Riverbank Filtration at the Charles M. Bolton Well Field Organic and Particle Reduction

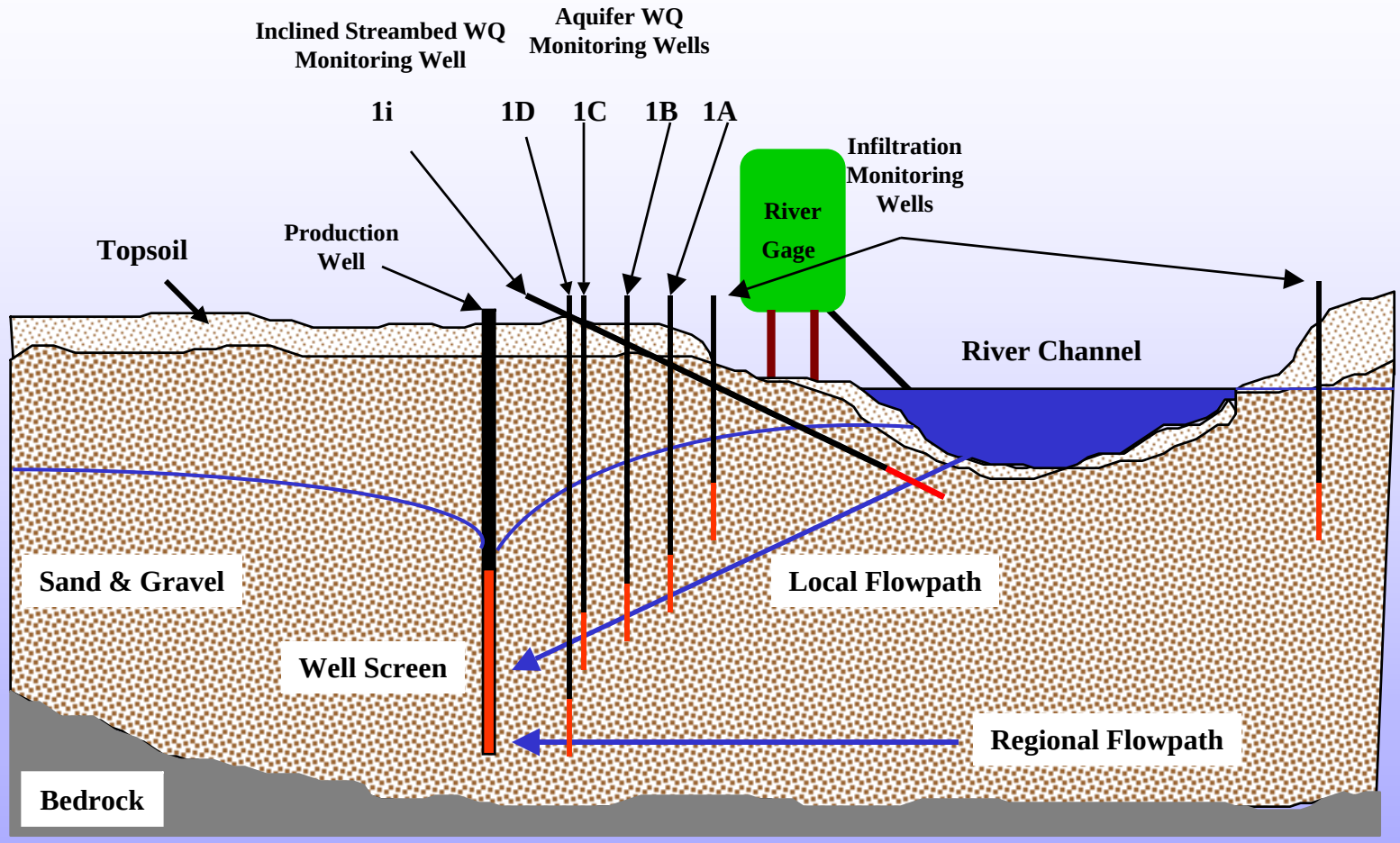
USEPA/USGS Meeting on Cryptosporidium
Removal by Bank Filtration
September 9-10, 2003

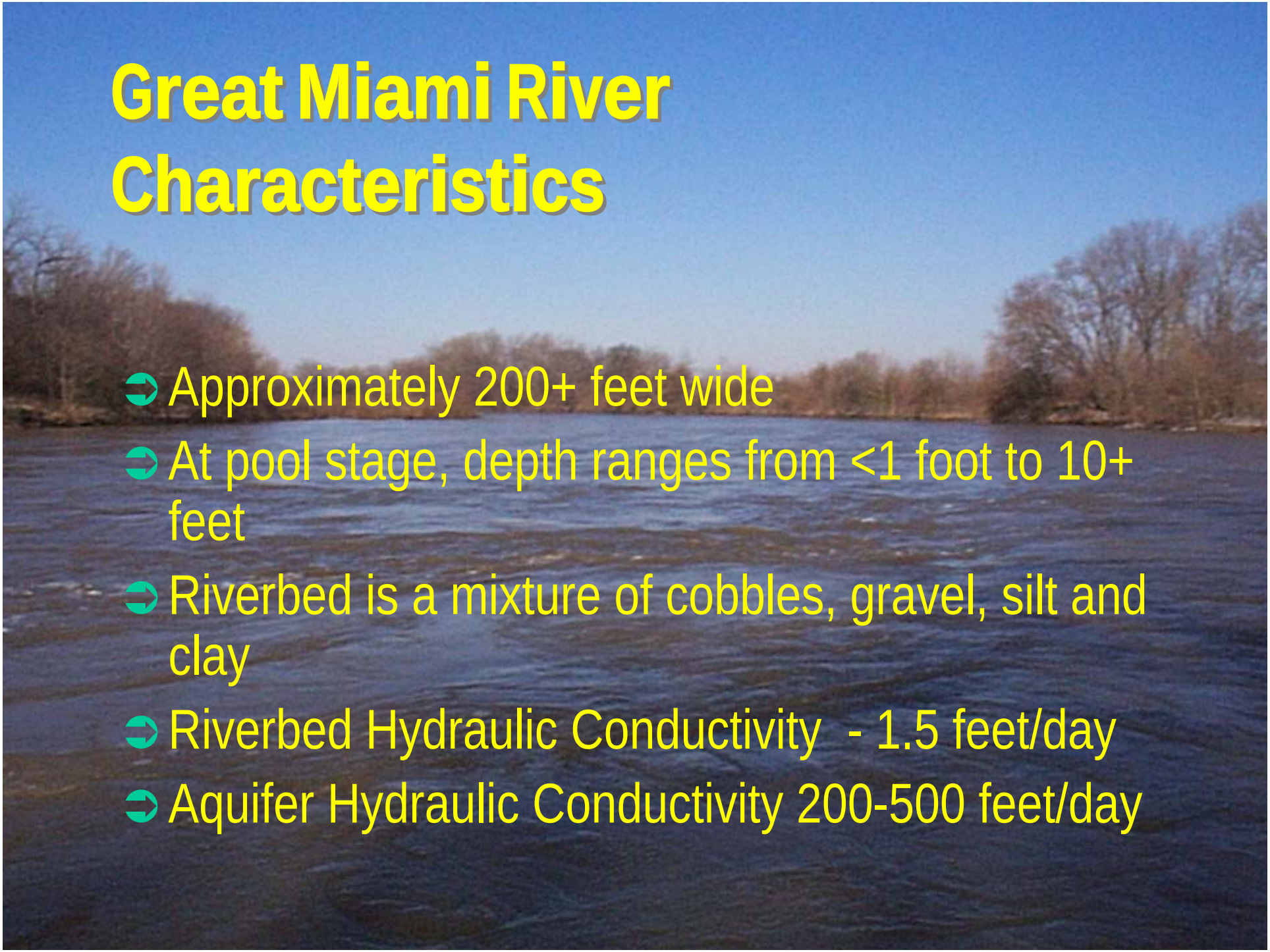
Bruce Whitteberry, Hydrogeologist

William Gollnitz, Supervisor of Treatment

Jeffrey Vogt, Chemist

Conceptual Aquifer Profile @ Bolton Well Field

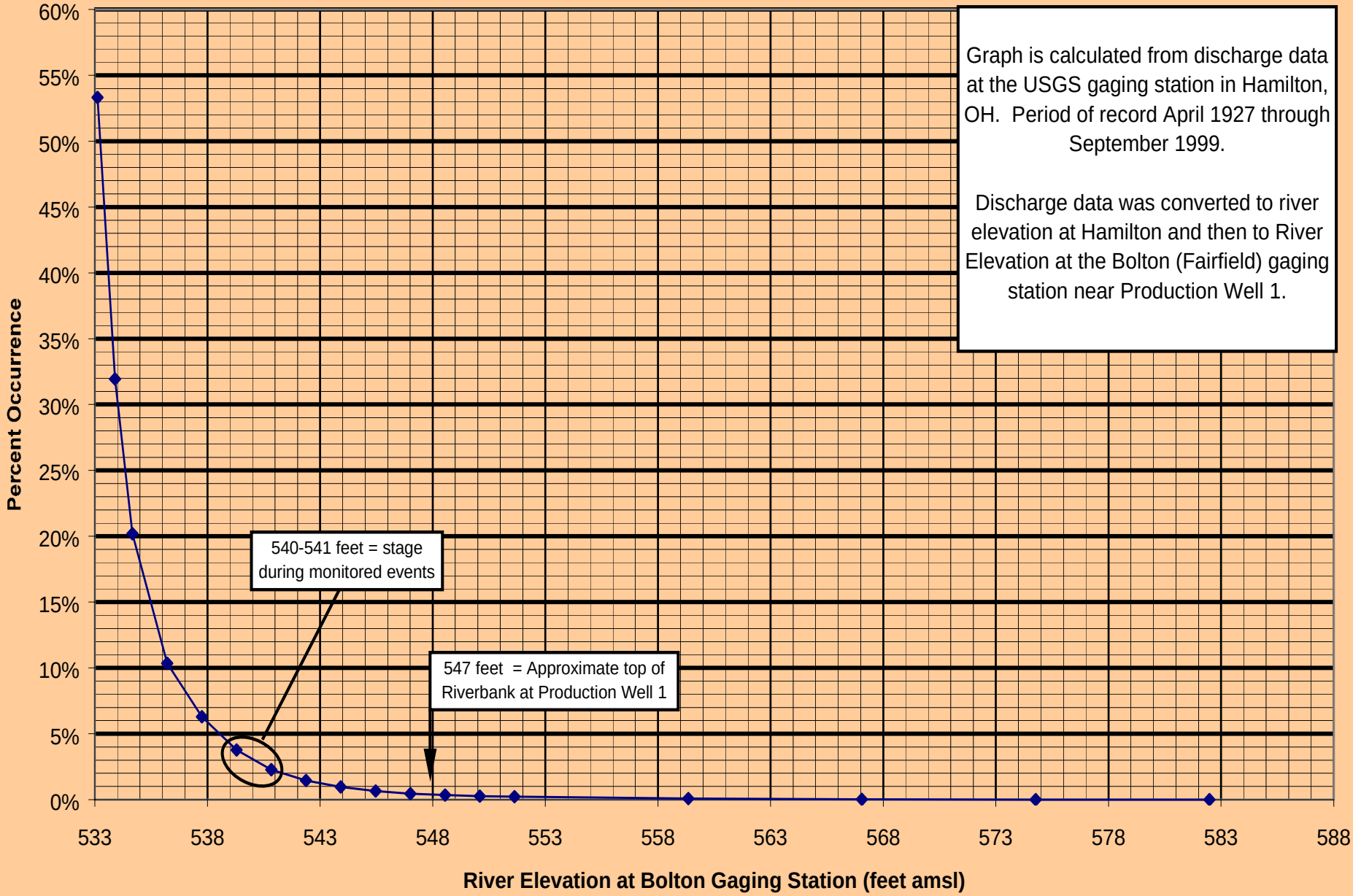


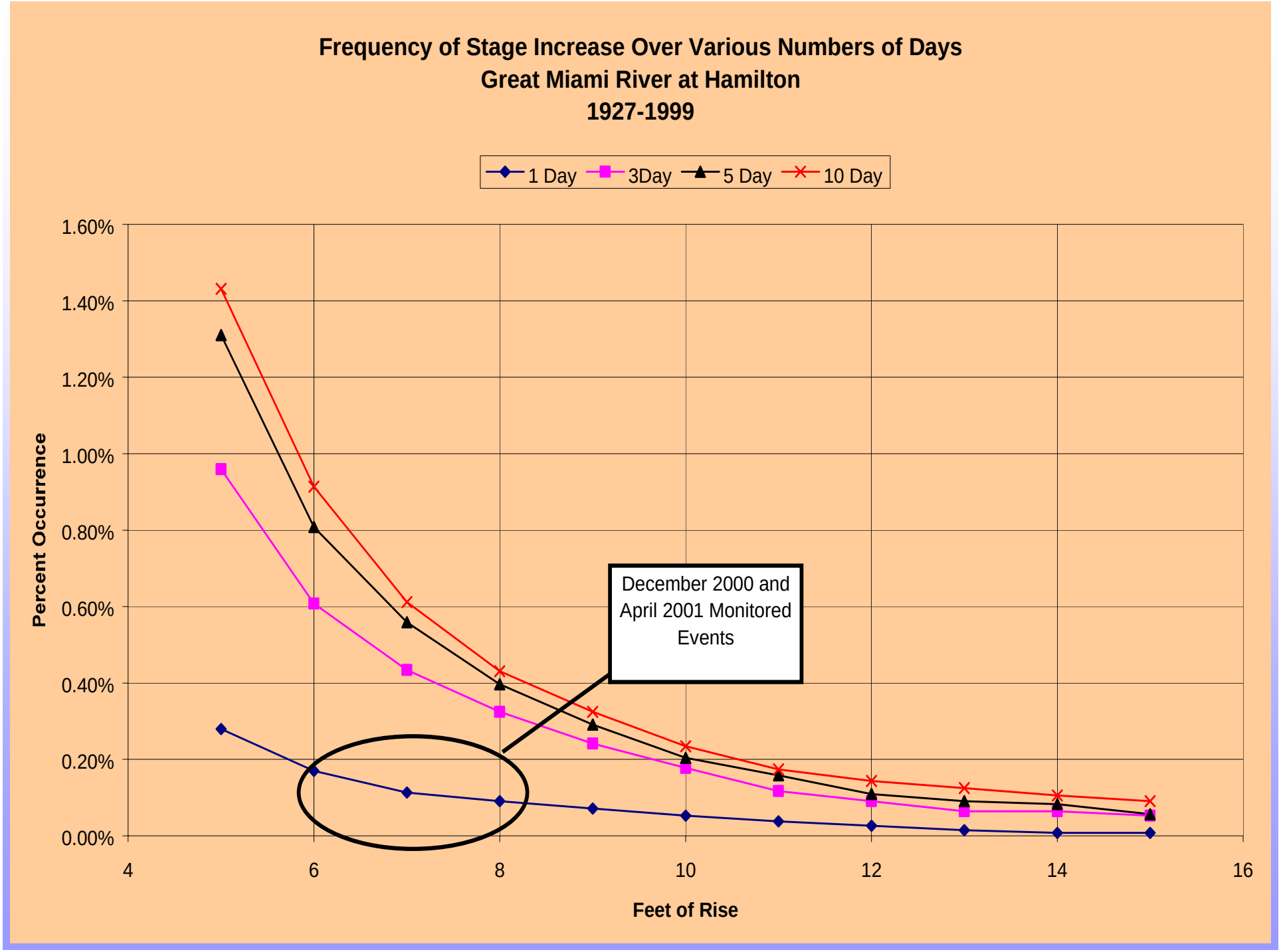


Great Miami River Characteristics

- Approximately 200+ feet wide
- At pool stage, depth ranges from <1 foot to 10+ feet
- Riverbed is a mixture of cobbles, gravel, silt and clay
- Riverbed Hydraulic Conductivity - 1.5 feet/day
- Aquifer Hydraulic Conductivity 200-500 feet/day

