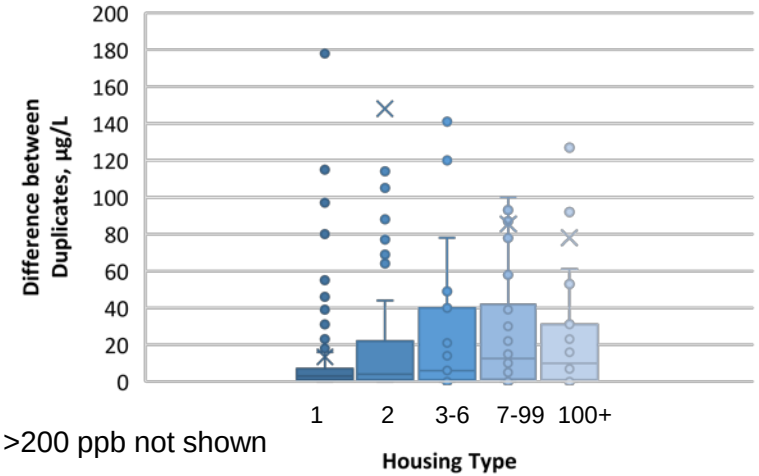
1-2MF Repeatability





First Draw – Variability by Housing Type

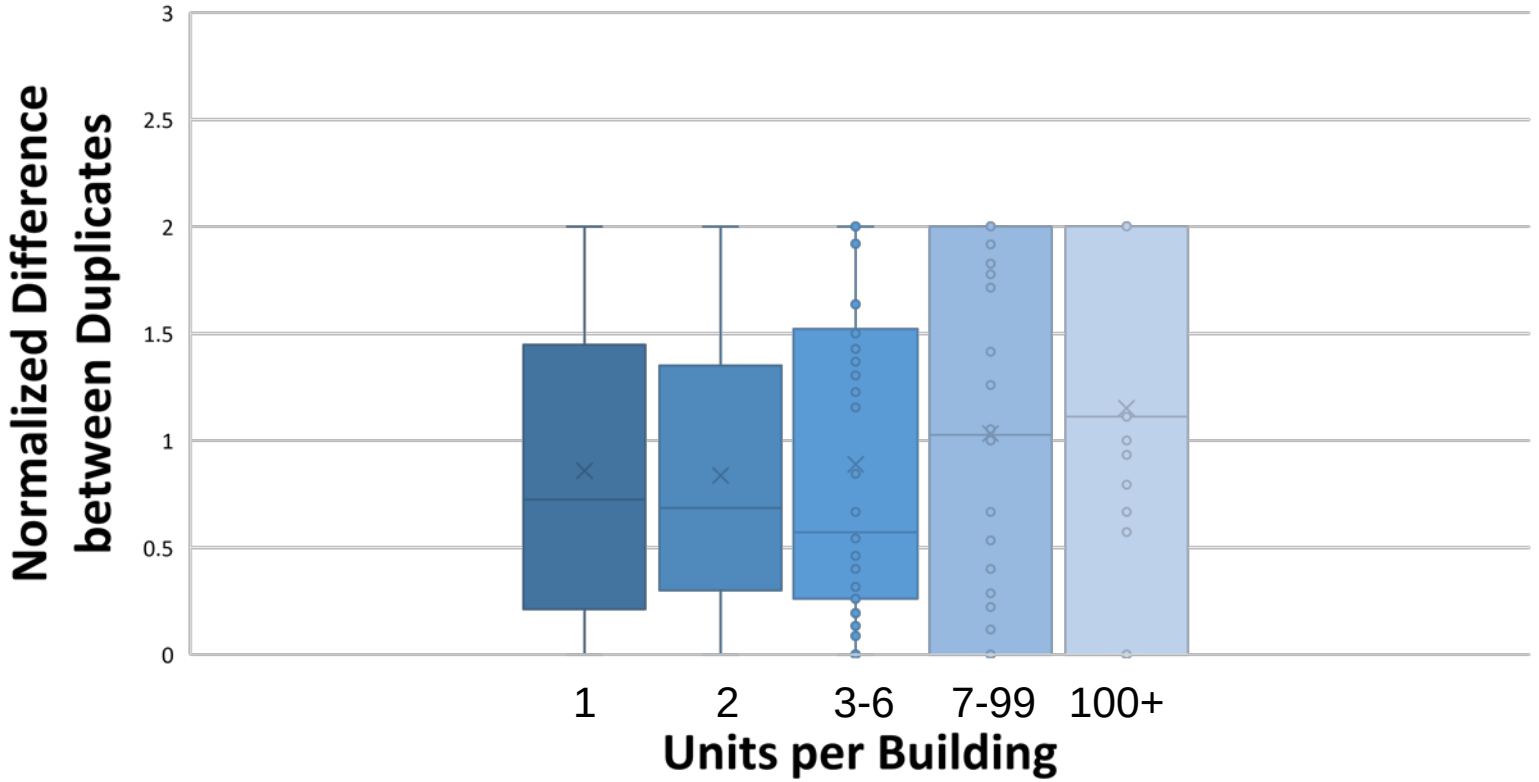


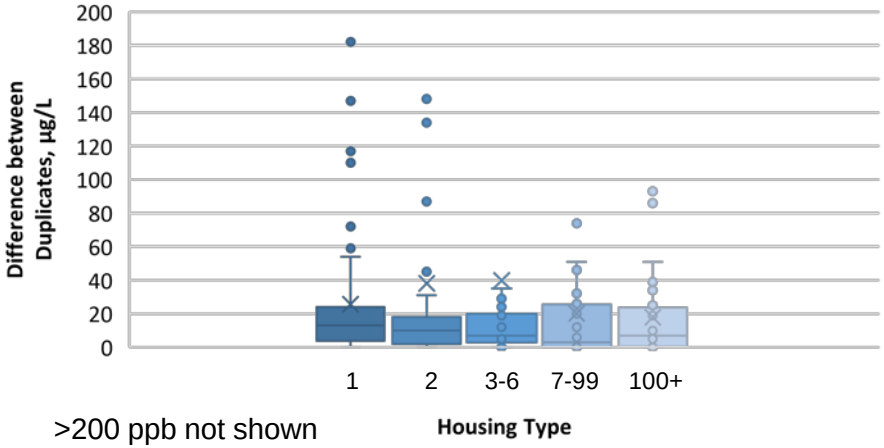


>200 ppb not shown

Units per Building	Median [Pb], µg/L	Count	Geometric Mean [Pb], µg/L	Max [Pb], µg/L
1	7	352	7.3	293
2	7	222	12.6	5924
3-6	6	79	2.0	6768
7-99	7.5	80	8.7	2015
100+	4	55	9.9	1469

1-2MF – Variability by Housing Type





>200 ppb not shown

Units per Building	Median [Pb], µg/L	Count	Geometric Mean [Pb], µg/L	Max [Pb], µg/L
1	19	353	2.5	1246
2	11.5	221	9.0	1519
3-6	11	79	7.3	904
7-99	2	81	4.8	279
100+	0	54	7.1	93

Special Cases

Sample Date	Tap location	FD Stagnation time (h)	FD Pb (µg/L)	1-2 MF Pb (µg/L)	5MF Pb (µg/L)	FD Cu (µg/L)	1-2 MF Cu (µg/L)	5MF Cu (µg/L)
4/21/2017	Ice Maker	8	3	3		4257	4582	
5/13/2017	Kitchen	10	0	0	0	245	47	77

Manhattan, 28-story 316 unit residence built in 1941

Sample Date	Tap location	FD Stagnation time (h)	FD (µg/L)	1-2 MF (µg/L)	5MF (µg/L)
7/31/2014		6	17	47	
9/23/2014	Kitchen	6	18	30	10
11/25/2014			13	0	
3/19/2018	Kitchen	7	5	6	

2 months post LSL Removal →

Bronx, 2-story 1 unit residence built in 1939

Sample Date	Tap location	FD Stagnation time (h)	FD (µg/L)	1-2 MF (µg/L)	5MF (µg/L)
11/1/2017	Kitchen	10	106	49	
11/26/2017	Kitchen	48	1	0	0

2 days post LSL Removal →

27 days post LSL Removal →

Brooklyn, 3-story 2 unit residence built in 1899

Summary

- The Free Residential Program informs customers if a lead source is likely present and provides details on distribution system-wide lead levels.
- When limited to sites that likely have a lead source:
  - Extremely high lead levels (>500 µg/L) are generally not repeatable
  - 1-2MF duplicate samples are more correlated than FD samples, although neither are strongly correlated
  - 1-2MF sample values are dependent on housing type, with larger values observed in 1, 2, and 3-6 family homes, likely due to the presence of a LSL
  - 5MF is effective for reducing high lead (≥ 50 µg/L) to ≤15 ppb for most samples (84% in this case)
  - FD duplicate samples with an average concentration <6 µg/L are the most repeatable
  - Multi-unit residences produce less repeatable Pb samples than single and double unit residences, especially for first draw samples

Questions?

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More Information:

Agency Website:

www.nyc.gov/dep

2017 Annual Water Quality Report:

http://www.nyc.gov/html/dep/pdf/wsstate17.pdf