



Tropical Storms Irene and Lee in Perspective

Historical Precipitation and Microbiological Response
in the Kensico Watershed

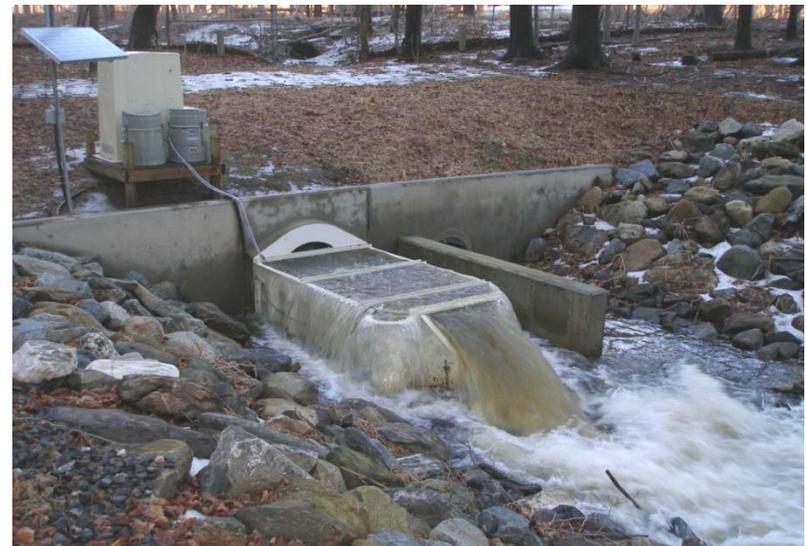
Kerri A. Alderisio and Christian Pace

NYWEA

September 14, 2012

Watershed Science and Technical Conference, West Point N.Y.

- Kensico Reservoir
- Summary of Irene and Lee
- Historical precipitation
- Similar storms
and fecal coliform data
- Compare with Irene and Lee
- Kensico streams
- Conclusions



Kensico Reservoir – Sites & Sub-basins

Aqueducts

2 Influent

2 Effluent

Streams

8 perennial

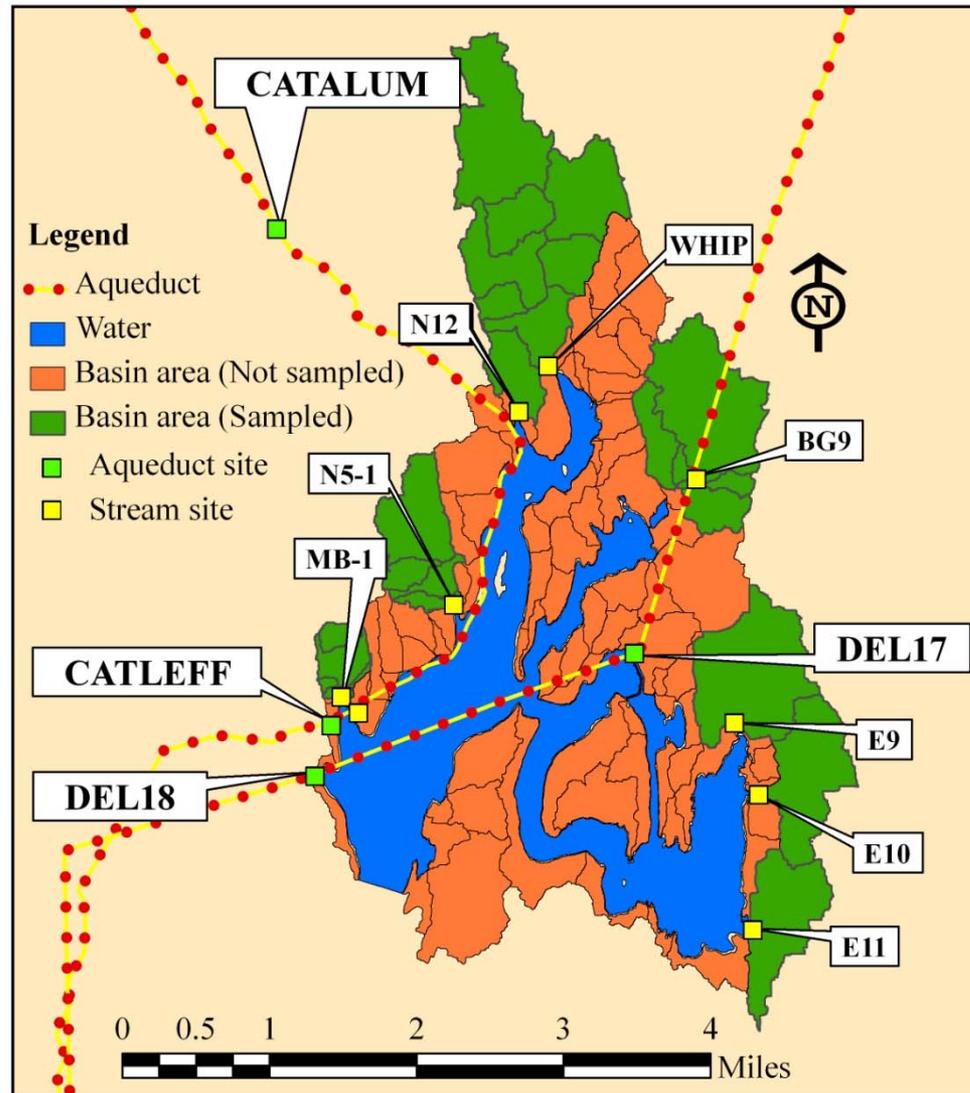
Watershed

46% sampled

(green)

54% not sampled

(orange)



Here come the storms...

Atlantic 2011 Storms

Hurricane Katia

Dates: 08/29 - 09/10 2011
 Maximum Wind Speed: 135 mph
 Minimum Pressure: 946 mb
 US Landfall Category: unknown
 Deaths: 0
 US Damage (Millions US \$): 0

Storm Category

Storm Category

| Tropical Depression | Tropical Storm | Category 1 | Category 2 | Category 3 | Category 4 | Category 5 |
|---------------------|----------------|------------|------------|-------------|-------------|------------|
| < 39 mph | 39-73 mph | 74-95 mph | 96-110 mph | 111-130 mph | 131-155 mph | 156+ mph |