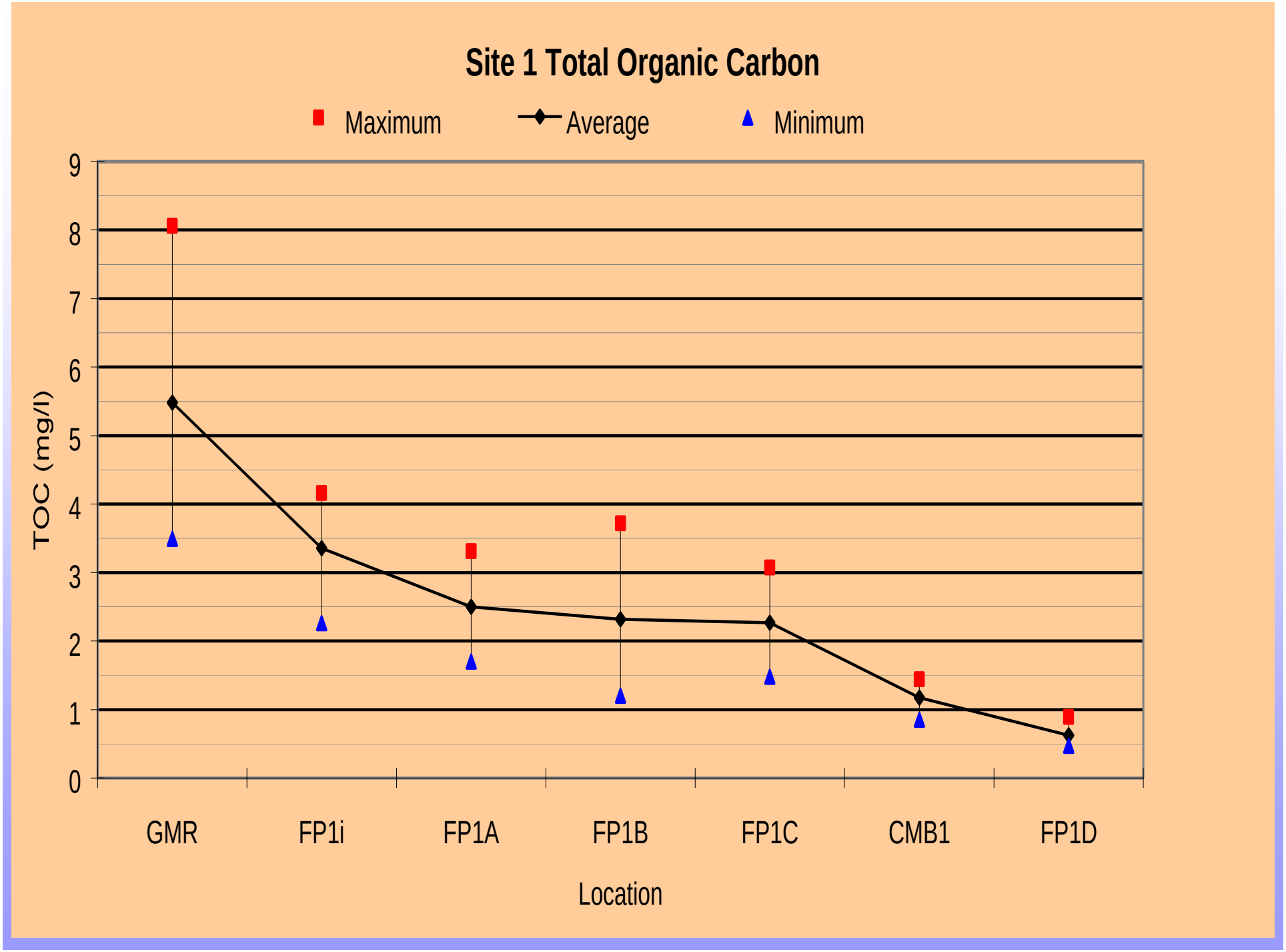
Stage Occurrences at C.M. Bolton Well Field

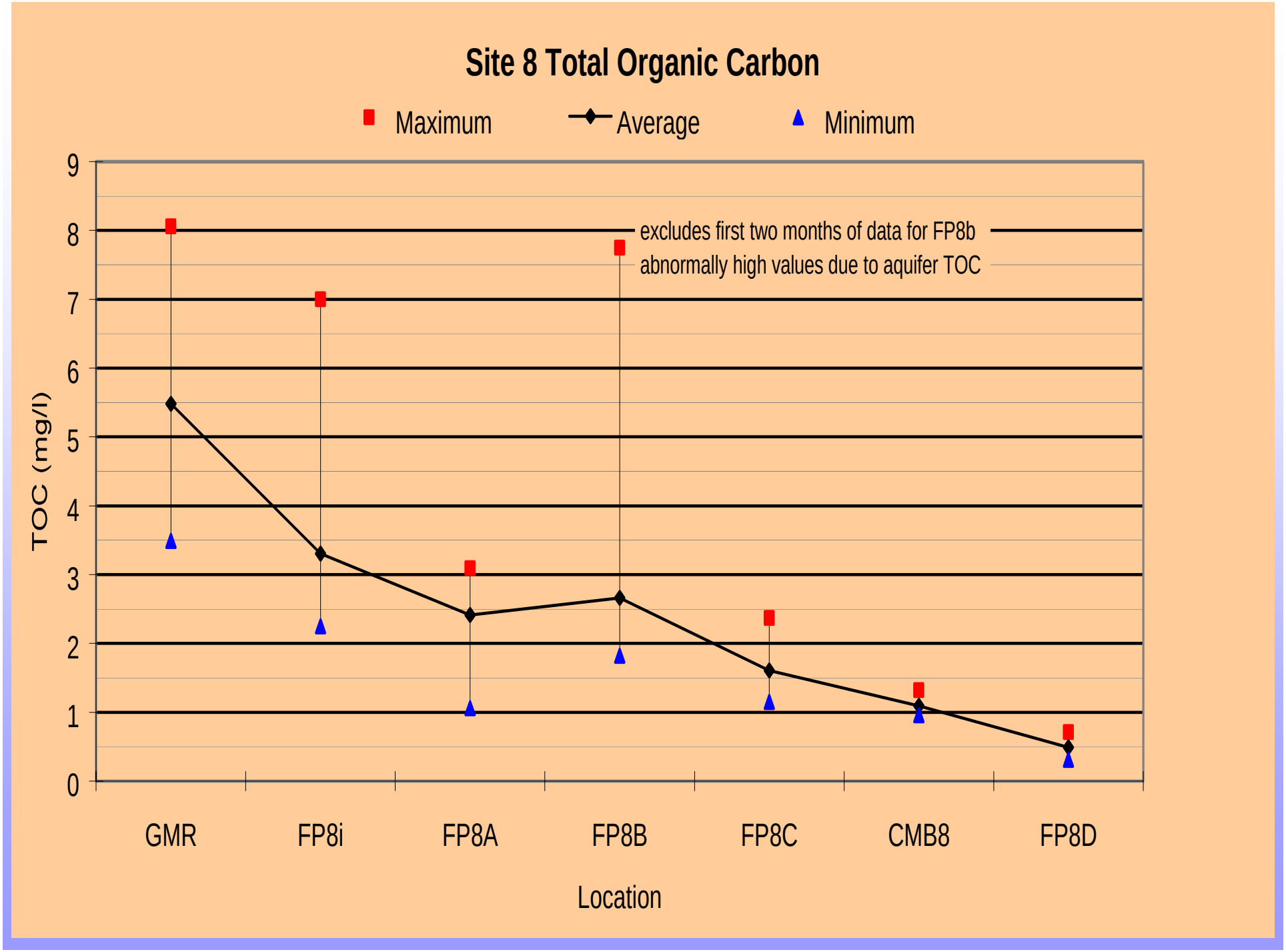


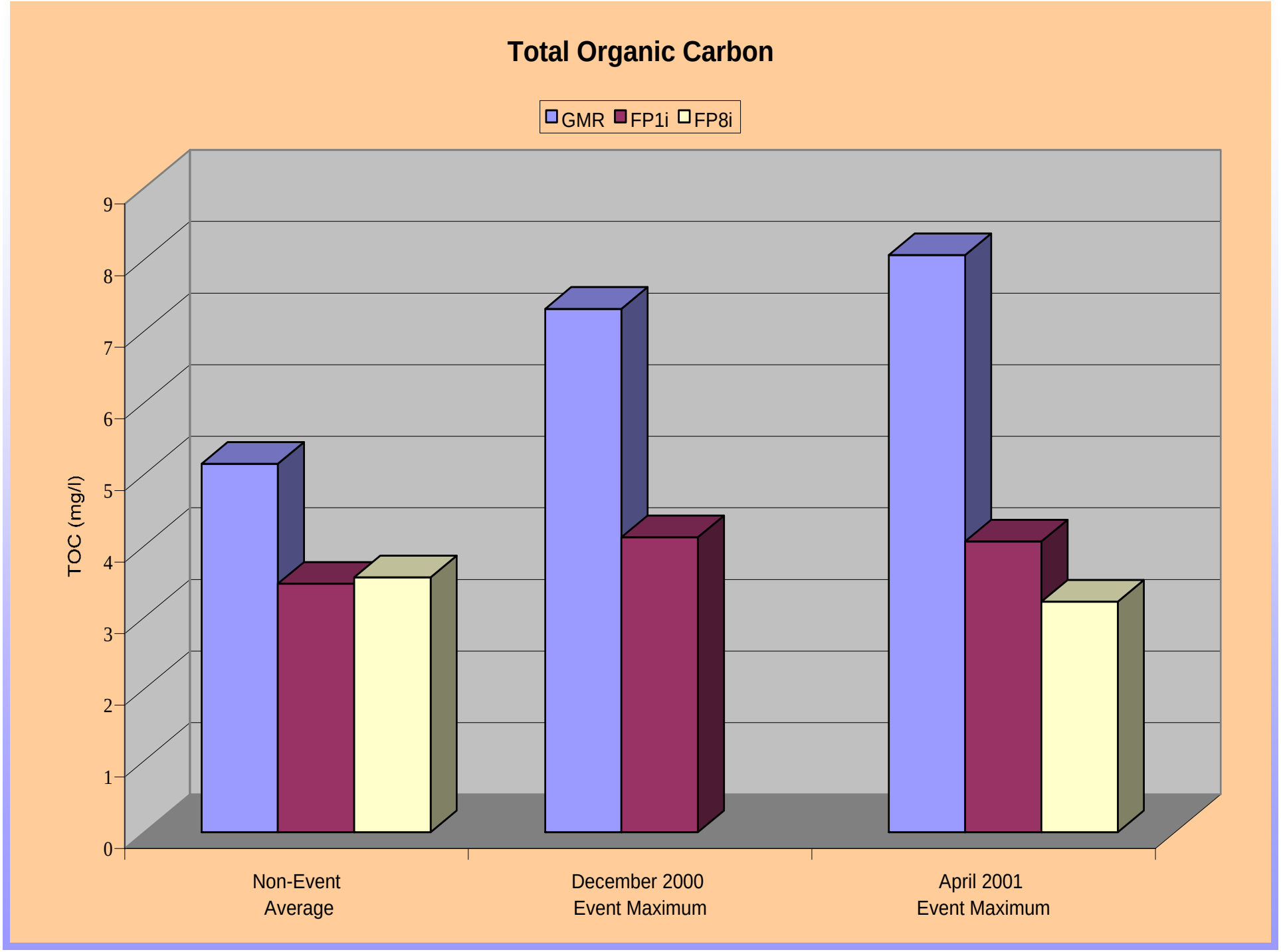

Frequency of Stage Increase Over Various Numbers of Days
Great Miami River at Hamilton
1927-1999
1 Day
3Day
5 Day
10 Day
1.60%
1.40%
1.20%
1.00%
0.80%
0.60%
0.40%
0.20%
0.00%
Percent Occurrence
December 2000 and April 2001 Monitored Events
4
6
8
10
12
14
16
Feet of Rise

