Quantifying Methane Emissions from Abandoned Legacy Gas Wells in Indiana County, Pennsylvania

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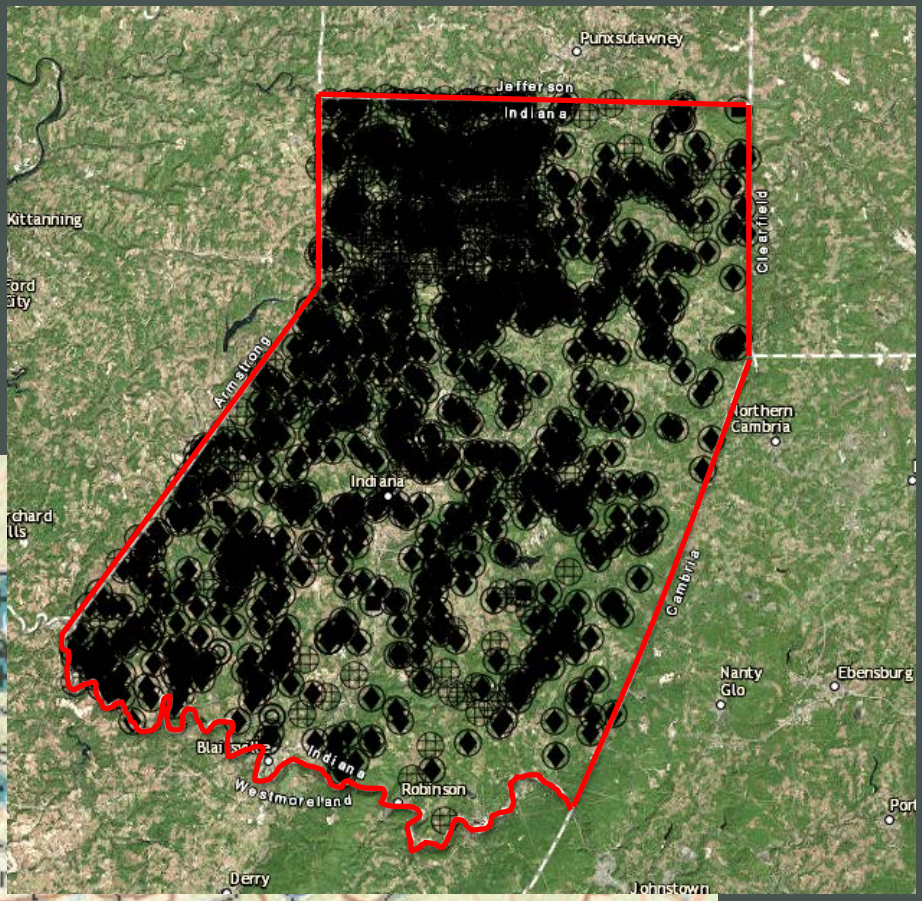
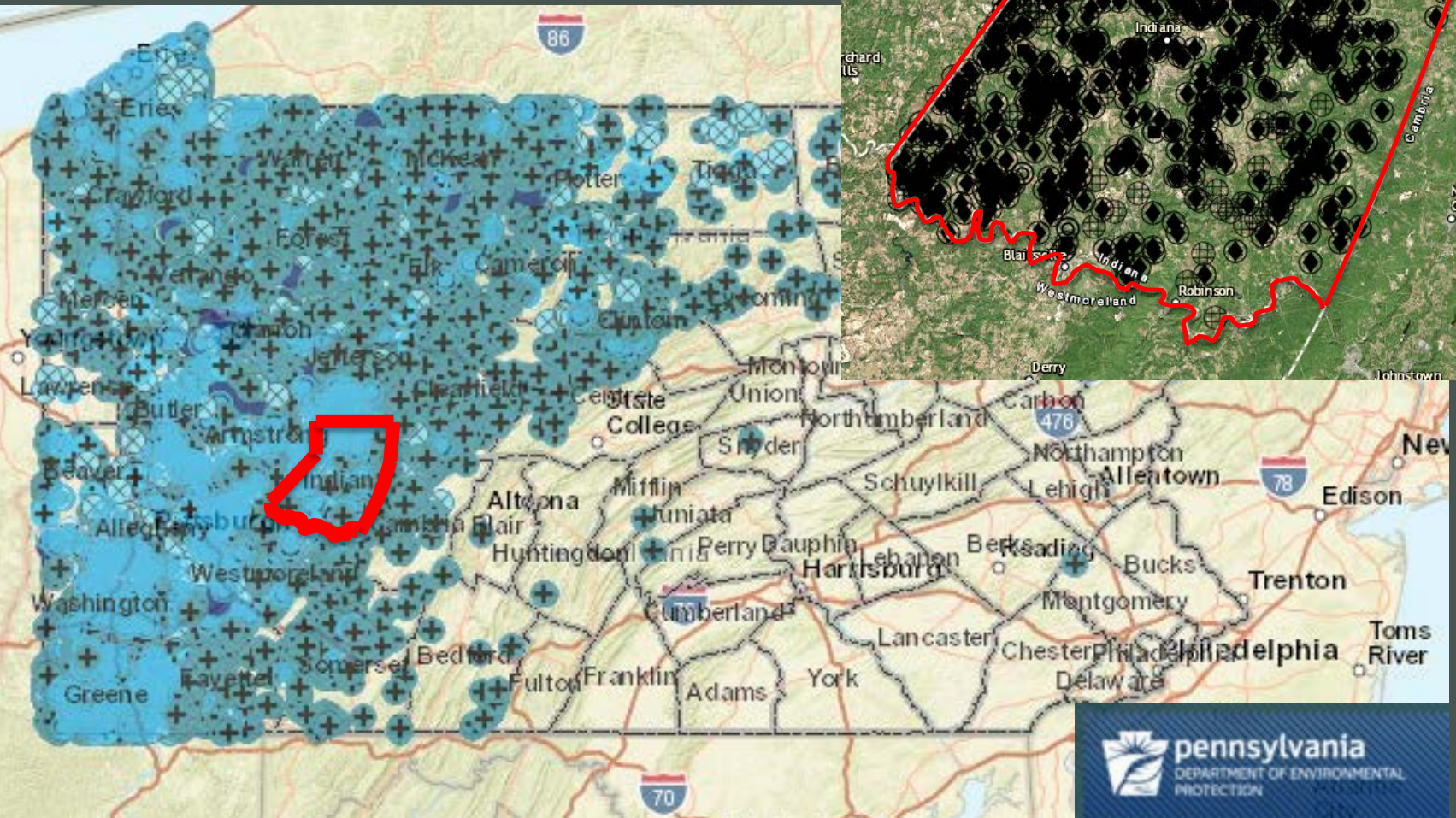
300,000-750,000 abandoned wells in PA