Weather Underground®
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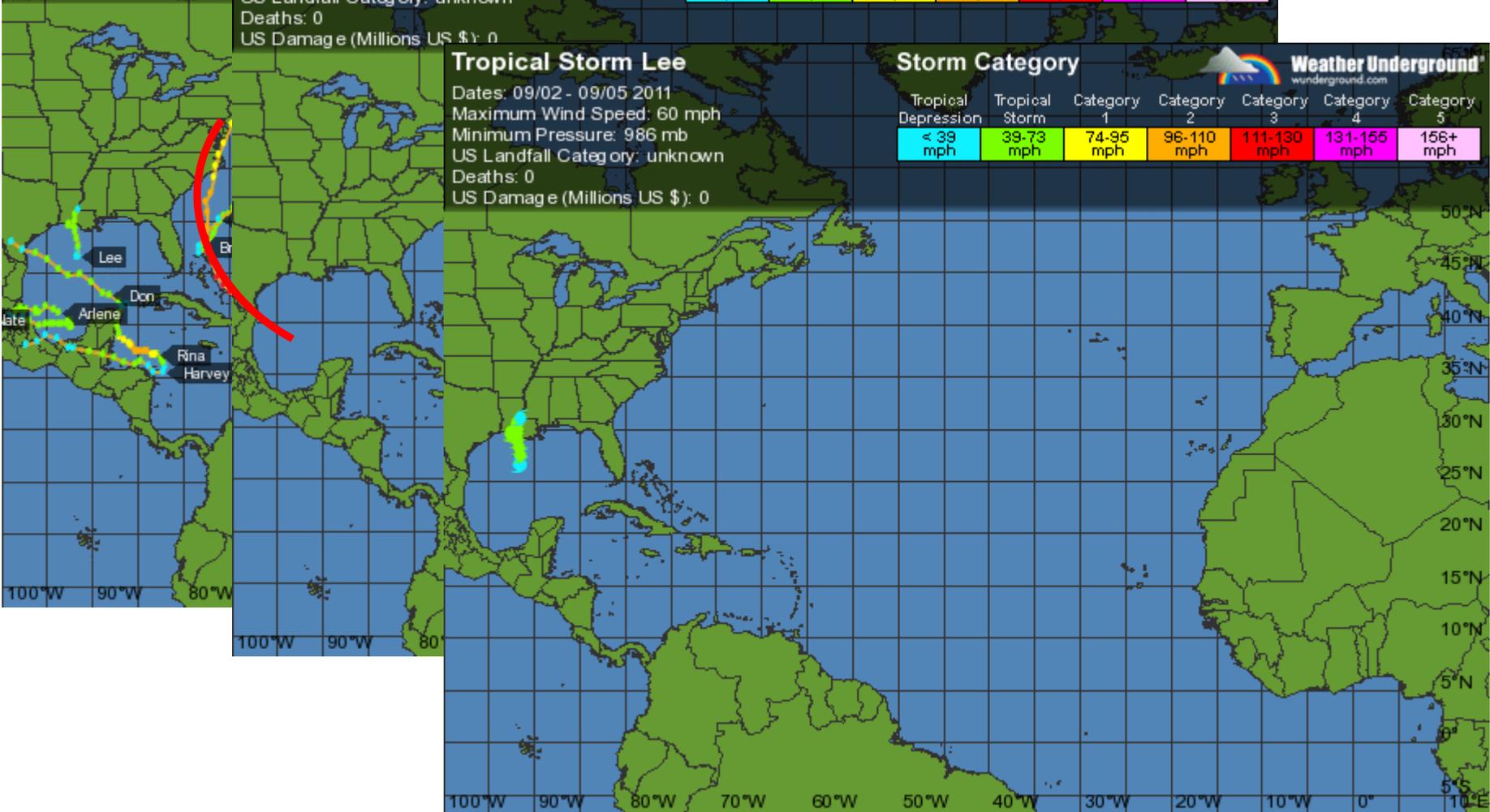
Tropical Storm Lee

Dates: 09/02 - 09/05 2011
 Maximum Wind Speed: 60 mph
 Minimum Pressure: 986 mb
 US Landfall Category: unknown
 Deaths: 0
 US Damage (Millions US \$): 0

Storm Category

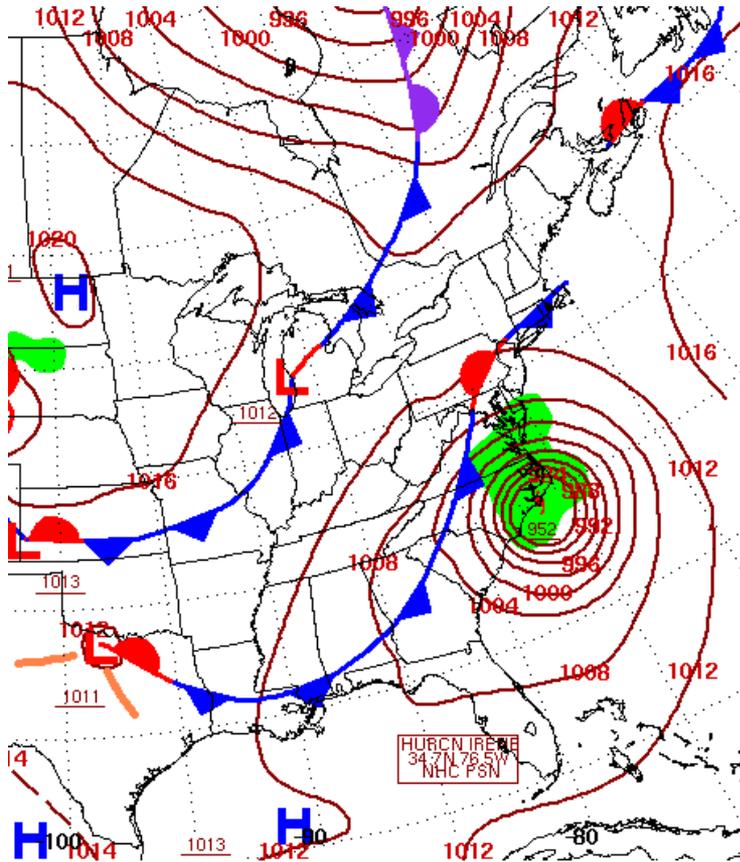
| Tropical Depression | Tropical Storm | Category 1 | Category 2 | Category 3 | Category 4 | Category 5 |
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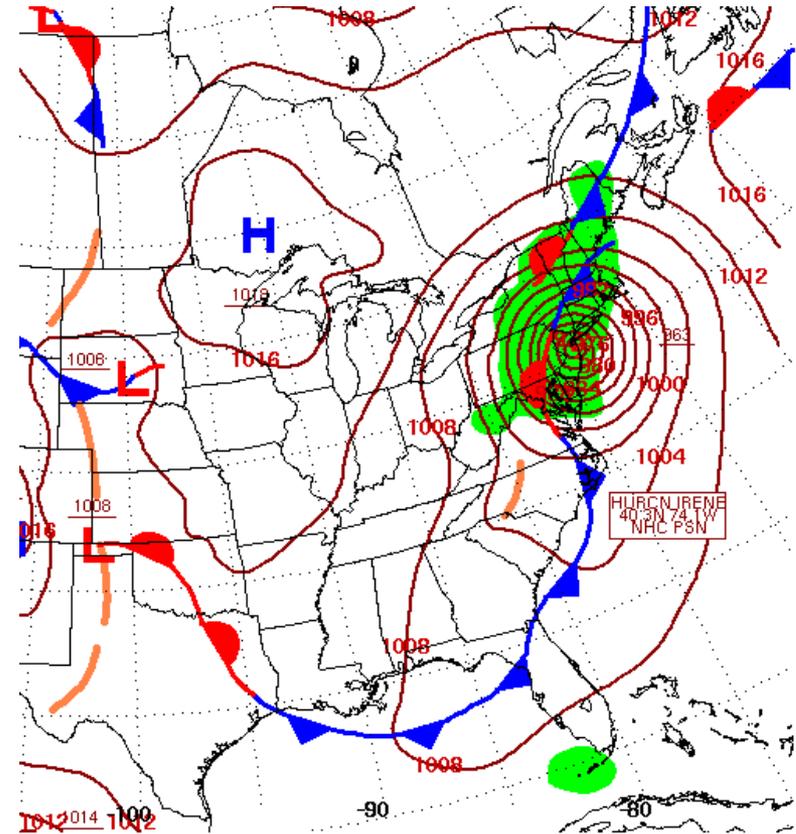
Irene's Arrival