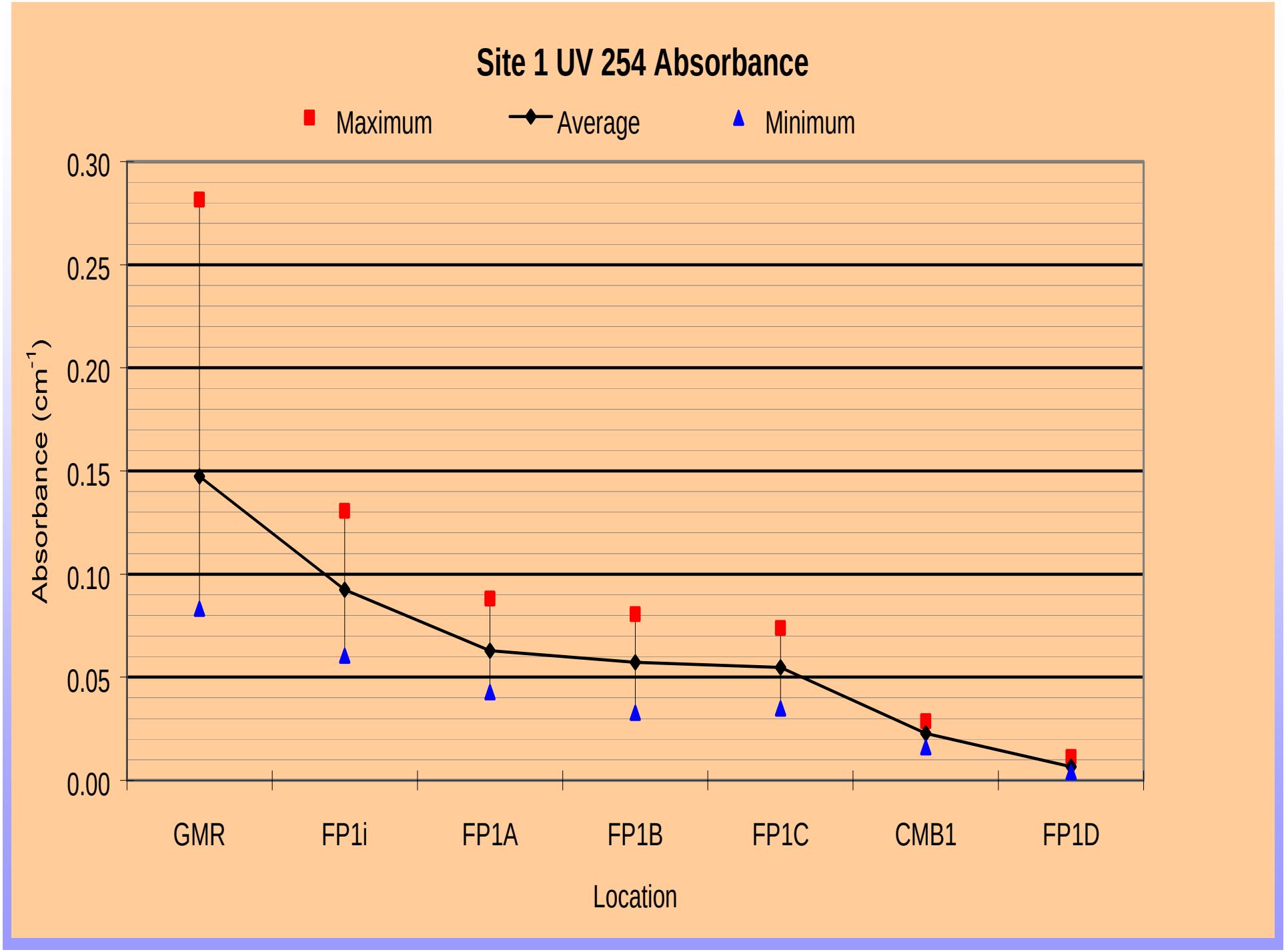
Water Quality Data

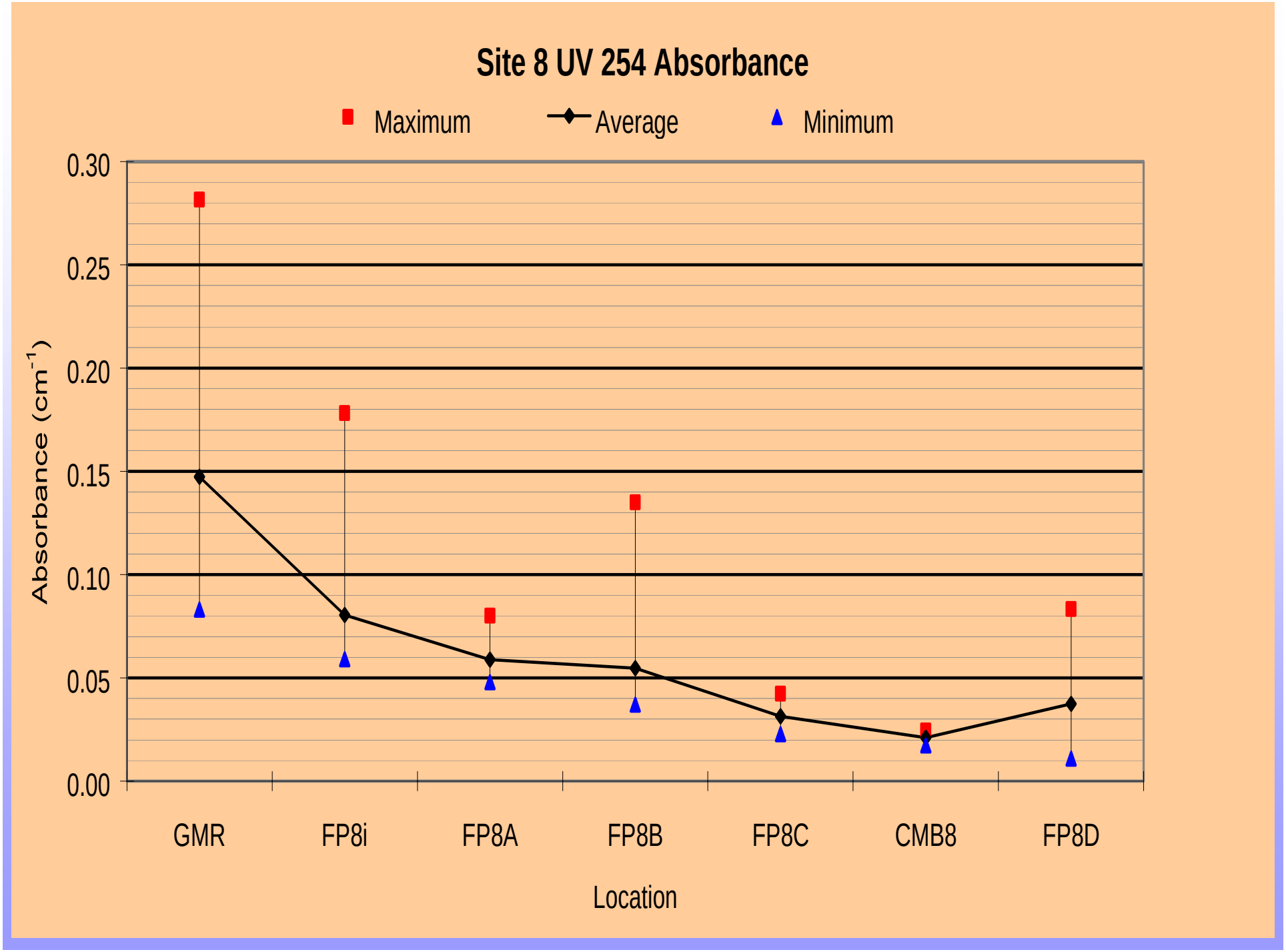
- Organic Reduction
- Particle Reduction

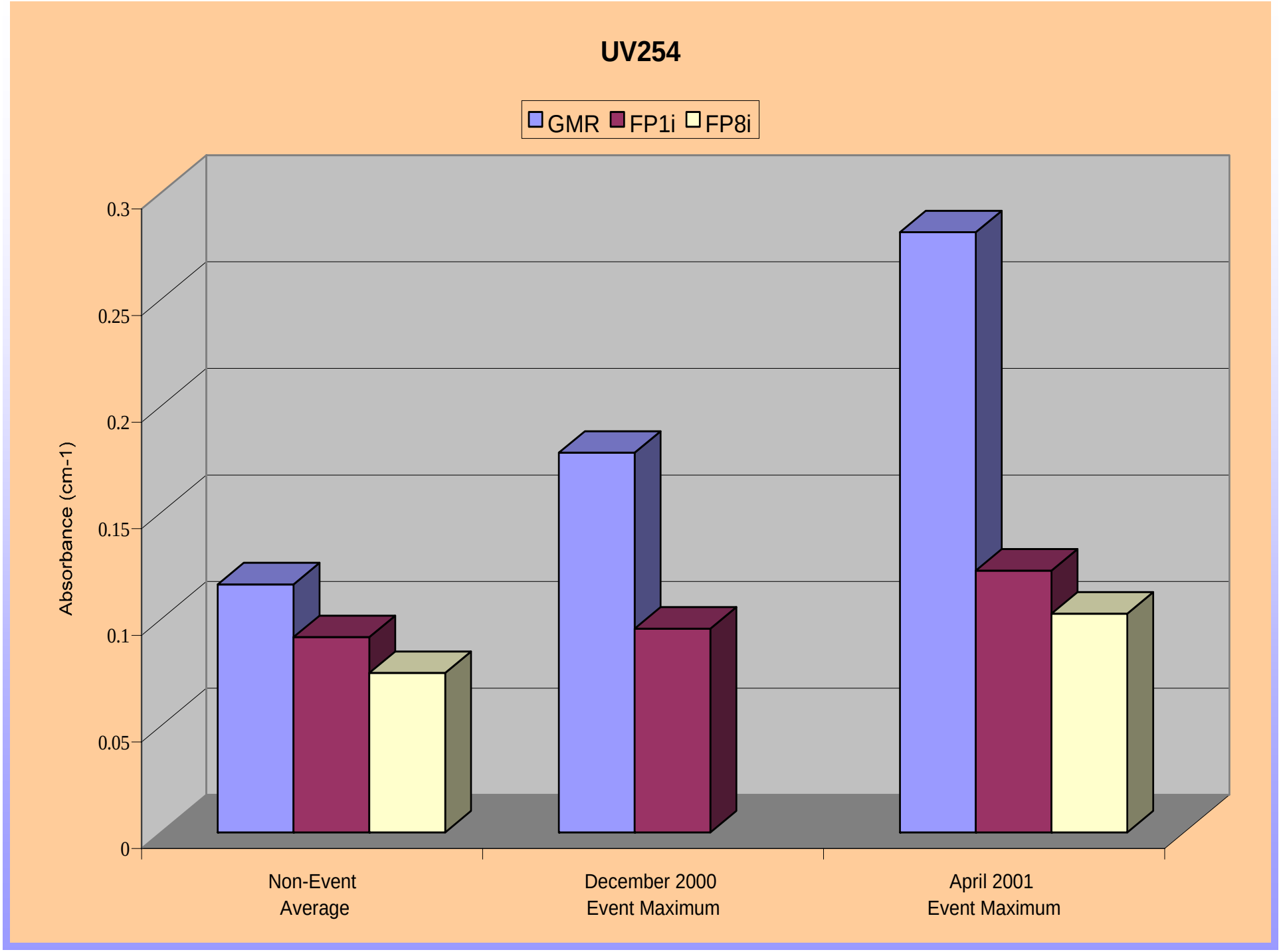

Site 1 Total Organic Carbon
Maximum
Average
Minimum
TOC (mg/l)
0
1
2
3
4
5
6
7
8
9
GMR
FP1i
FP1A
FP1B
FP1C
CMB1
FP1D
Location


Site 8 Total Organic Carbon
Maximum
Average
Minimum
excludes first two months of data for FP8b
abnormally high values due to aquifer TOC
TOC (mg/l)
0
1
2
3
4
5
6
7
8
9
GMR
FP8i
FP8A
FP8B
FP8C
CMB8
FP8D
Location


Total Organic Carbon
GMR
FP1i
FP8i
TOC (mg/l)
0
1
2
3
4
5
6
7
8
9
Non-Event
Average
December 2000
Event Maximum
April 2001
Event Maximum

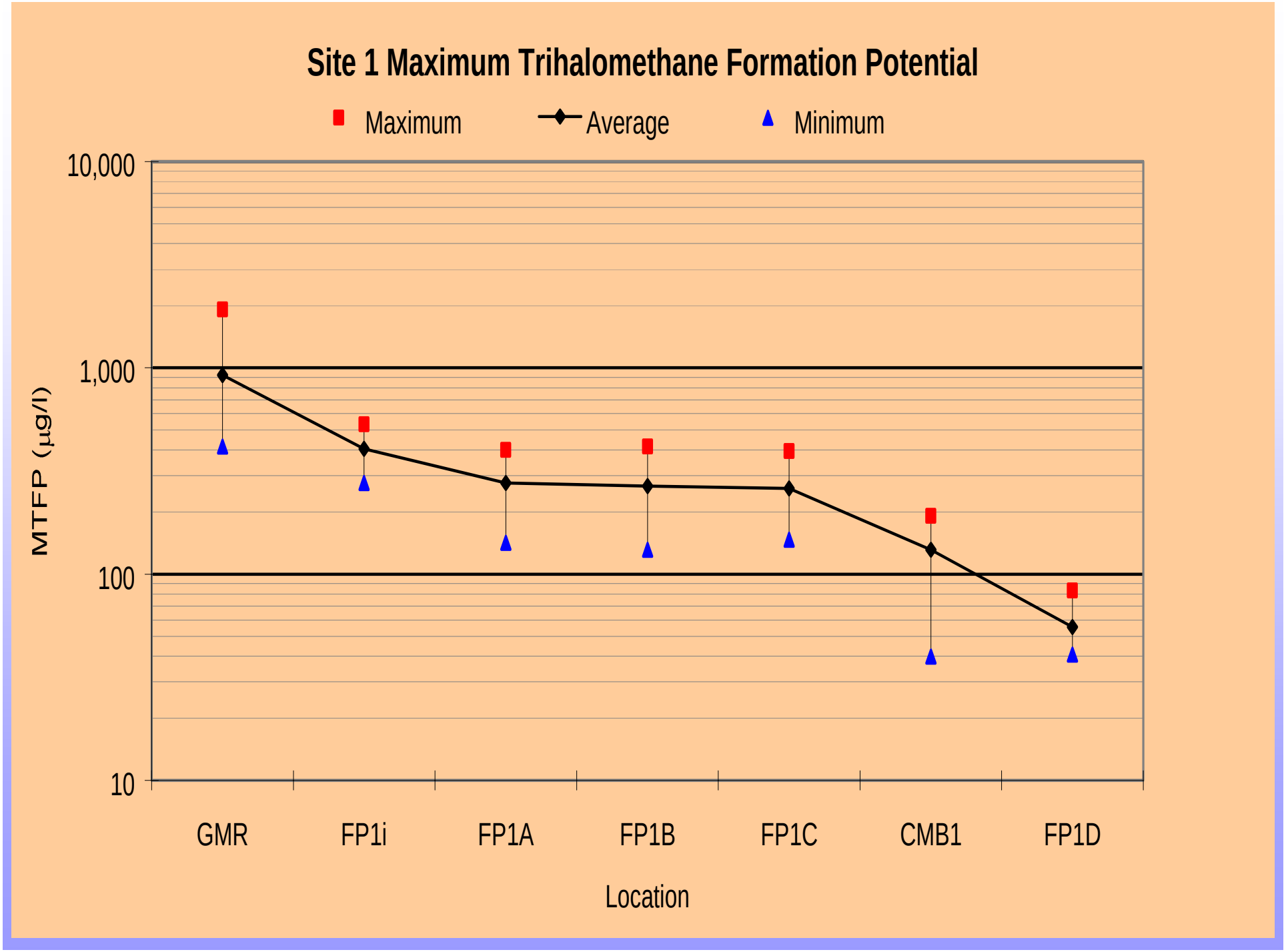

Site 1 UV 254 Absorbance
Maximum
Average
Minimum
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Absorbance (cm-1)
GMR
FP1i
FP1A
FP1B
FP1C
CMB1
FP1D
Location