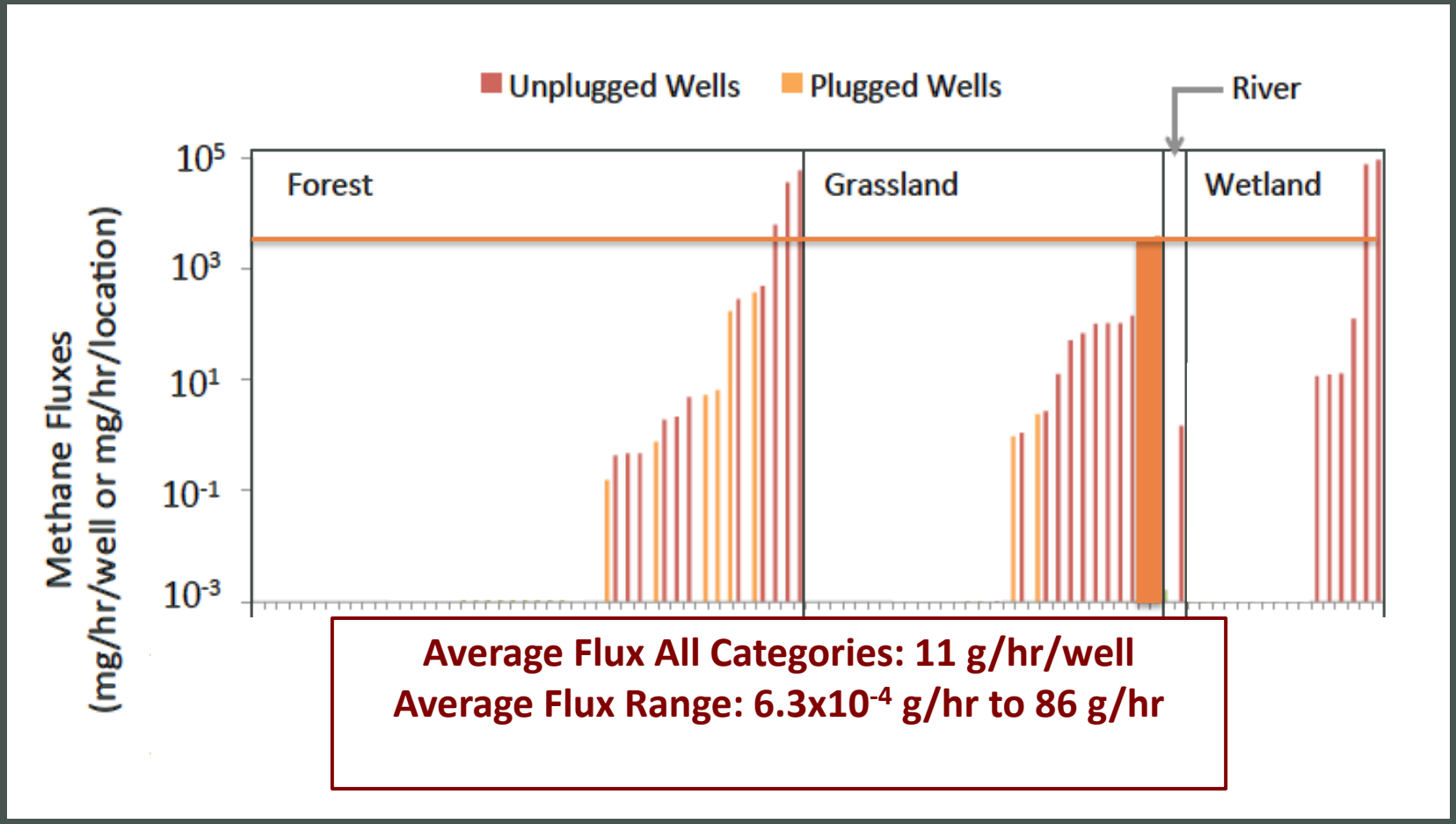


Previous studies show variations in methane flow rates

Well Category	Number of Measurements	Mean (g CH_4 h^{-1})	95% UCL (g CH_4 h^{-1})
All wells (entire U.S.)	138	1.38	3.17
All wells (eastern U.S.)	12	14.00	32.87
All wells (western U.S.)	126	0.18	0.41
Plugged wells (entire U.S.)	119	0.002	0.005
Unplugged wells (entire U.S.)	19	10.02	22.47
Plugged (eastern U.S.)	6	0	NA
Unplugged (eastern U.S.)	6	28.01	64.00
Plugged (western U.S.)	113	0.002	0.005
Unplugged (western U.S.)	13	1.71	3.83