August 27, 2011 7:00am



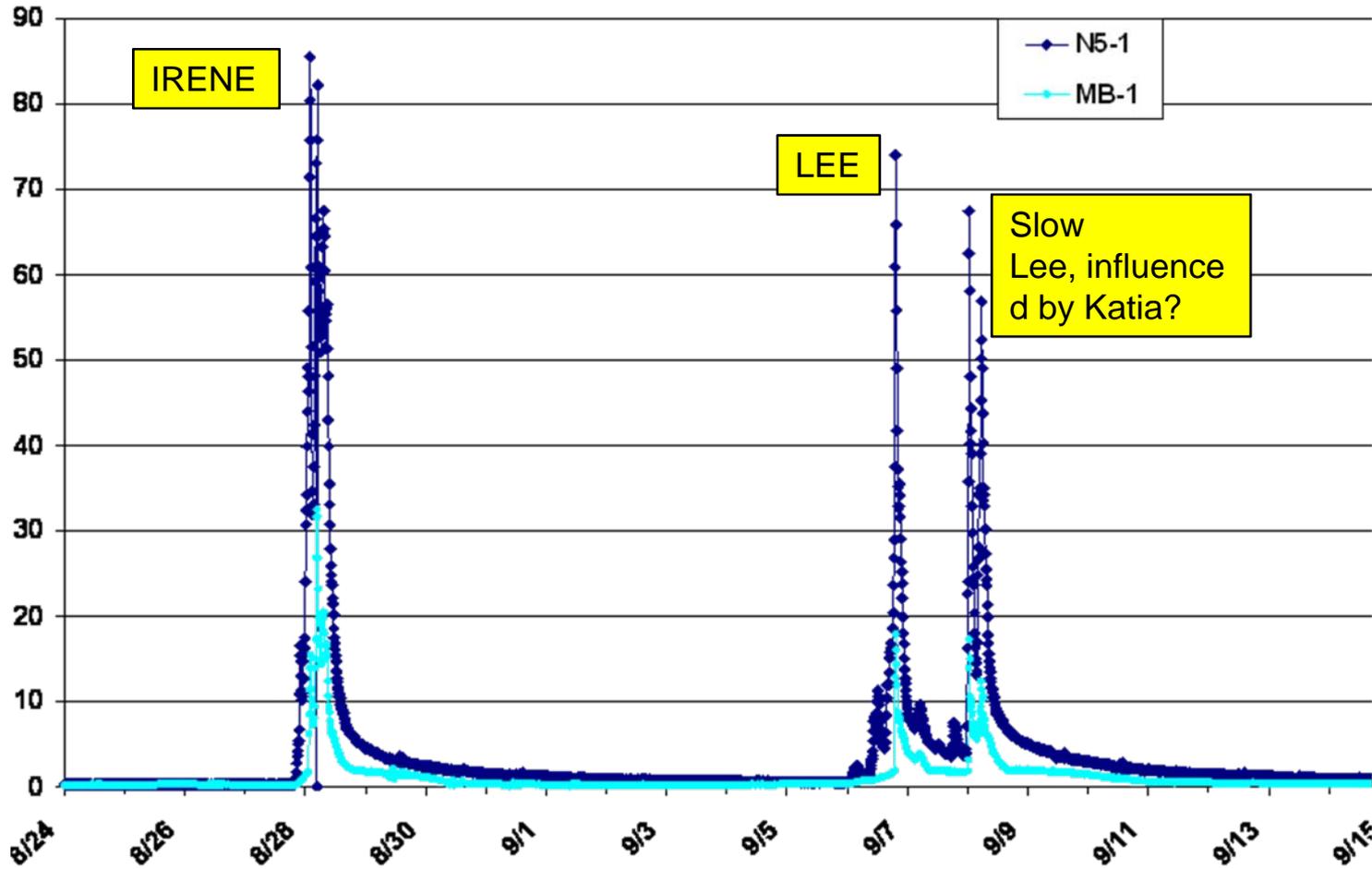
Weather Map at 7:00 A.M. E.S.T.

August 28, 2011 7:00am



Weather Map at 7:00 A.M. E.S.T.

Hydrograph of T.S. Irene, Lee, and...



T.S. Lee's Arrival, Hurricane Katia off shore

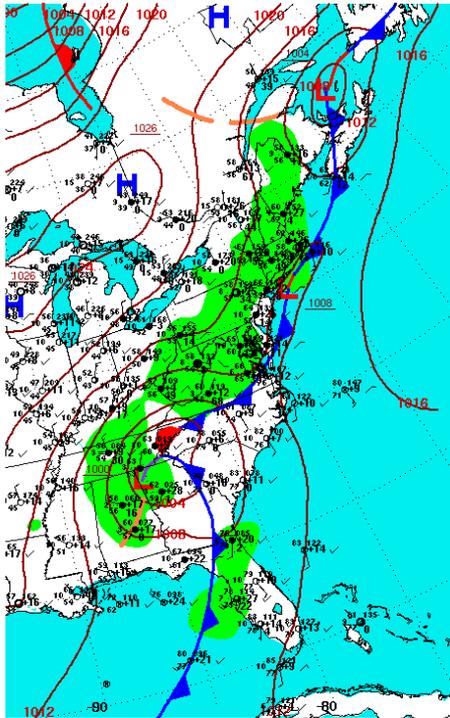
Precipitation began on Sep 5, 2011...

Sep 9, 2011

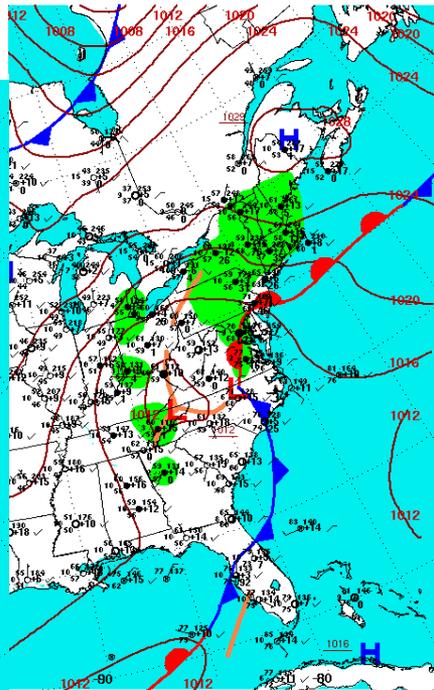
Sep 8, 2011

Sep 7, 2011

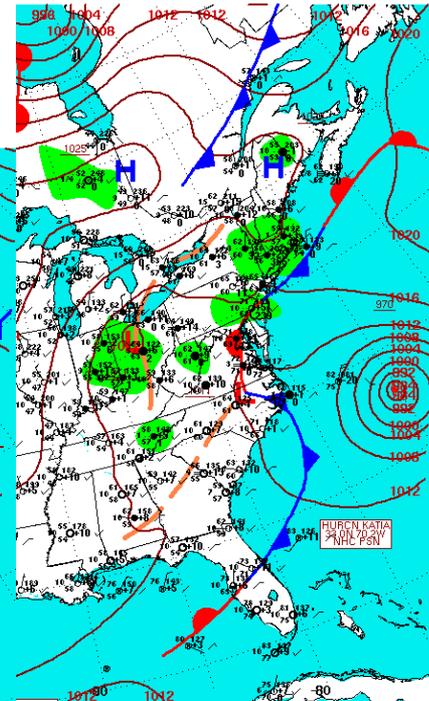
Sep 6, 2011



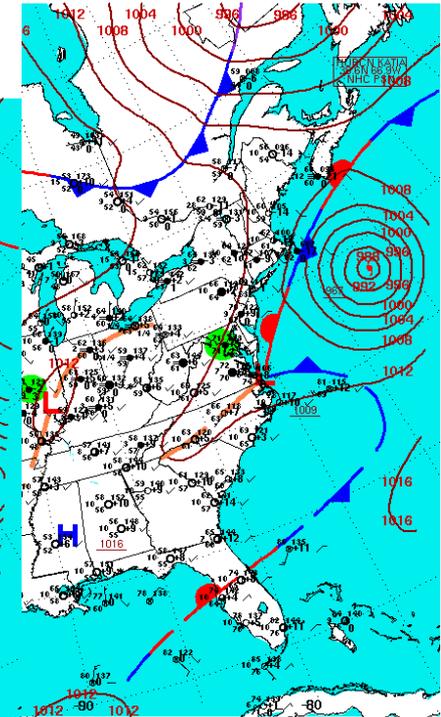
at 7:00 A.M. E.S.T.



at 7:00 A.M. E.S.T.



at 7:00 A.M. E.S.T.