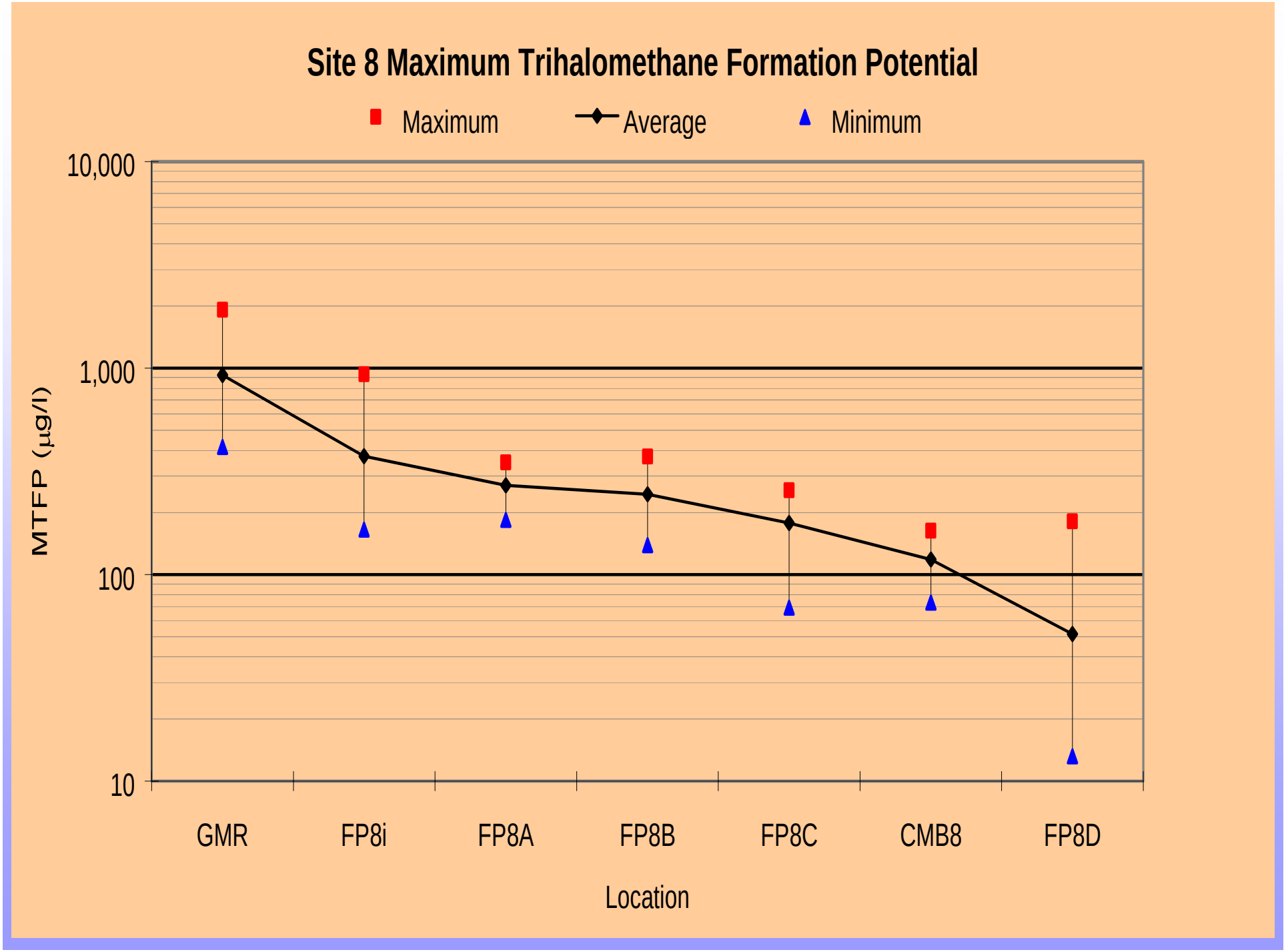

Site 8 UV 254 Absorbance
Maximum
Average
Minimum
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Absorbance (cm-1)
GMR
FP8i
FP8A
FP8B
FP8C
CMB8
FP8D
Location

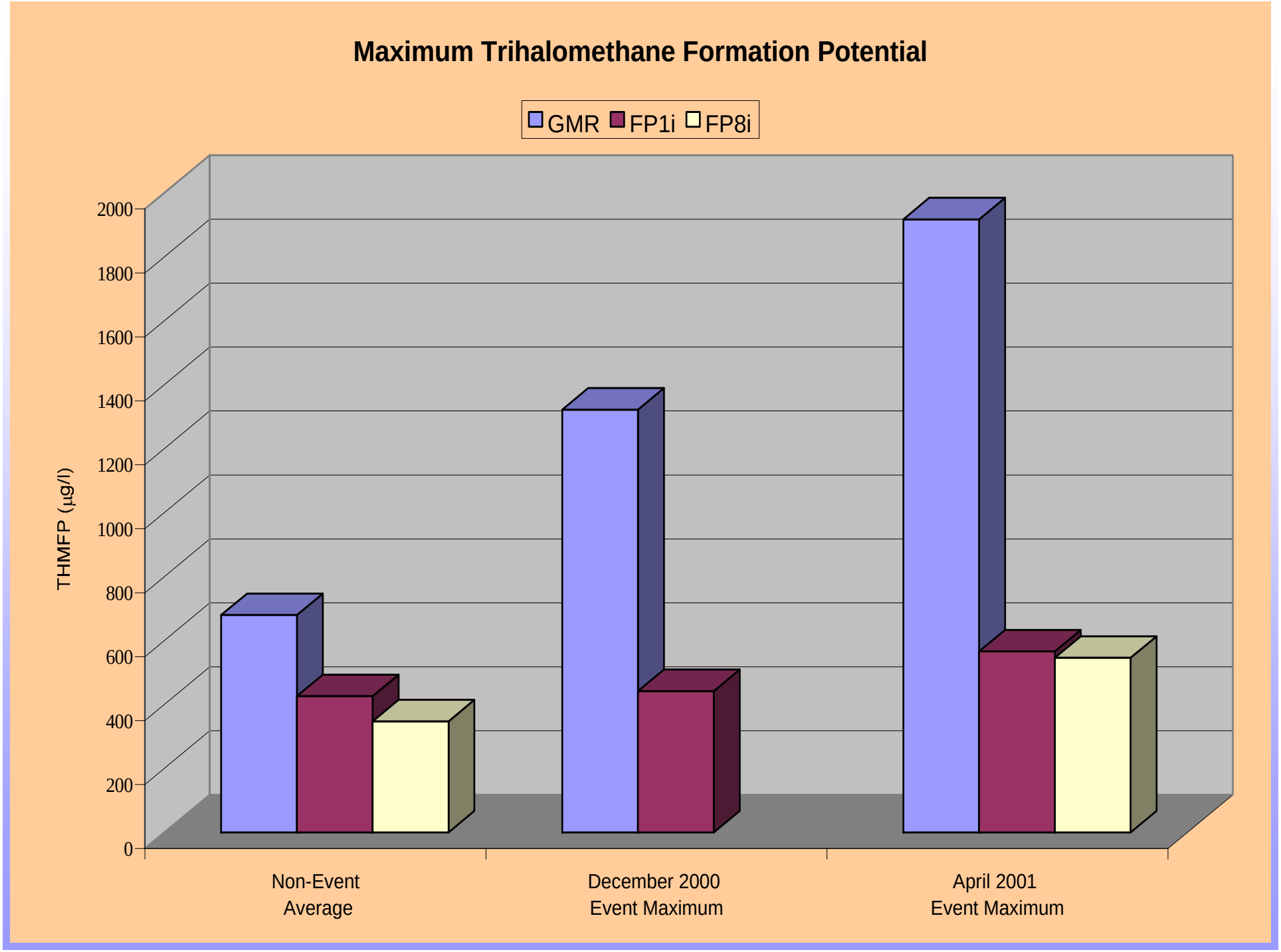

UV254
GMR
FP1i
FP8i
Absorbance (cm-1)
0.3
0.25
0.2
0.15
0.1
0.05
0
Non-Event Average
December 2000 Event Maximum
April 2001 Event Maximum

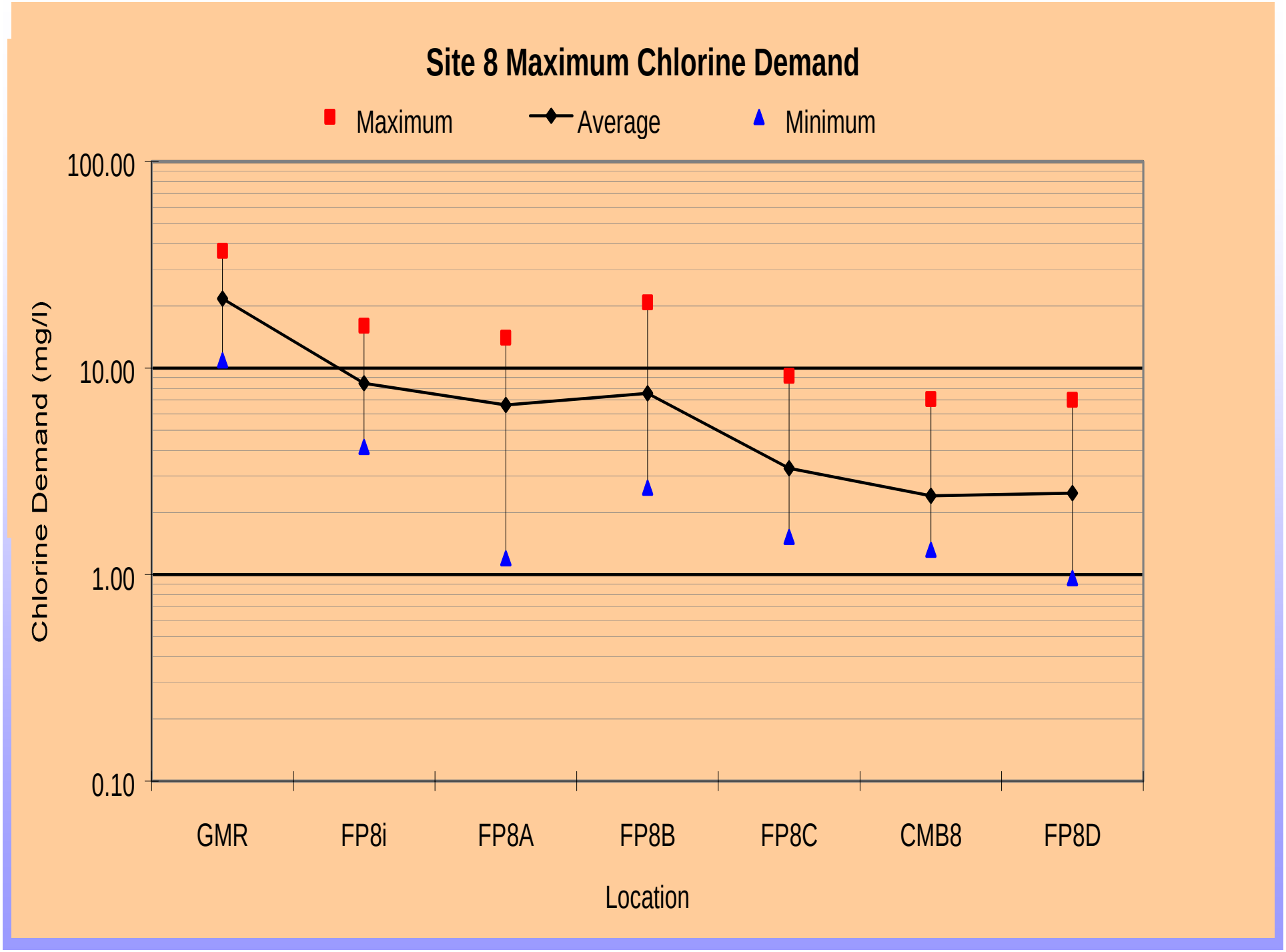
Trihalomethane Maximum Formation Potential

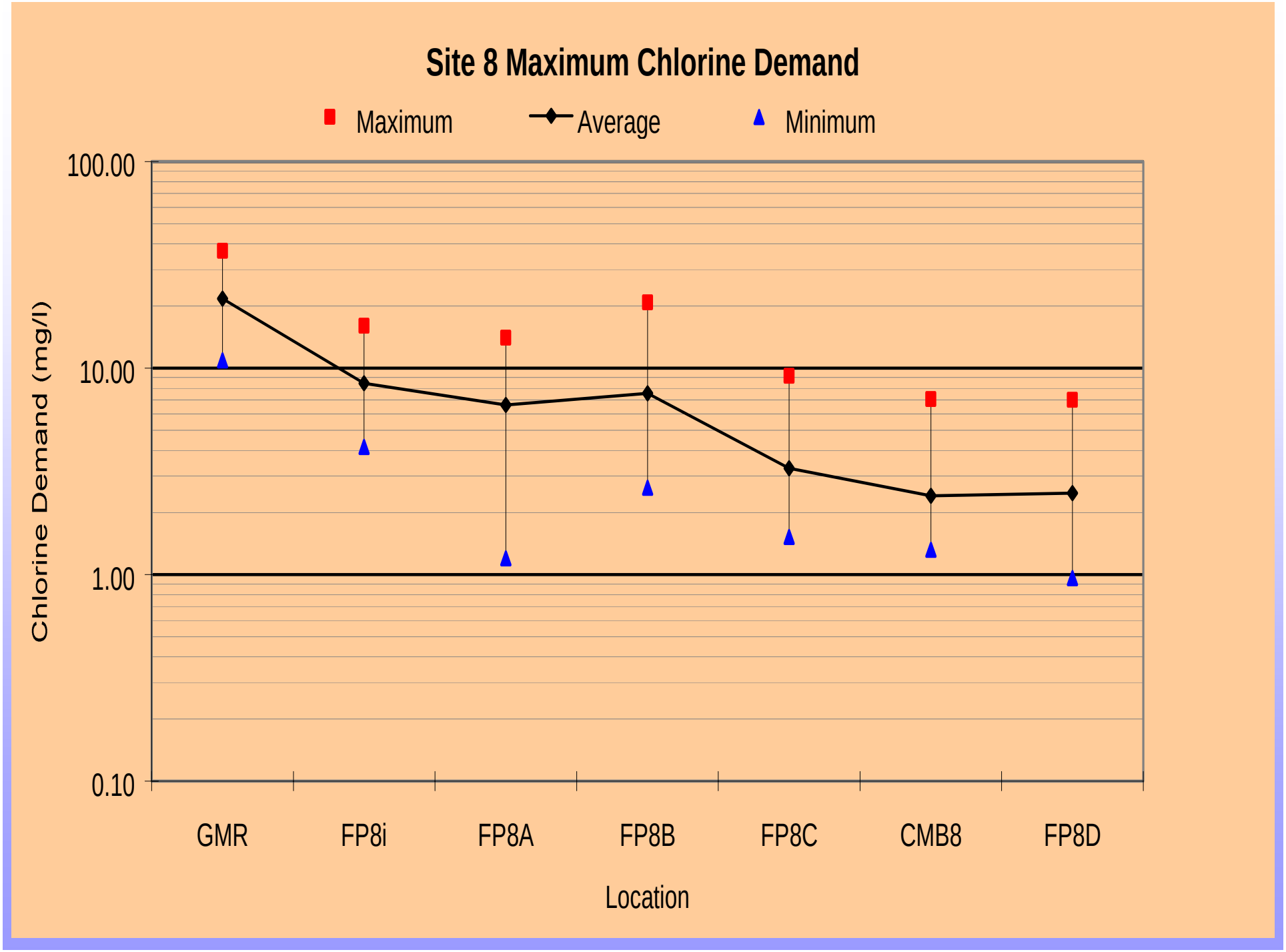
- **Laboratory “Bench Test”**
- **Provides a theoretical maximum amount of THMs which would form with the tested water.**
- **Water is dosed with chlorine and held at a constant temperature and pH for 7 days.**
- **THMs analyzed after 7 days of incubation.**