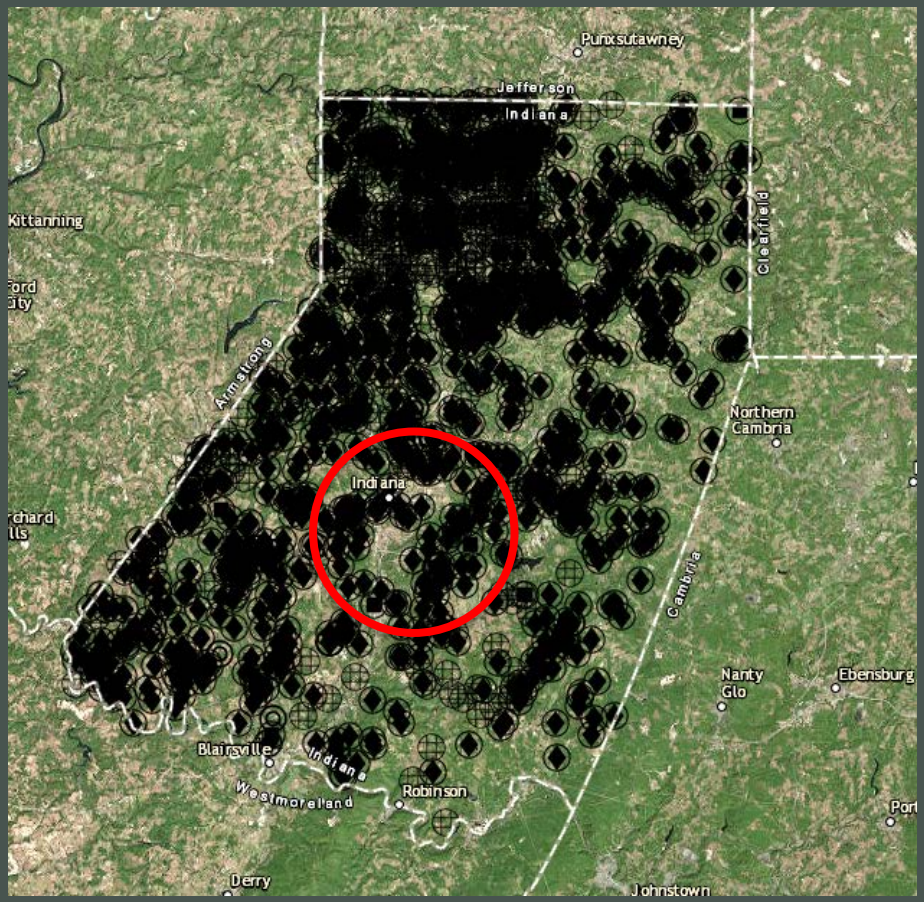
Townsend-Small et al., 2016

Previous studies show variations in methane flow rates



Modified from Kang, 2014

Well of focus is an Oriskany well completed in 1960s

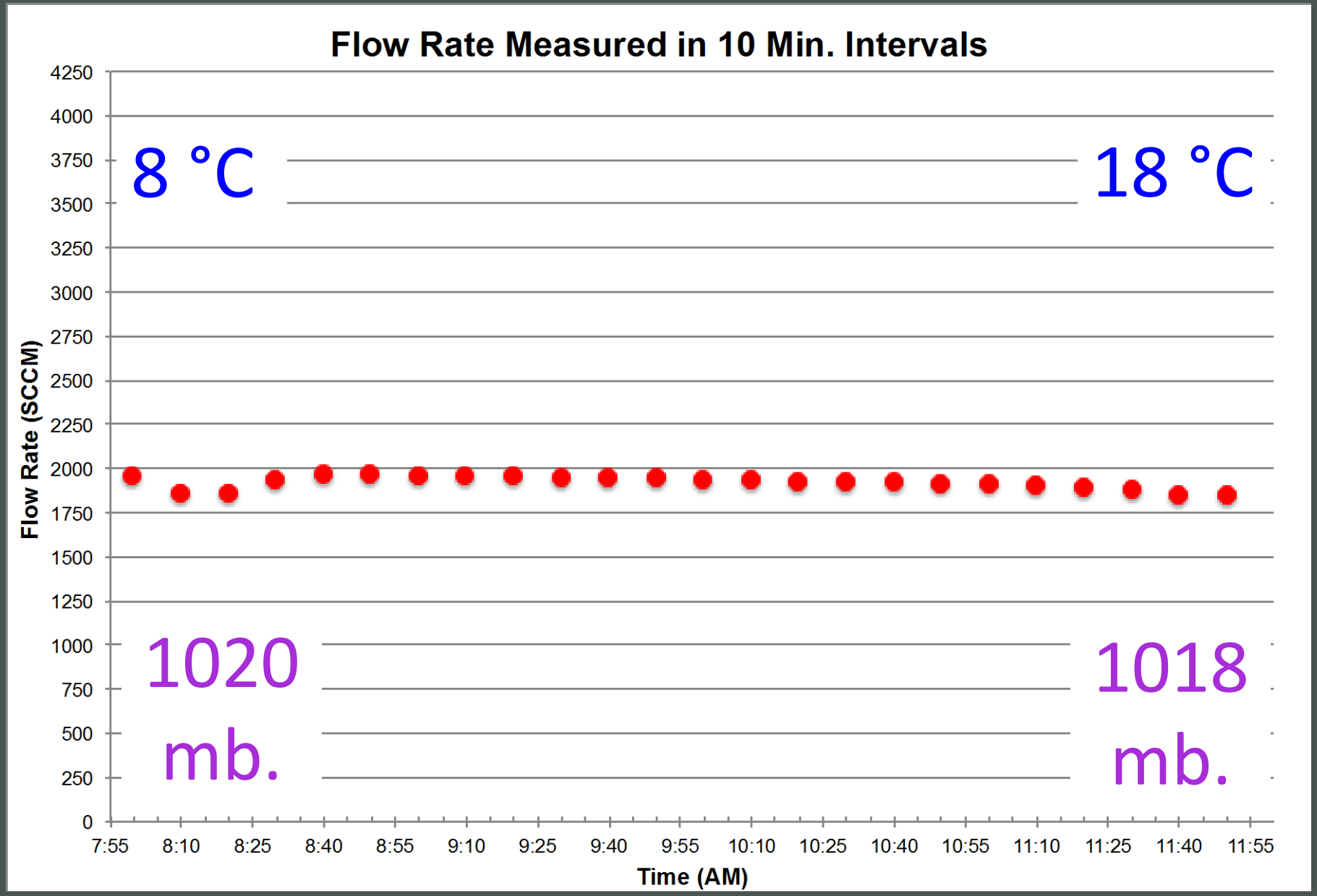


FORMATION	TOP	BOTTOM
Sandstone	0	120
Sand & Shale	120	161
Water Sand	161	190
Sandstone	190	236
Coal	236	240
Sandstone	240	322
Coal	322	325
Sandy Shale	325	365
Coal	365	369
Sandy Shale	369	760
Sand & Shale	760	920
Sandy Shale	920	1013
Shale & Sand	1013	1163
Sandy Shale	1163	1650
Red Shale	1650	1825
Sand & Shale	1825	2450
Gray Shale & Lime Stks	2450	2785
Sandy Shale w/lime stks	2785	3030
Sand, Shale, lime strks	3030	3675
Dark Shale	3675	3885
Sandy lime & Shale	3885	4395
Shale	4395	6280
Shale w/lime streaks	6280	6400
Shale	6400	6958
Tully Lime	6958	6996
Shale w/lime streaks	6996	7584
Onondaga Lime	7584	7601
Chert	7601	7717
Oriskany Sand	7717	7727
Total Depth		7730