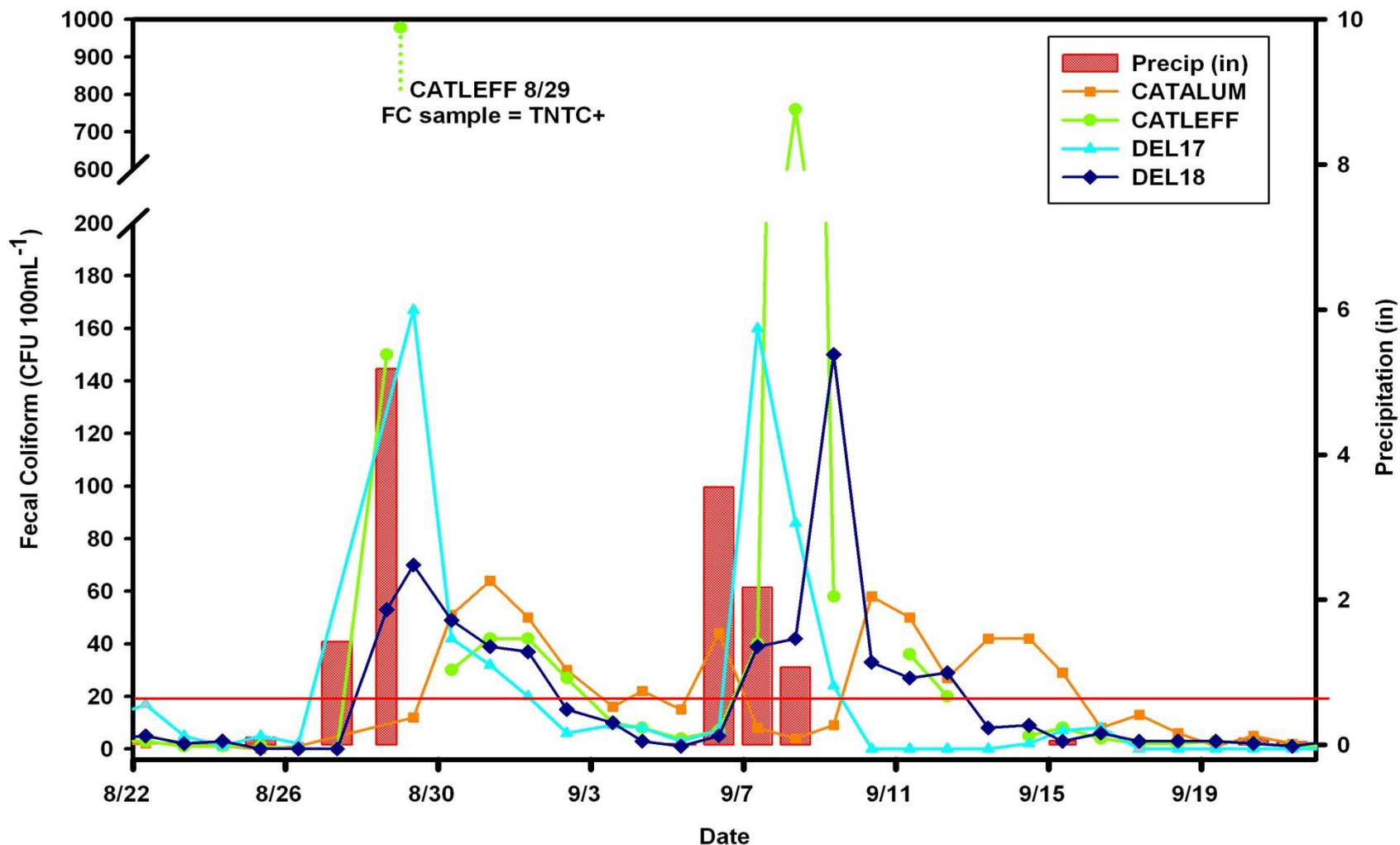


7:00 A.M. E.S.T.

Each image captured at 7:00am

Kensico Fecal Coliform Results

T. S. Irene and Lee, late August – early September 2011

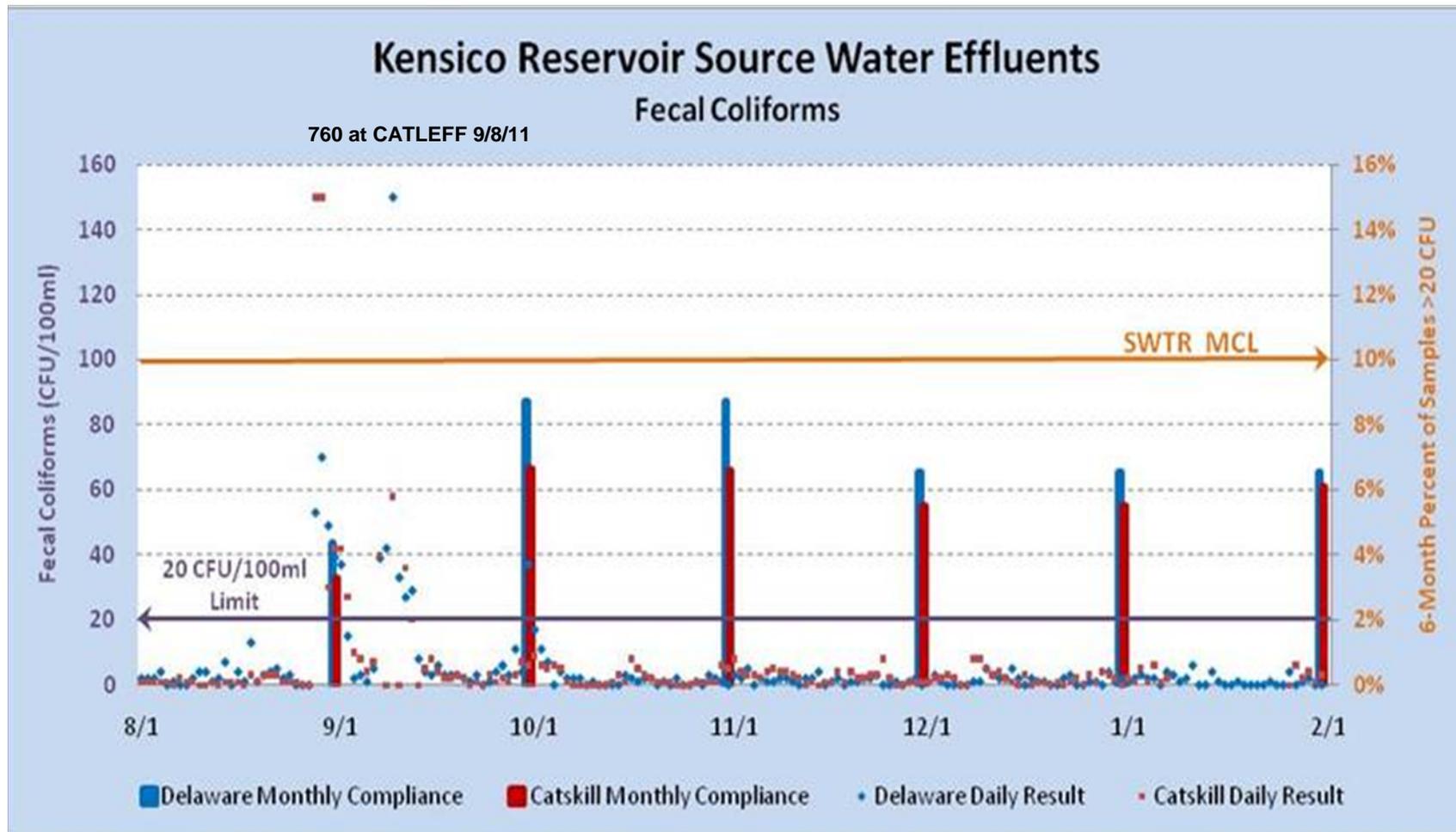


- Filtration Avoidance (FA) allows <10% samples to have fecal coliform (FC) concentrations over 20/100mL per 6 month period
- IRENE
 - Precip: 1.42" 8/27 and 5.18" 8/28 = 6.60" total
 - 6 hits CAT (8/28 – 9/2) and
5 hits DEL (8/28 – 9/1)
- LEE
 - Precip: 0.01" 9/5, 3.55" 9/6, 2.17" 9/7, 1.07" 9/8 = 6.80" total
 - 4 hits CAT (9/7-9/11...9/10 = no sample) and 6 hits DEL (9/7-9/12)
- From Apr-Sep 2011 CAT/DEL had 28 samples >20 FC/100mL, 21 of which were a result of IRENE and LEE
- 28 out of 36 samples >20 FC, or 7.8% out of <10% allowed, is the maximum NYC has seen since the promulgation of the SWTR (1989) and FA (1991)