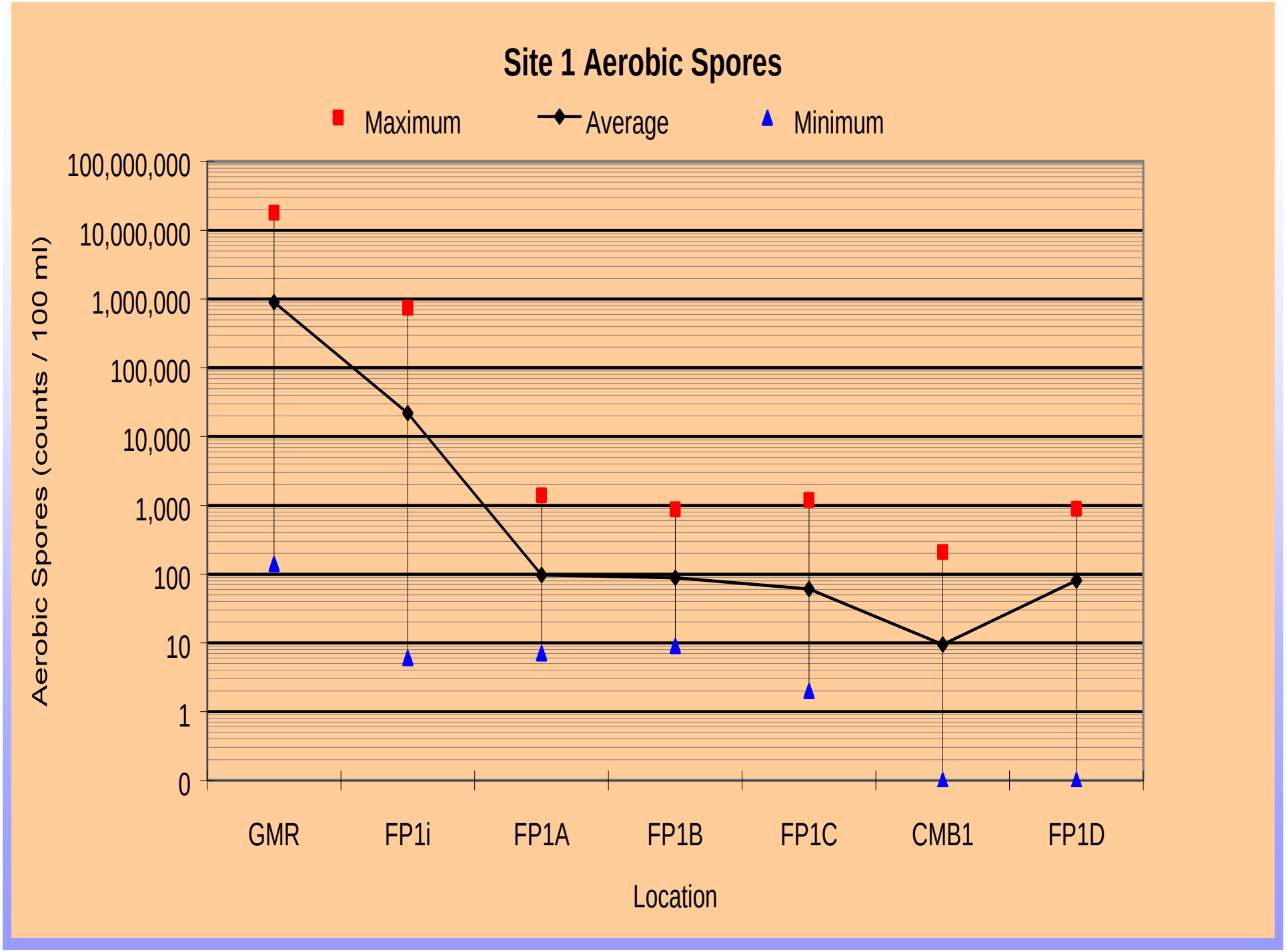

Site 1 Maximum Trihalomethane Formation Potential
Maximum
Average
Minimum
10,000
1,000
100
10
MTFP (µg/l)
GMR
FP1i
FP1A
FP1B
FP1C
CMB1
FP1D
Location

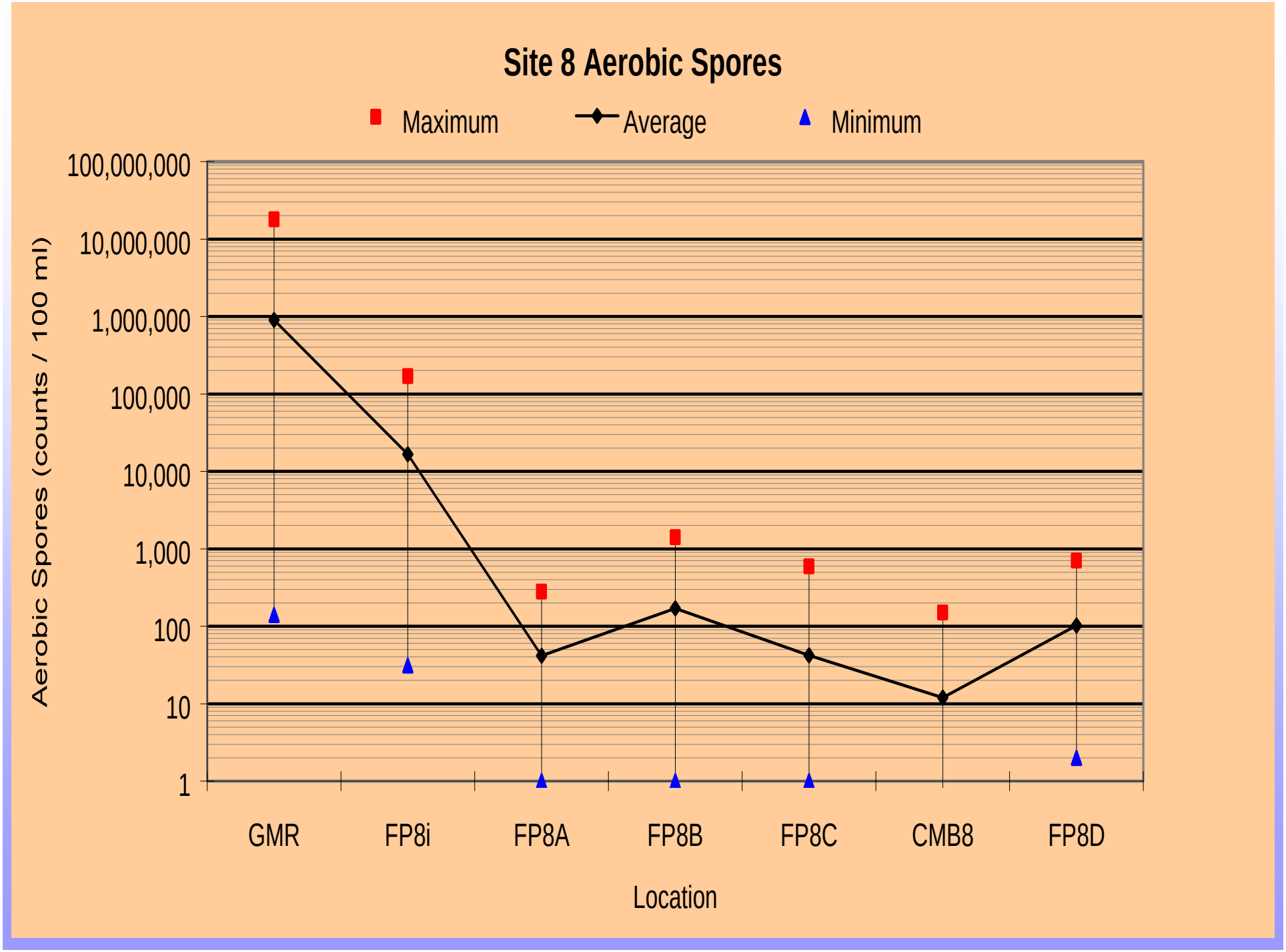

Site 8 Maximum Trihalomethane Formation Potential
Maximum
Average
Minimum
10,000
1,000
100
10
MTFP (µg/l)
GMR
FP8i
FP8A
FP8B
FP8C
CMB8
FP8D
Location

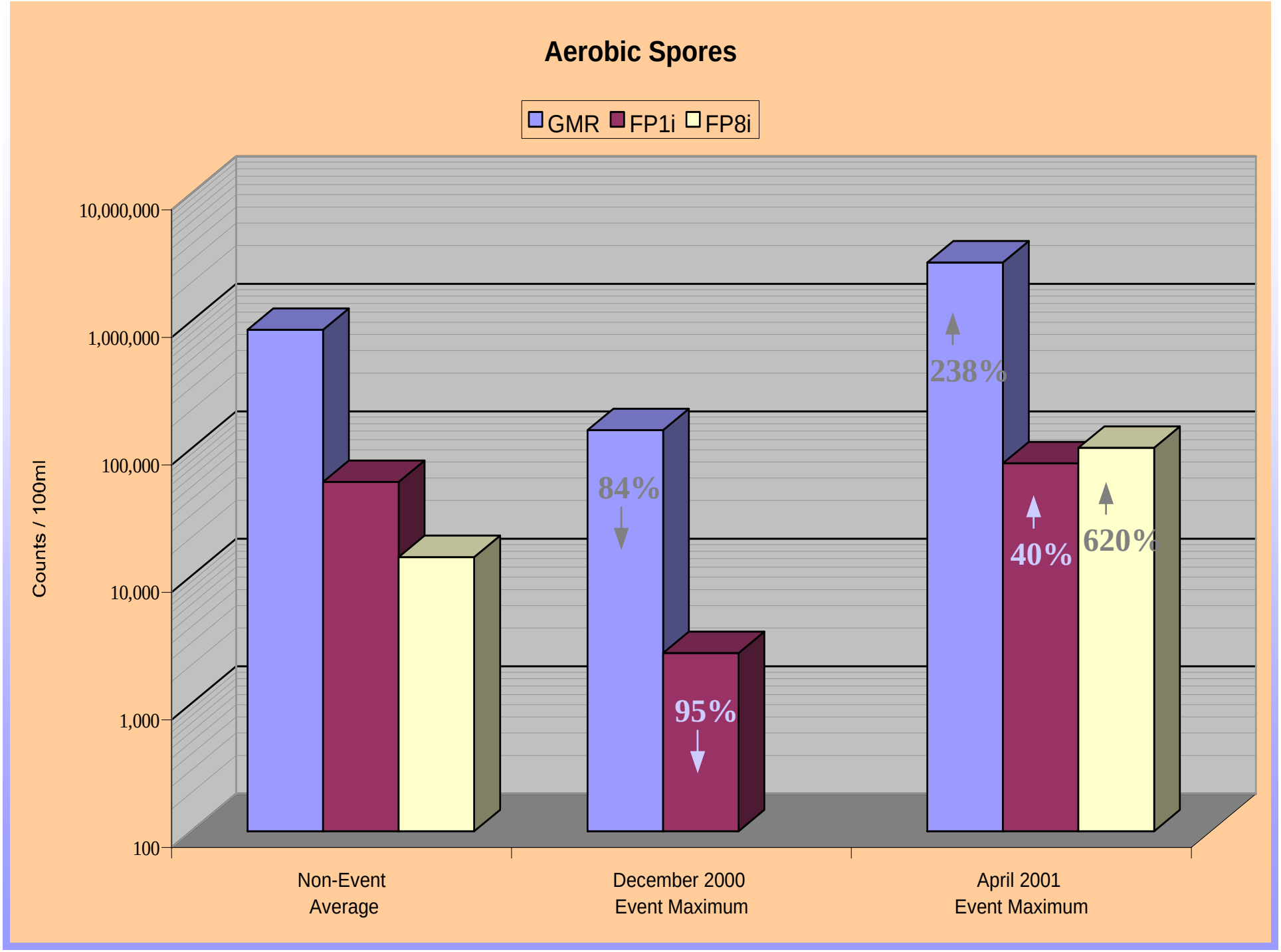

Maximum Trihalomethane Formation Potential
GMR
FP1i
FP8i
THMFP (µg/l)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Non-Event Average
December 2000 Event Maximum
April 2001 Event Maximum

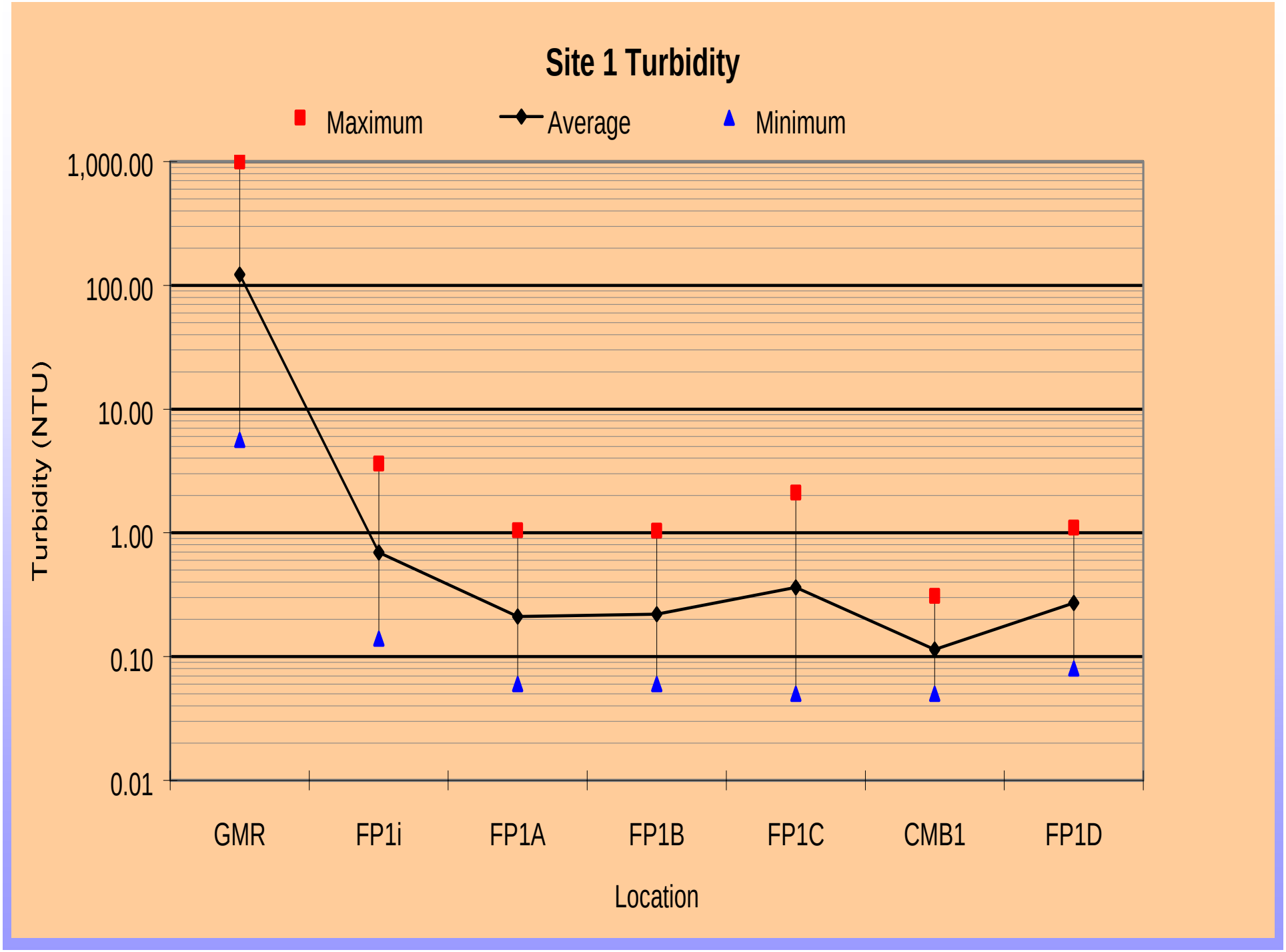

Site 8 Maximum Chlorine Demand
Maximum
Average
Minimum
100.00
10.00
1.00
0.10
Chlorine Demand (mg/l)
GMR
FP8i
FP8A
FP8B
FP8C
CMB8
FP8D
Location