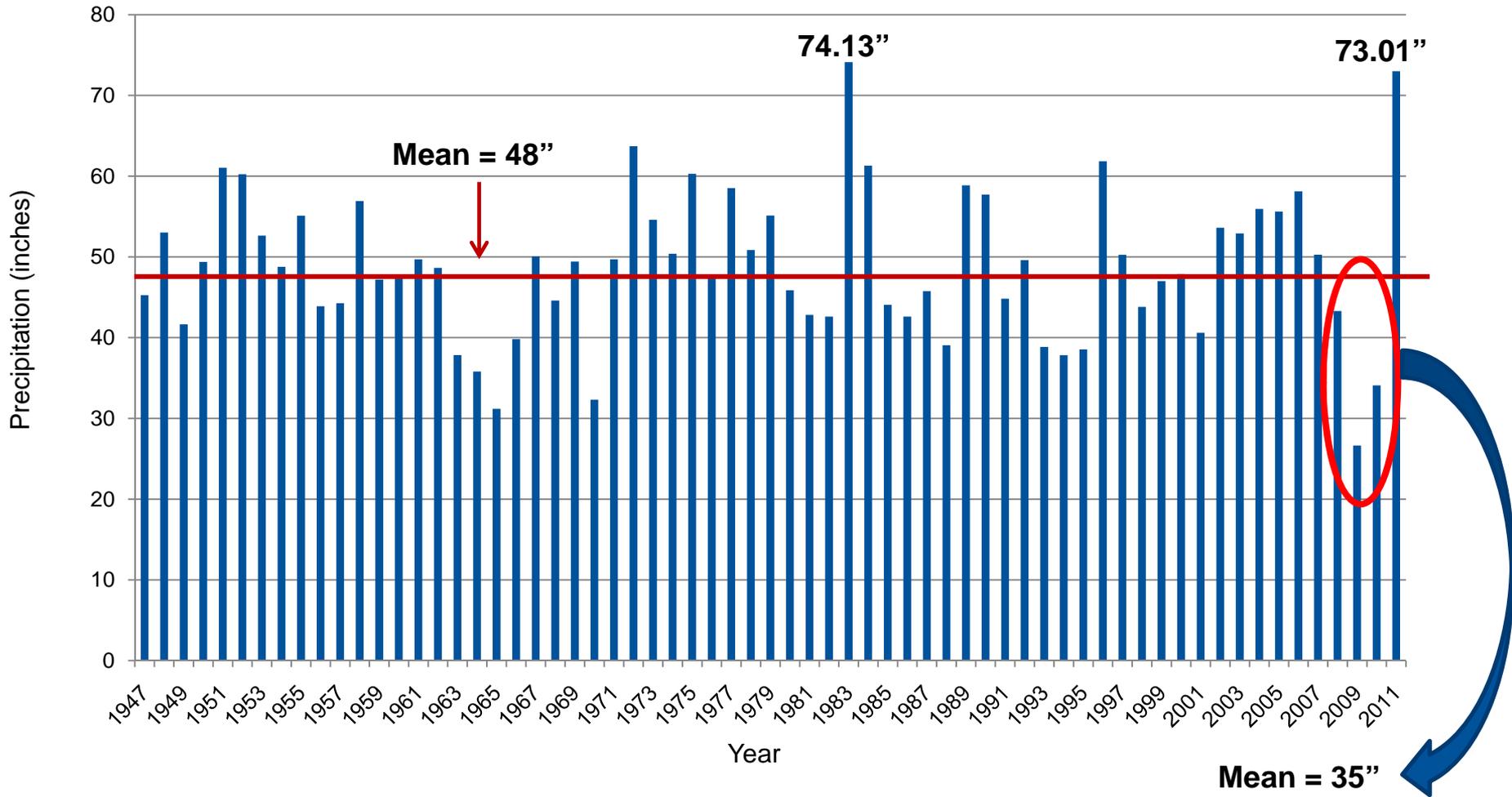
Satellite image: Susquehanna R. Sep, 10, 2011

NYC Source Water Results Aug 2011– Jan 2012



Have we seen this precipitation before?

Kensico Area Precipitation 1947 – 2011 Westchester County Airport Measurements – 65 years



65 Year Precipitation Summary

Top 10 Precipitation Events at Kensico

| Year | Total rainfall |
|------|----------------|
| 1983 | 74.13 |
| 2011 | 73.01 |
| 1972 | 63.71 |
| 1996 | 61.85 |
| 1984 | 61.30 |
| 1951 | 61.05 |
| 1975 | 60.29 |
| 1952 | 60.24 |
| 1989 | 58.87 |
| 1977 | 58.52 |

Annual mean rainfall for all data (n=65) = 48 inches

Number of days per year >1.5" precipitation

| 65 year dataset | # days >1.5"/ year |
|-----------------------------|--------------------|
| Mean | 6.27 |
| Median | 6 |
| 95 th percentile | 11 |

Years 95th percentile was exceeded:

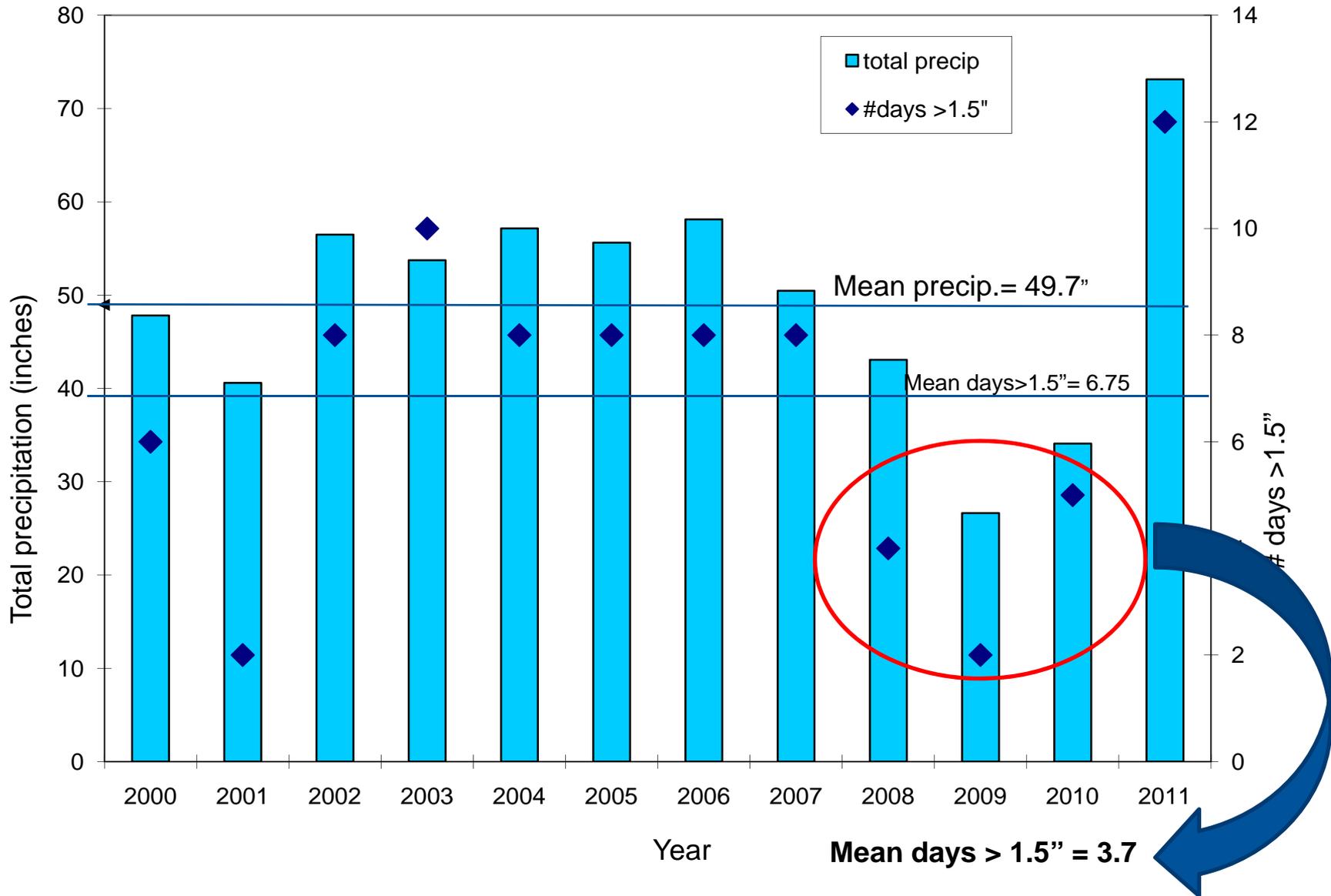
1952 = 13 days

1983 = 13 days

2011 = 12 days

Kensico Total Precipitation and Days >1.5"

Most Recent 12 years of data...



Rain vs. Duration - History

- From when T.S. Irene precipitation started to when Lee ended = 13 days
- Only 6 other times in 65 years did precipitation exceed 10 inches in 13 days

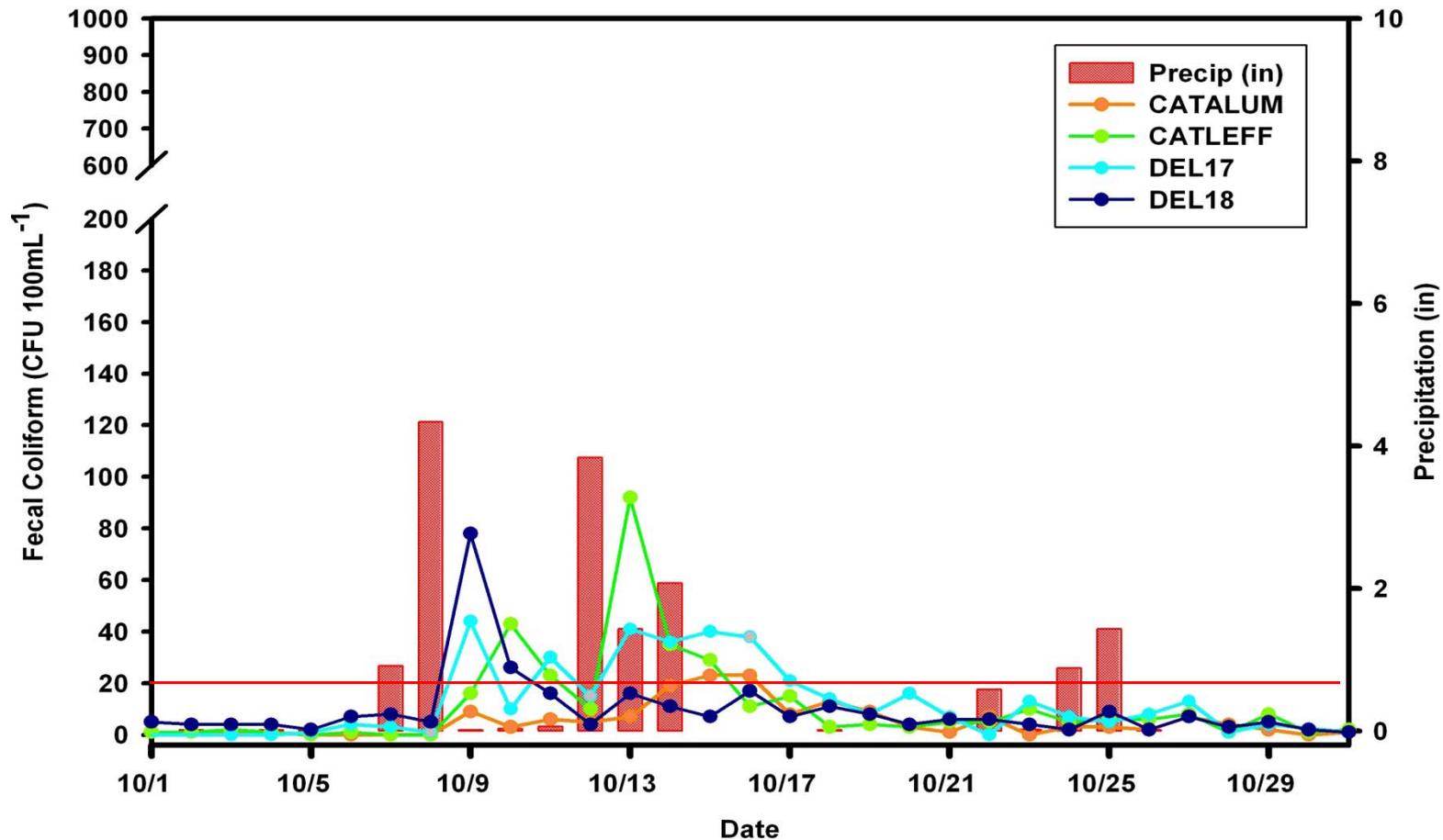
| Date | 13 day precip. | Source |
|---------------------------|----------------|-----------------------|
| Aug 1955 | 11.92" | Hurricane Connie |
| Oct 1955 | 10.31" | Not identified |
| (About 20 years later...) | | |
| Jun 1972 | 11.90" | Hurricane Agnes |
| Sep 1975 | 12.15" | Hurricane Eloise |
| (30 years later...) | | |
| Oct 2005 | 12.74" | T.S. Tammy |
| Apr 2007 | 10.29" | Not identified |
| Sep 2011 | 13.41" | T.S. Irene & T.S. Lee |

1987 FC record,
1989 SWTR &
1991 FA

Let's see
what
happened
here...