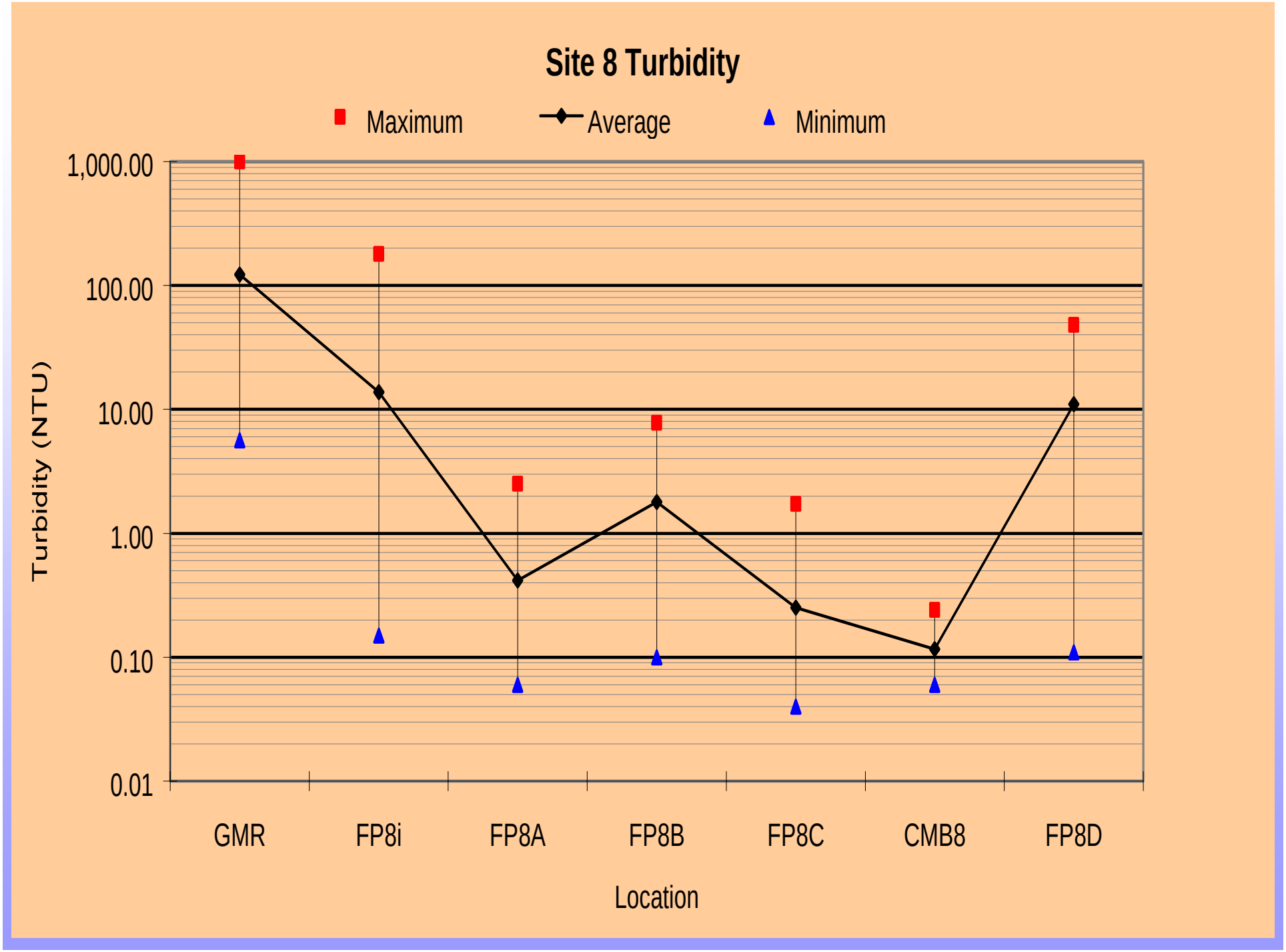

Site 8 Maximum Chlorine Demand
Maximum
Average
Minimum
100.00
10.00
1.00
0.10
Chlorine Demand (mg/l)
GMR
FP8i
FP8A
FP8B
FP8C
CMB8
FP8D
Location

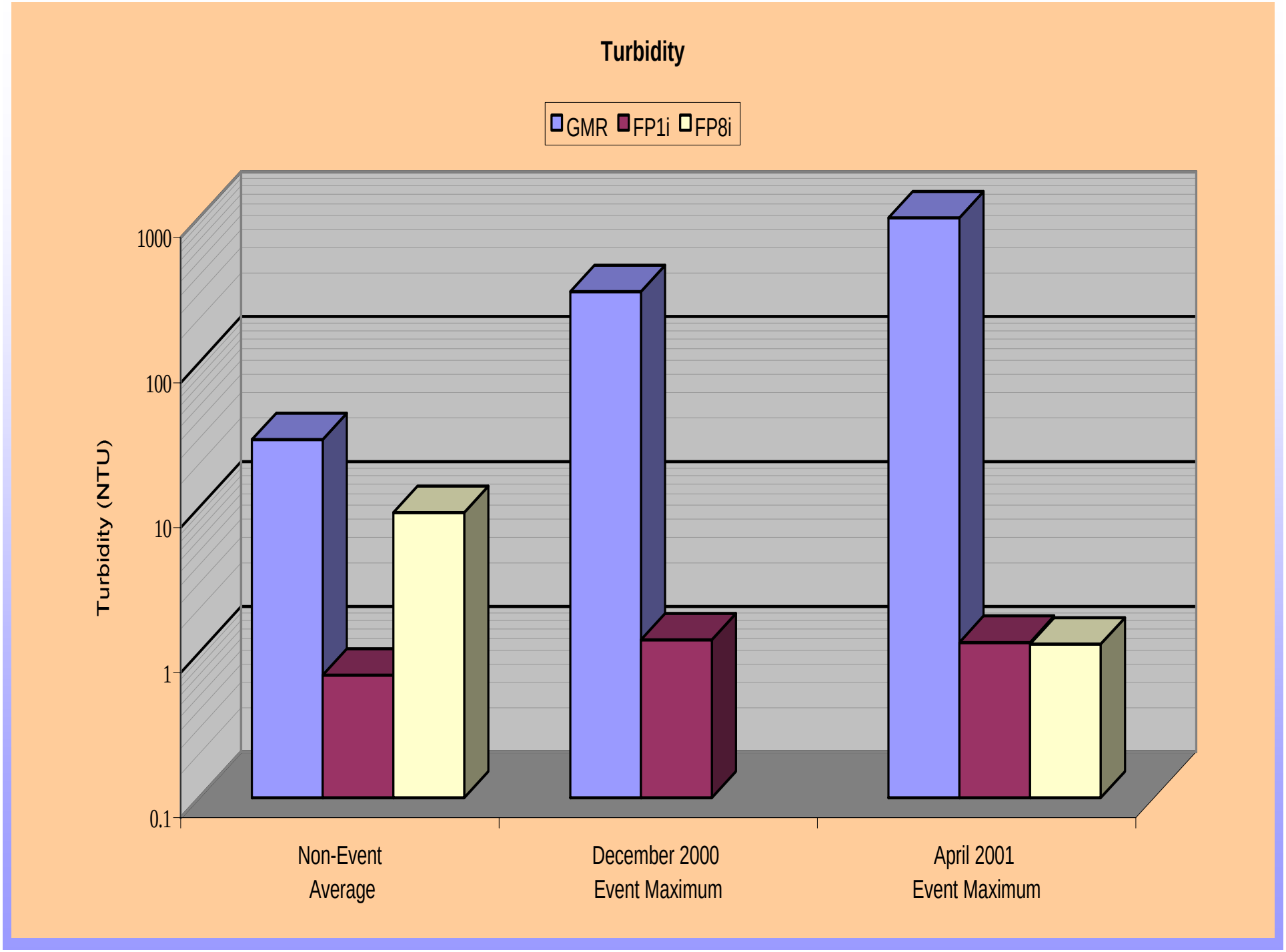

Site 1 Aerobic Spores
Maximum
Average
Minimum
Aerobic Spores (counts / 100 ml)
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0
GMR
FP1i
FP1A
FP1B
FP1C
CMB1
FP1D
Location

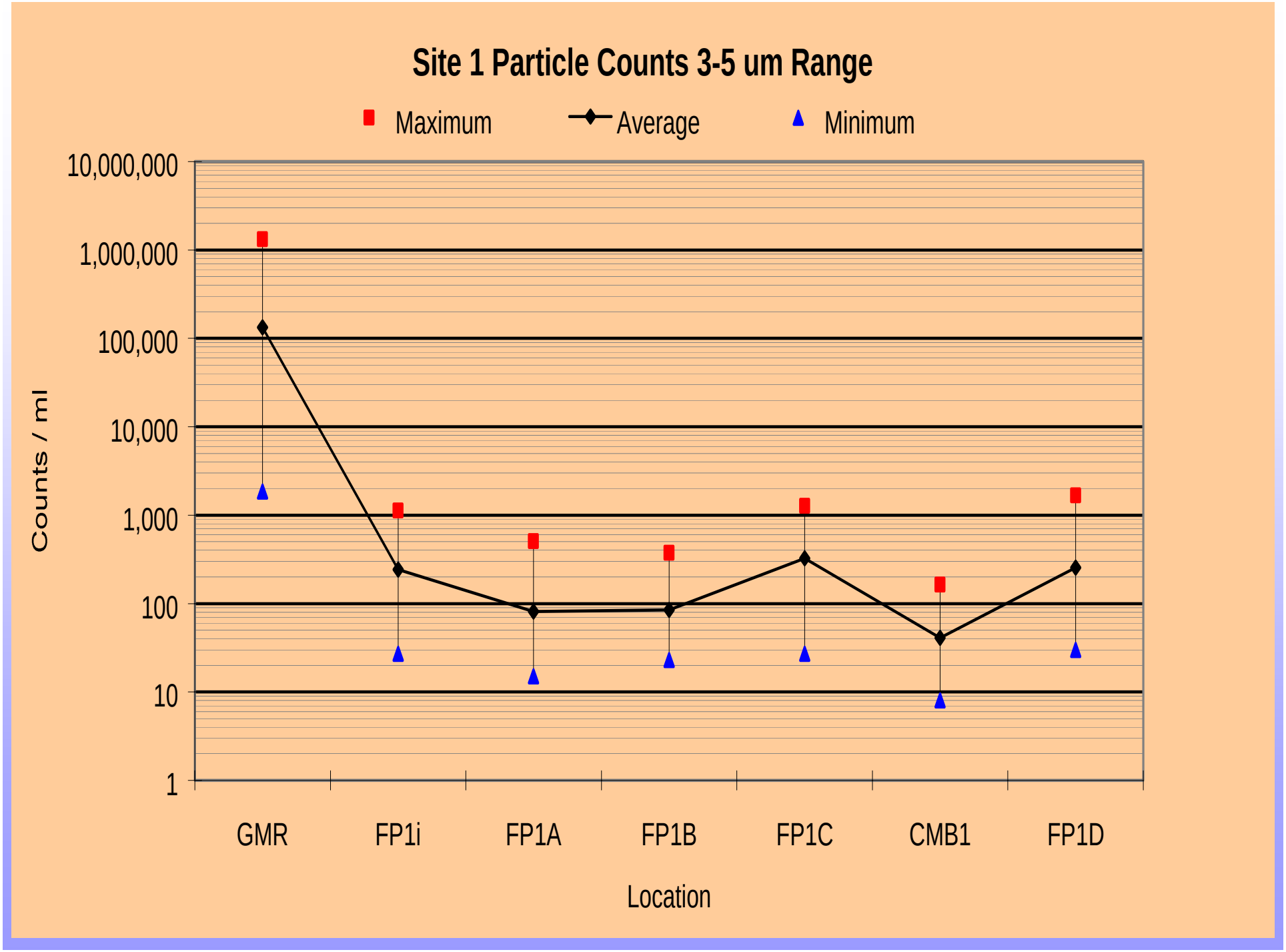

Site 8 Aerobic Spores
Maximum
Average
Minimum
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Aerobic Spores (counts / 100 ml)
GMR
FP8i
FP8A
FP8B
FP8C
CMB8
FP8D
Location