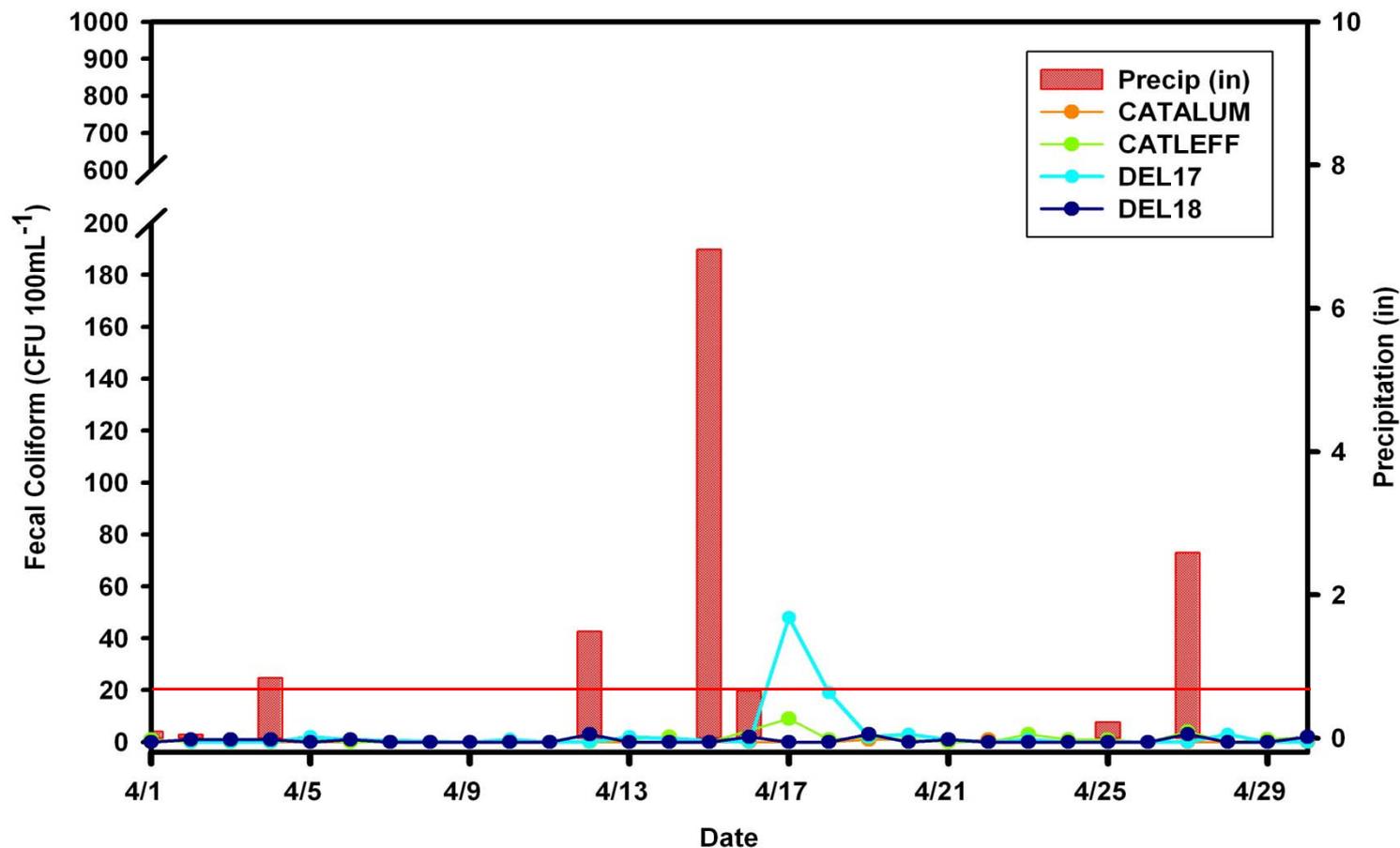
Microbial Response to Oct 2005 Event

- Tropical Storm Tammy
- 12.74" in 13 day period
- 7 hits >20 FC at Kensico effluents combined

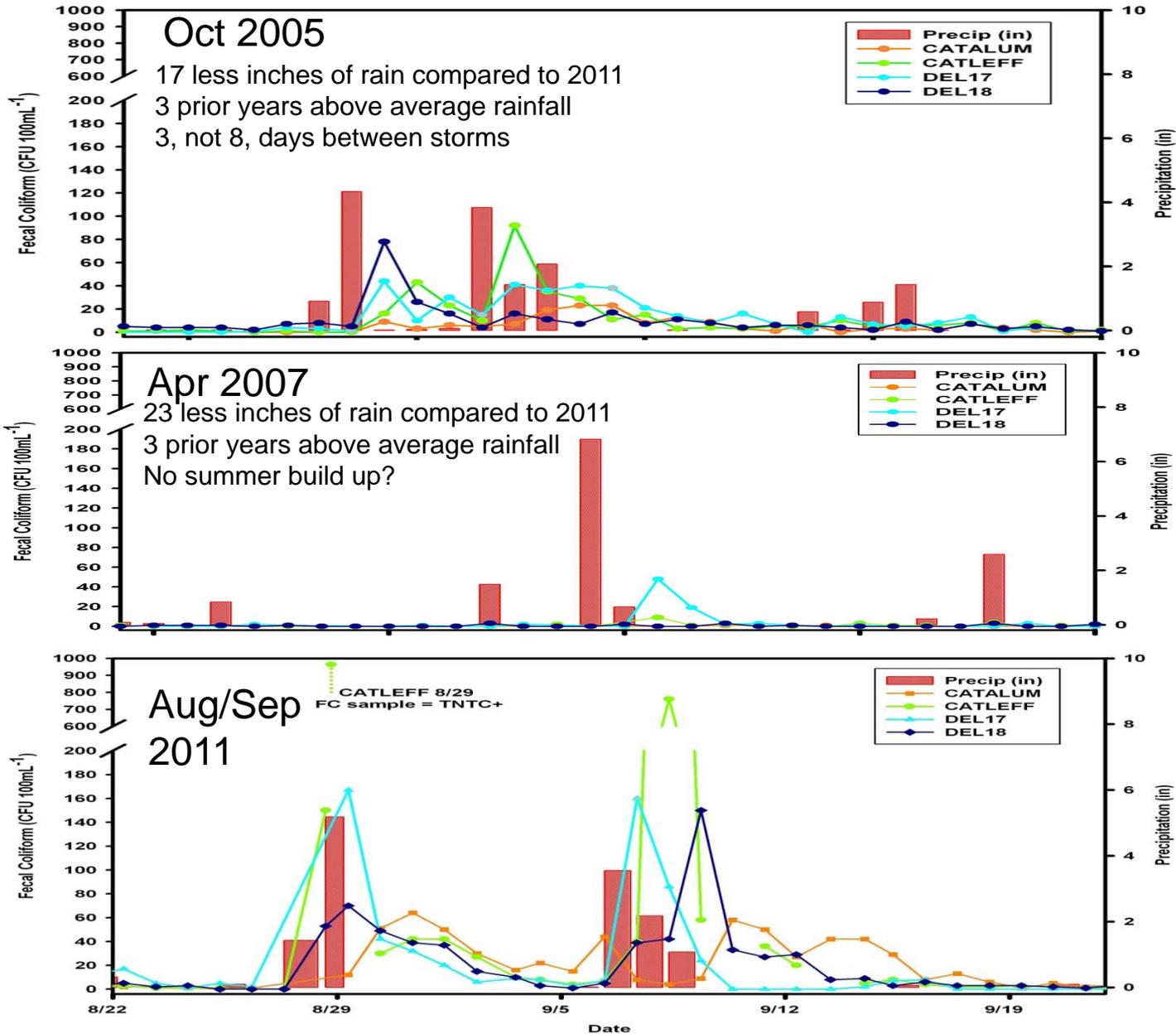


Microbial Response to April 2007 Event

- Unnamed Storm April 2007
- 10.29" in 13 day period
- No hits >20 FC at Kensico effluents



How was it different?



Kensico Fecal Coliform for events >10" in 13 days

- Irene and Lee = 17 days from first hit >20 FC to last
- Data for 17 day period after each storm examined
- 2011 data resulted in all maximum values (in and out of the reservoir)

| | | T.S. Tammy '05 | | Unkn Storm '07 | | T.S. Irene/Lee '11 | |
|---------------------|----------|----------------|------|----------------|-----|--------------------|-------|
| | FC/100ml | CAT | DEL | CAT | DEL | CAT | DEL |
| Aqueduct Inputs | Mean | 8.0 | 19.8 | 0.2 | 4.8 | 30.7 | 37.6 |
| | Median | 7 | 15 | 0 | 0 | 27 | 9 |
| | Max | 23 | 44 | 1 | 48 | 64 | 167 |
| | # >20 | 2 | 7 | 0 | 1 | 12 | 6 |
| Aqueduct Outputs | Mean | 17.9 | 13.8 | 1.6 | 0.8 | 78.5 | 35.41 |
| | Median | 10 | 8 | 1 | 0 | 30 | 33 |
| | Max | 92 | 78 | 9 | 3 | 760 | 150 |
| | # >20 | 5 | 2 | 0 | 0 | 10 | 11 |

- Catskill and Delaware Aqueduct inflows comprise nearly all of the input flow for Kensico Reservoir water budget
- Kensico water budget from 8 perennial streams:
 - Base flow <1%
 - Storm flow increases to 5%... or more...
- Drainage for the 8 streams is only 46% of the watershed
 - During storms, runoff is also coming in from 54% of the watershed by ephemeral streams and overland sheet flow
 - Especially during heavy events, many more particulates and microbes will be mobilized
- The heavier and longer it rains, the zone of mobilization will be increased
- Increased FC load from aqueduct inflows increases the baseline level, and the increased FC from 8 streams, and increased load due to larger zone of mobilization in unsampled areas = YIKES!

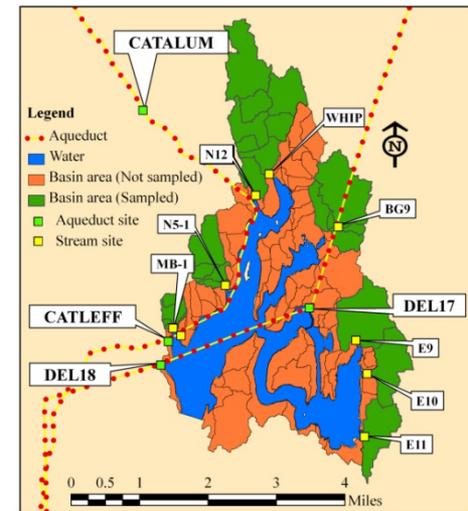
| | BG9 | E10 | E11 | E9 | MB-1 | N12 | N5-1 | WHIP |
|--------------------------------|-------|-------|--------|-------|-------|-------|-------|------|
| n | 4 | 4 | 4 | 4 | 6 | 4 | 6 | 5 |
| Mean FC 100ml ⁻¹ | 2,027 | 1,027 | 12,300 | 5,771 | 5,578 | 1,000 | 2,856 | 780 |
| 95%-tile 2001-2010 | 1,005 | 2,515 | 2,000 | 2,160 | 2,745 | 964 | 2,100 | 630 |

7 of 8 mean values exceeded 10 year 95th percentile, some by A LOT

Samples were not collected during peak flow, peak FC not represented

Based on loading calculations from other storms, a broad estimate of approximately 92 Trillion fecal coliforms entered the reservoir from these 8 streams in this 27 day period.

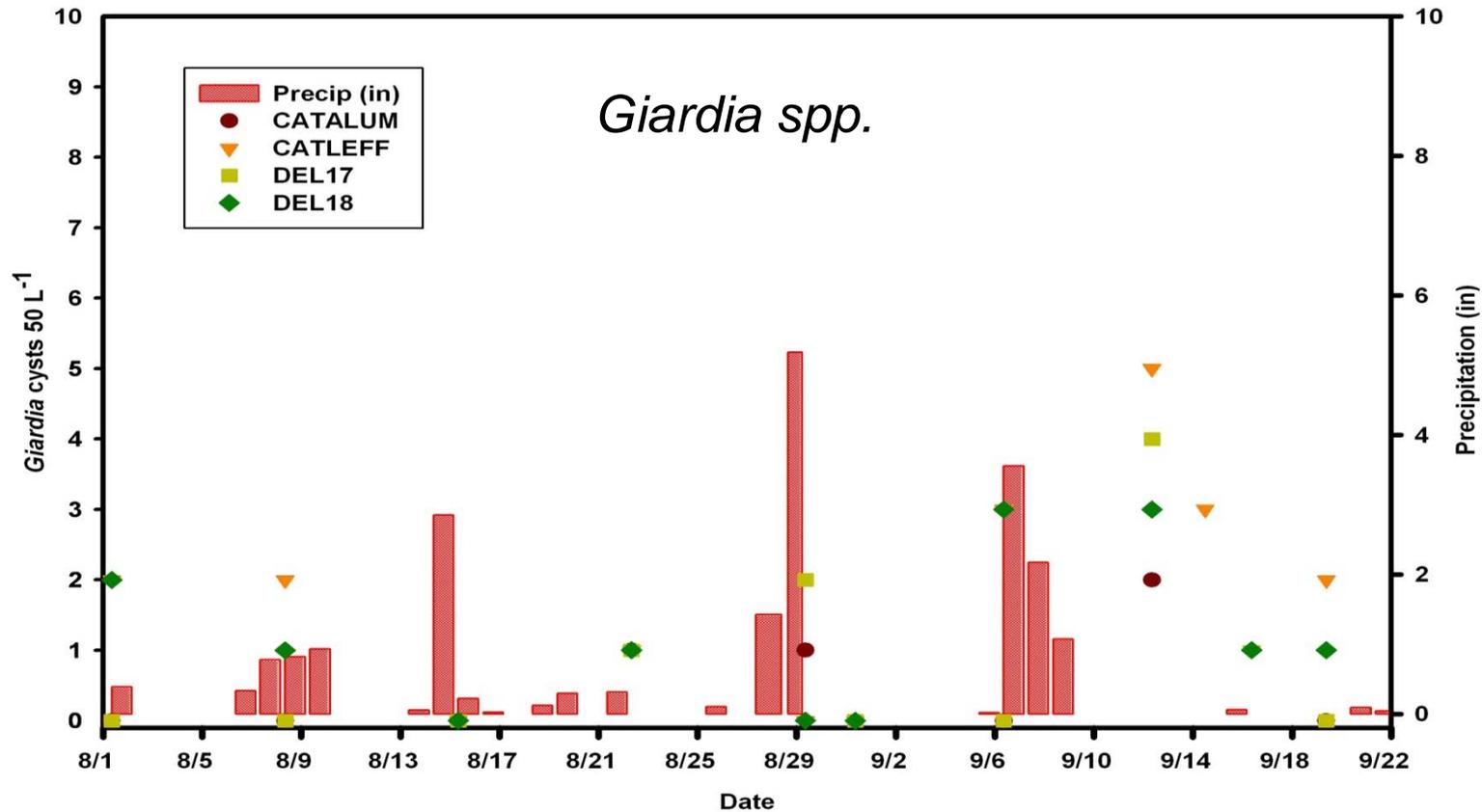
Only 46% of the watershed area is represented by these streams



Pathogen Response

- No *Cryptosporidium* oocysts were detected at the effluents of Kensico during this period, and no unusual virus results were noted.

Tropical Storms Irene and Lee
August - September 2011



- 2011 = 3 years prior, sub-average precipitation and less large events
- 2011 = 2nd wettest year on record since 1946
- 2011 = 2nd highest number of days >1.5" rain (>95th percentile, 12 yrs.)
- T.S. Irene and Lee = most rain in any 13 day period on 65 year record (13.42")
- T.S. Irene and Lee = highest mean, median, max and hits >20 FC compared to other storms >10" rain/ 13 day periods (reservoir inputs and outputs)
- Kensico FC output can be > aqueduct input (streams, sheet flow, sediments)
- Past mass balance protozoan work on perennials cannot not account for 26% of load – likely from unsampled parts of the watershed – FC are there too
- Safe to say the combination of storms in Aug/ Sep 2011, and the microbial response, has never occurred before in the history examined

Acknowledgements

- Jim Porter, Watershed Monitoring and Operations Support
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- Watershed WQ Operations field and laboratory staff