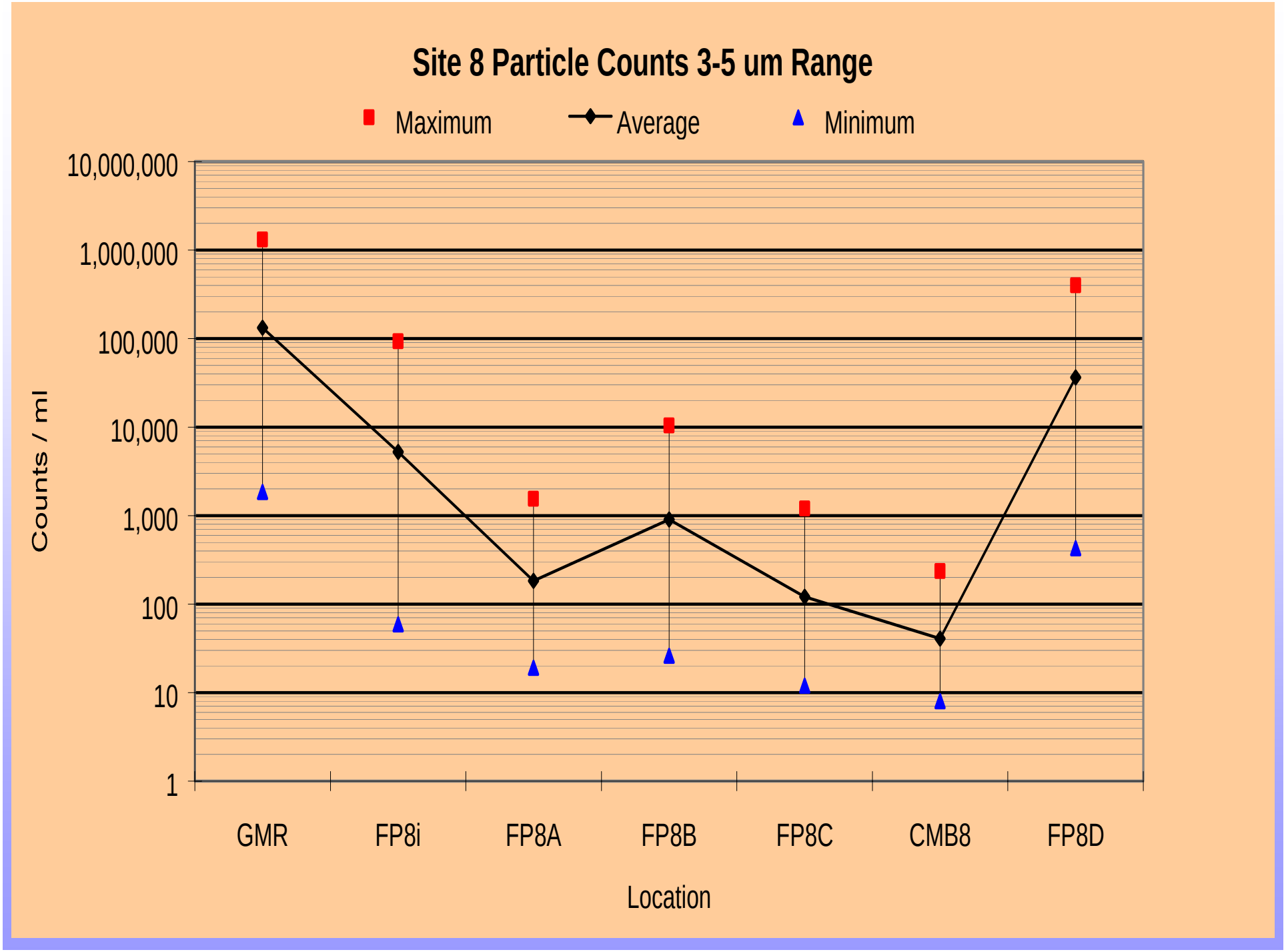

Aerobic Spores
GMR
FP1i
FP8i
Counts / 100ml
10,000,000
1,000,000
100,000
10,000
1,000
100
84%
95%
238%
40%
620%
Non-Event
Average
December 2000
Event Maximum
April 2001
Event Maximum

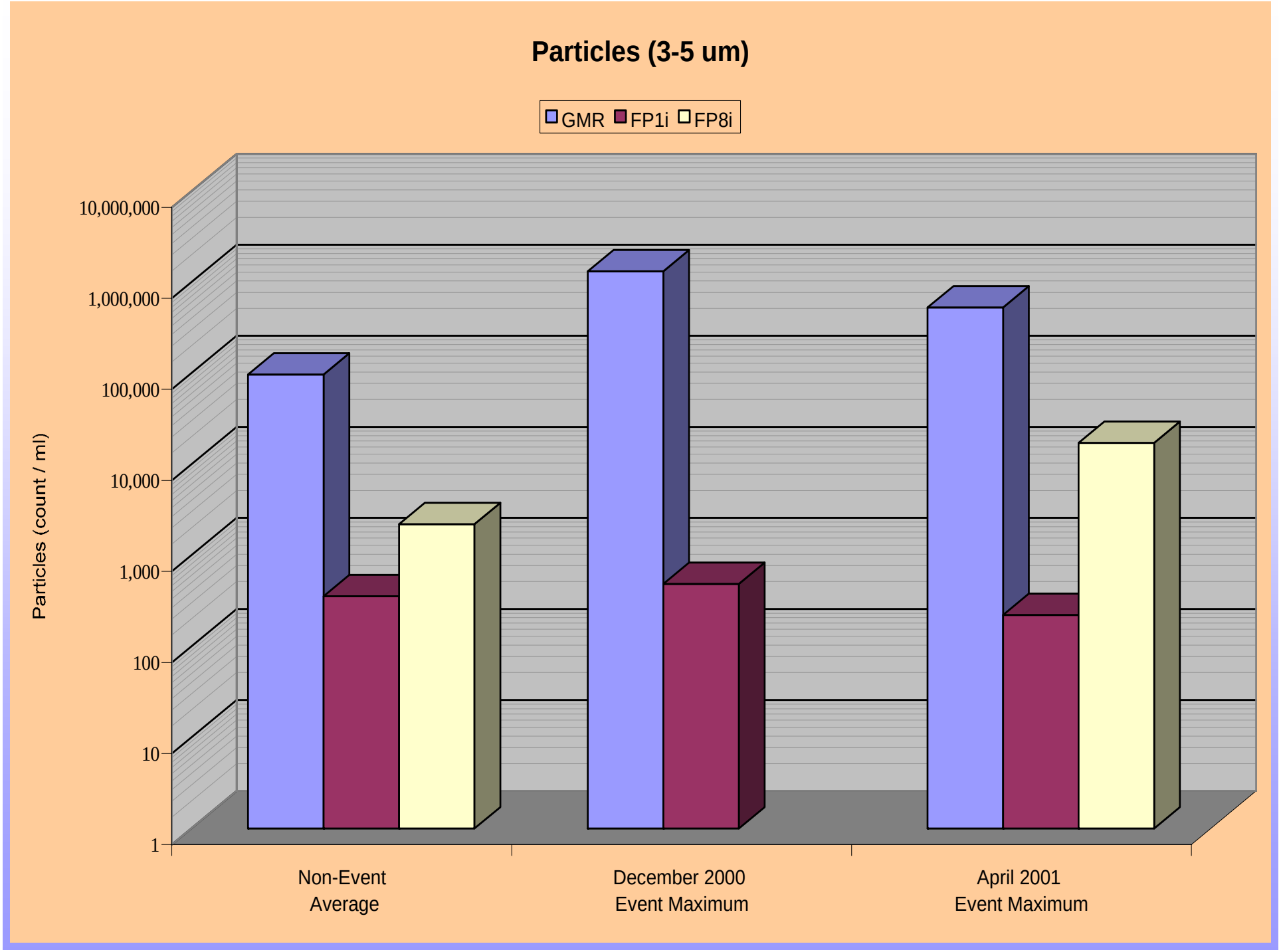

Site 1 Turbidity
Maximum
Average
Minimum
1,000.00
100.00
10.00
1.00
0.10
0.01
Turbidity (NTU)
GMR
FP1i
FP1A
FP1B
FP1C
CMB1
FP1D
Location

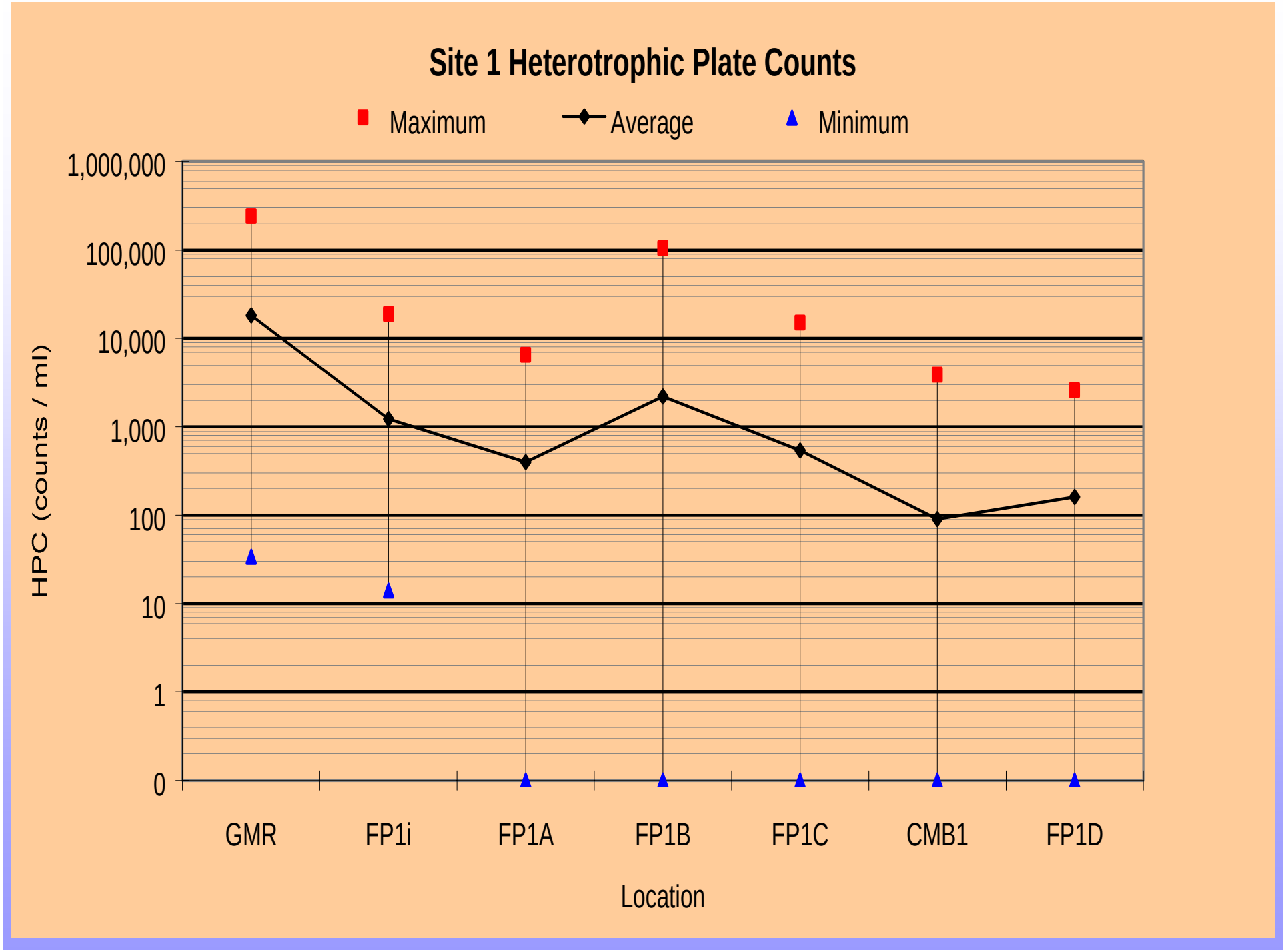

Site 8 Turbidity
Maximum
Average
Minimum
1,000.00
100.00
10.00
1.00
0.10
0.01
Turbidity (NTU)
GMR
FP8i
FP8A
FP8B
FP8C
CMB8
FP8D
Location

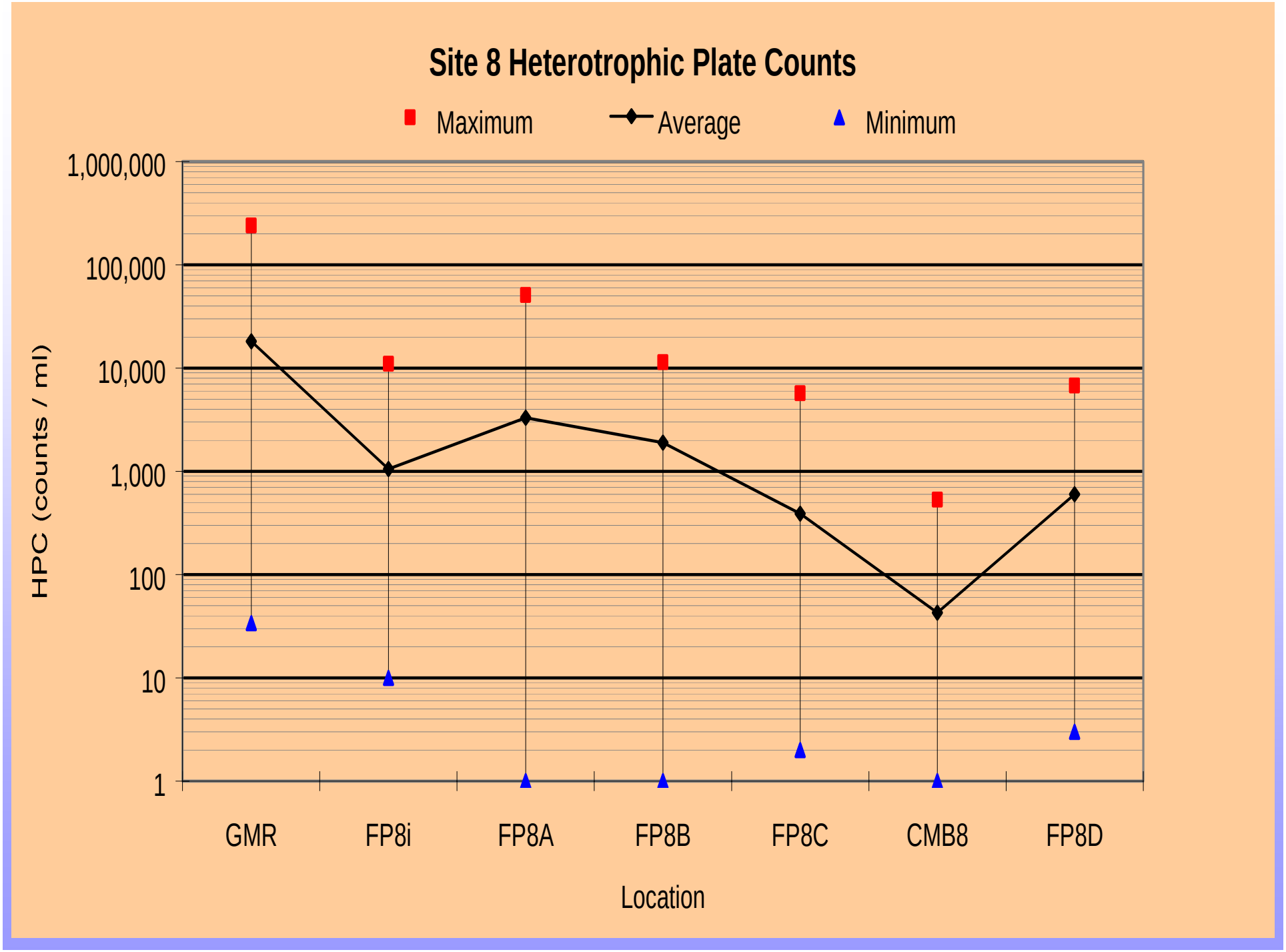

Turbidity
GMR
FP1i
FP8i
Turbidity (NTU)
1000
100
10
1
0.1
Non-Event
Average
December 2000
Event Maximum
April 2001
Event Maximum

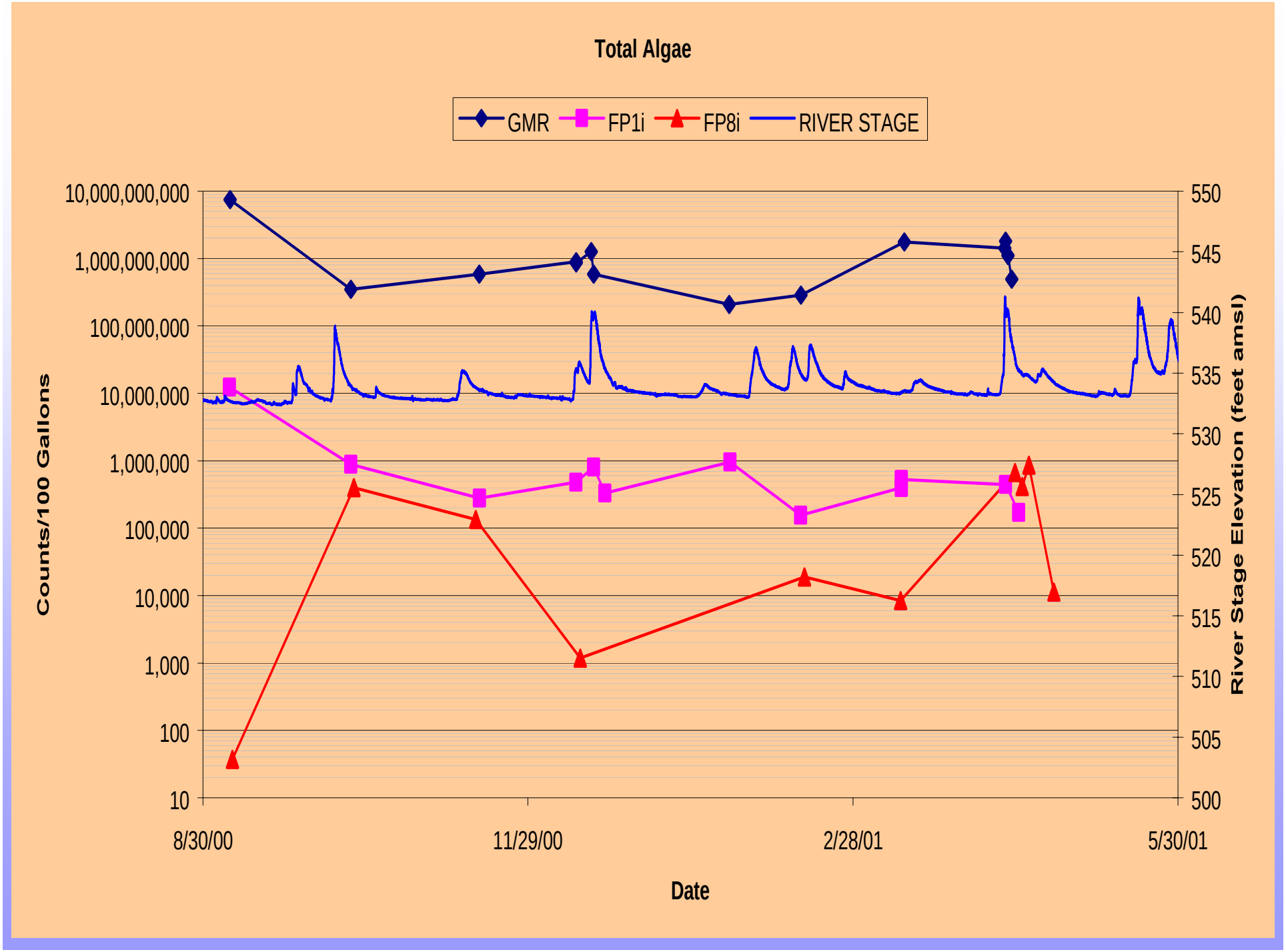

Site 1 Particle Counts 3-5 um Range
Maximum
Average
Minimum
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Counts / ml
GMR
FP1i
FP1A
FP1B
FP1C
CMB1
FP1D
Location

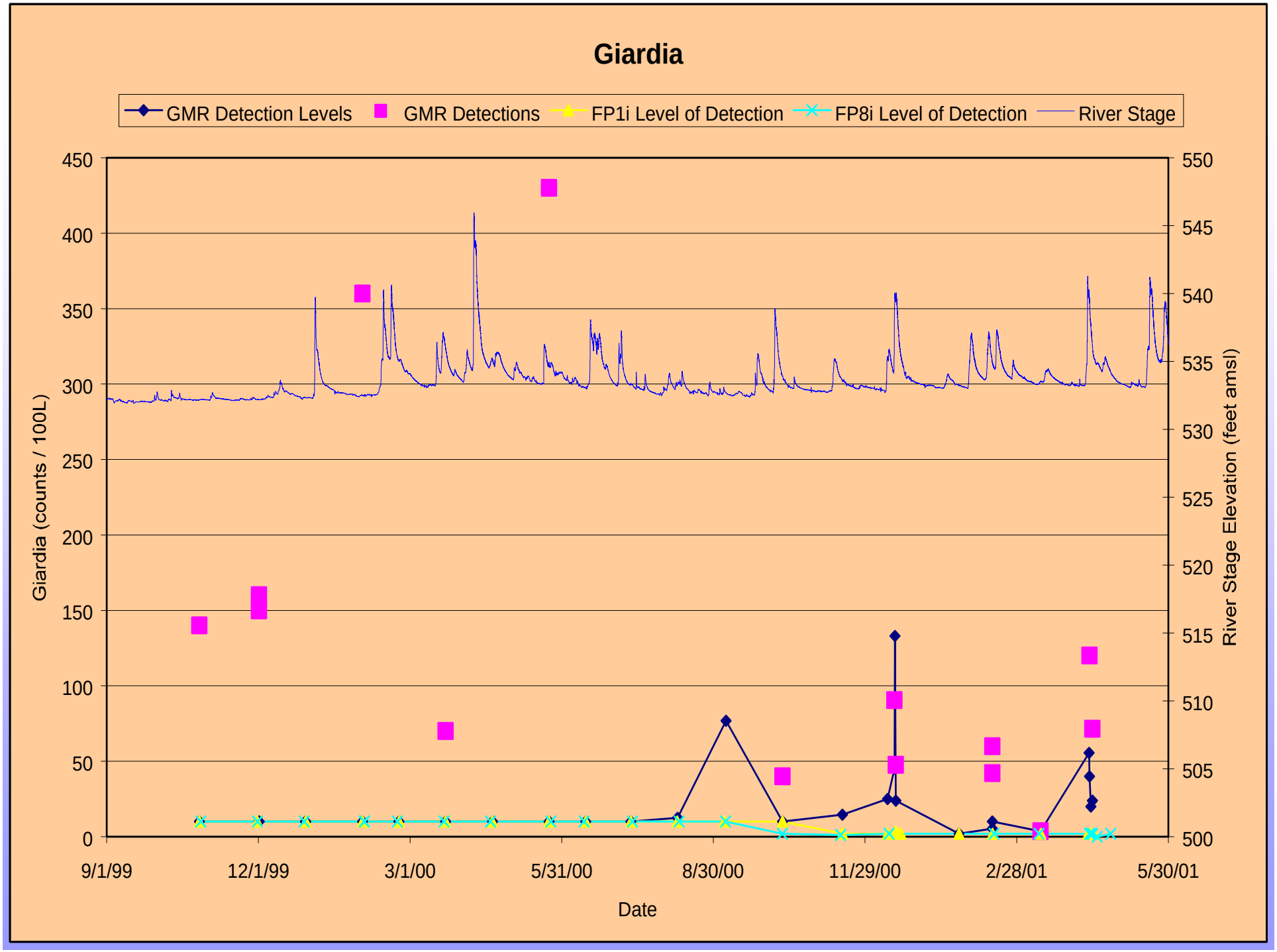

Site 8 Particle Counts 3-5 um Range
Maximum
Average
Minimum
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Counts / ml
GMR
FP8i
FP8A
FP8B
FP8C
CMB8
FP8D
Location

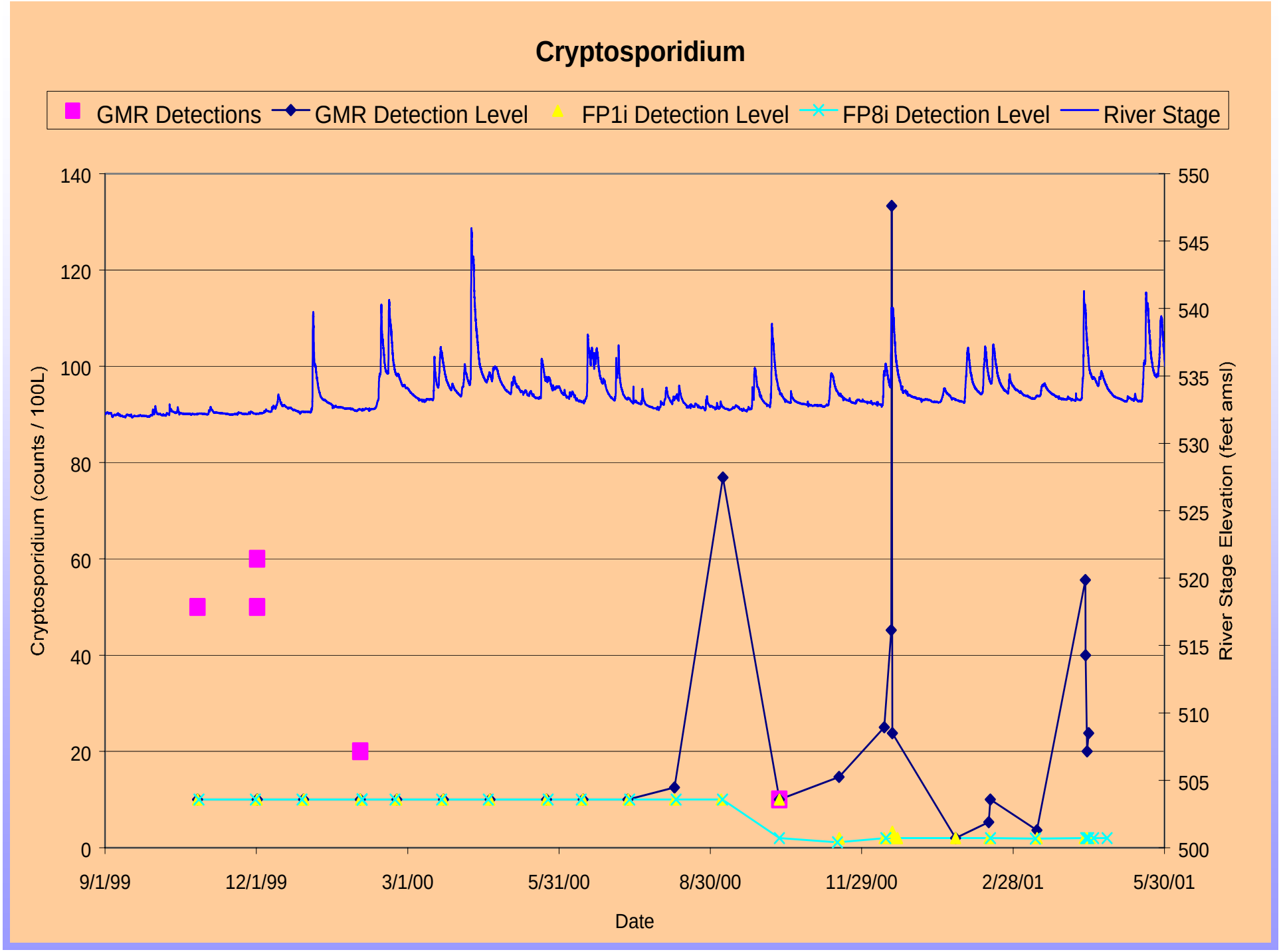

Particles (3-5 um)
GMR
FP1i
FP8i
Particles (count / ml)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Non-Event Average
December 2000 Event Maximum
April 2001 Event Maximum


Site 1 Heterotrophic Plate Counts
Maximum
Average
Minimum
1,000,000
100,000
10,000
1,000
100
10
1
0
HPC (counts / ml)
GMR
FP1i
FP1A
FP1B
FP1C
CMB1
FP1D
Location


Site 8 Heterotrophic Plate Counts
Maximum
Average
Minimum
1,000,000
100,000
10,000
1,000
100
10
1
HPC (counts / ml)
GMR
FP8i
FP8A
FP8B
FP8C
CMB8
FP8D
Location


Total Algae
GMR
FP1i
FP8i
RIVER STAGE
10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
Counts/100 Gallons
550
545
540
535
530
525
520
515
510
505
500
River Stage Elevation (feet amsl)
8/30/00
11/29/00
2/28/01
5/30/01
Date


Giardia
GMR Detection Levels
GMR Detections
FP1i Level of Detection
FP8i Level of Detection
River Stage
Giardia (counts / 100L)
River Stage Elevation (feet amsl)
450
400
350
300
250
200
150
100
50
0
550
545
540
535
530
525
520
515
510
505
500
9/1/99
12/1/99
3/1/00
5/31/00
8/30/00
11/29/00
2/28/01
5/30/01
Date


Cryptosporidium
GMR Detections
GMR Detection Level
FP1i Detection Level
FP8i Detection Level
River Stage
Cryptosporidium (counts / 100L)
River Stage Elevation (feet amsl)
0
20
40
60
80
100
120
140
500
505
510
515
520
525
530
535
540
545
550
9/1/99
12/1/99
3/1/00
5/31/00
8/30/00
11/29/00
2/28/01
5/30/01
Date

Conclusions

- No *Giardia* or *Cryptosporidium* detected in any of the 285 GW samples (71% using Method 1623)
- In general, streambed/aquifer provides a 2-6 log reduction of surrogates, even during events
  - Aerobic spores - 2 to 6 log
  - Turbidity - 3 to 4 log
  - Particle counts - 3 to 5 log
    - cysts size - 2 to 4 log
    - oocysts size - 2 to 3 log
  - Algae - 3 to 6 log
  - Total coliform - 3.5 to 5+
- Streambed is important in the reduction process

Conclusions (cont.)

- Conclusions drawn from water quality data, particularly monitoring wells, must be based on averages (or similar "multiple data point" statistics) and not on isolated sampling events.

- Monitoring wells are more affected by aquifer heterogeneity (both physical, chemical, and biological), than are properly developed production wells. This is due to short screened intervals and smaller capture zones.

- Riverbed dredging should not be done in the vicinity of a production well utilizing riverbank filtration.

Argument for RBF Credit

- Water quality from production wells continues to meet high standards, and is comparatively better than effluent from a conventional SW plant.
- Multiple surrogates demonstrate log reductions ranging from 2 to 6 log.
- No *Giardia* or *Cryptosporidium* have been found in any ground water samples, even those with relatively high concentrations of algae (i.e. inclined wells)
- Periods of high infiltration rates continue to produce high quality water
- Frequency and period of high infiltration rates events is low

Future Riverbank Filtration Research - Our Wish List

- Quantification of infiltration rate variability
- Quantification of riverbed conductivity during high stage events
- Streambed scour - How can it be measured?
- Duplicate modified Flowpath Study @ other sites
- Aquifer spiking studies - How do you do it?
- Similar studies to evaluate the impact of bank filtration from lakes and gravel pits (are the risks higher or lower?)

A Parting Thought

33 gallons filtered from the river

1,100 gallons filtered from 5 feet below the riverbed