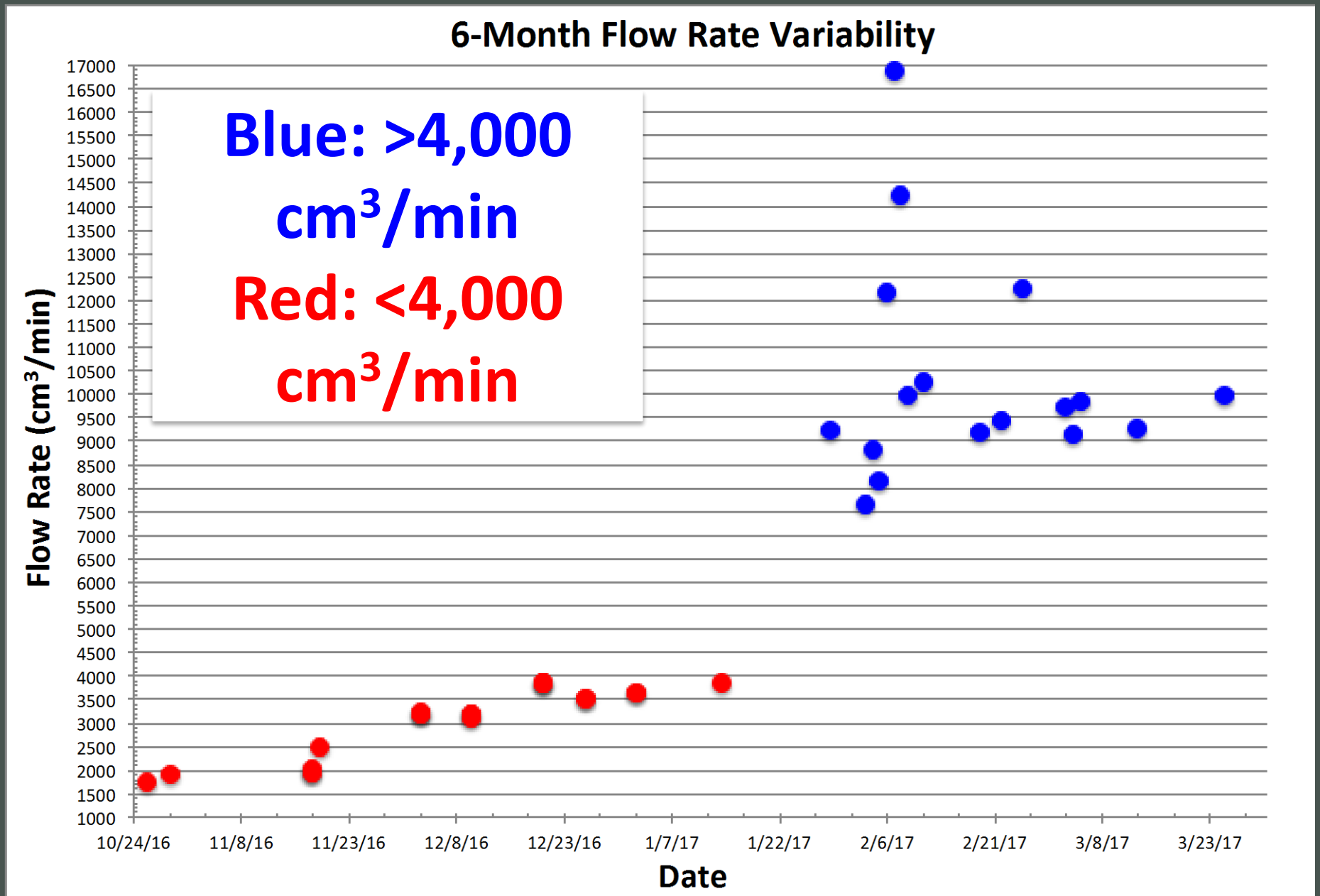
Alicat Flow Meter

Orifice Well Tester

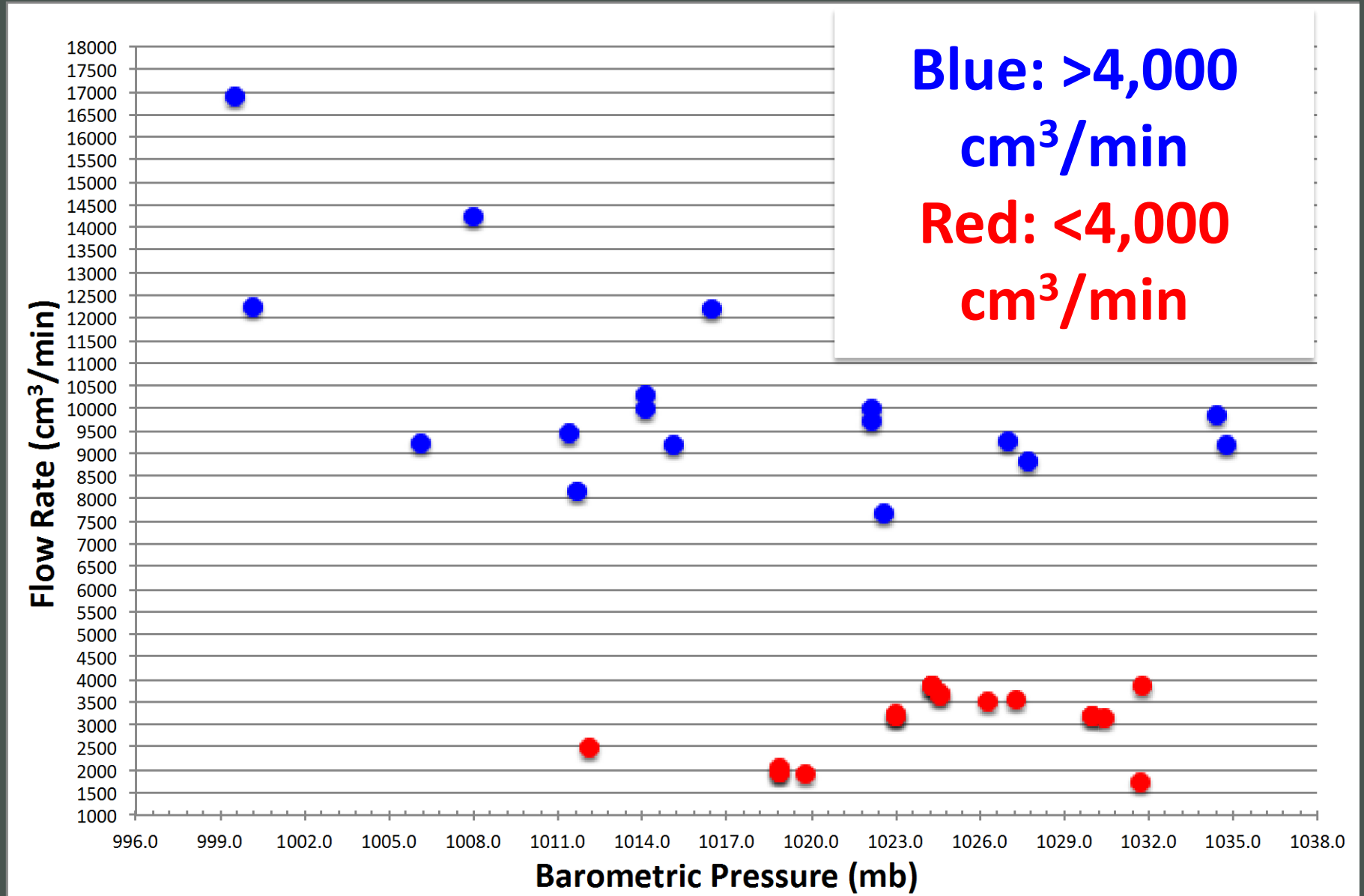
Minimal variability in high-resolution



Significant variability over a long timescale



Barometric pressure has a strong control on flow



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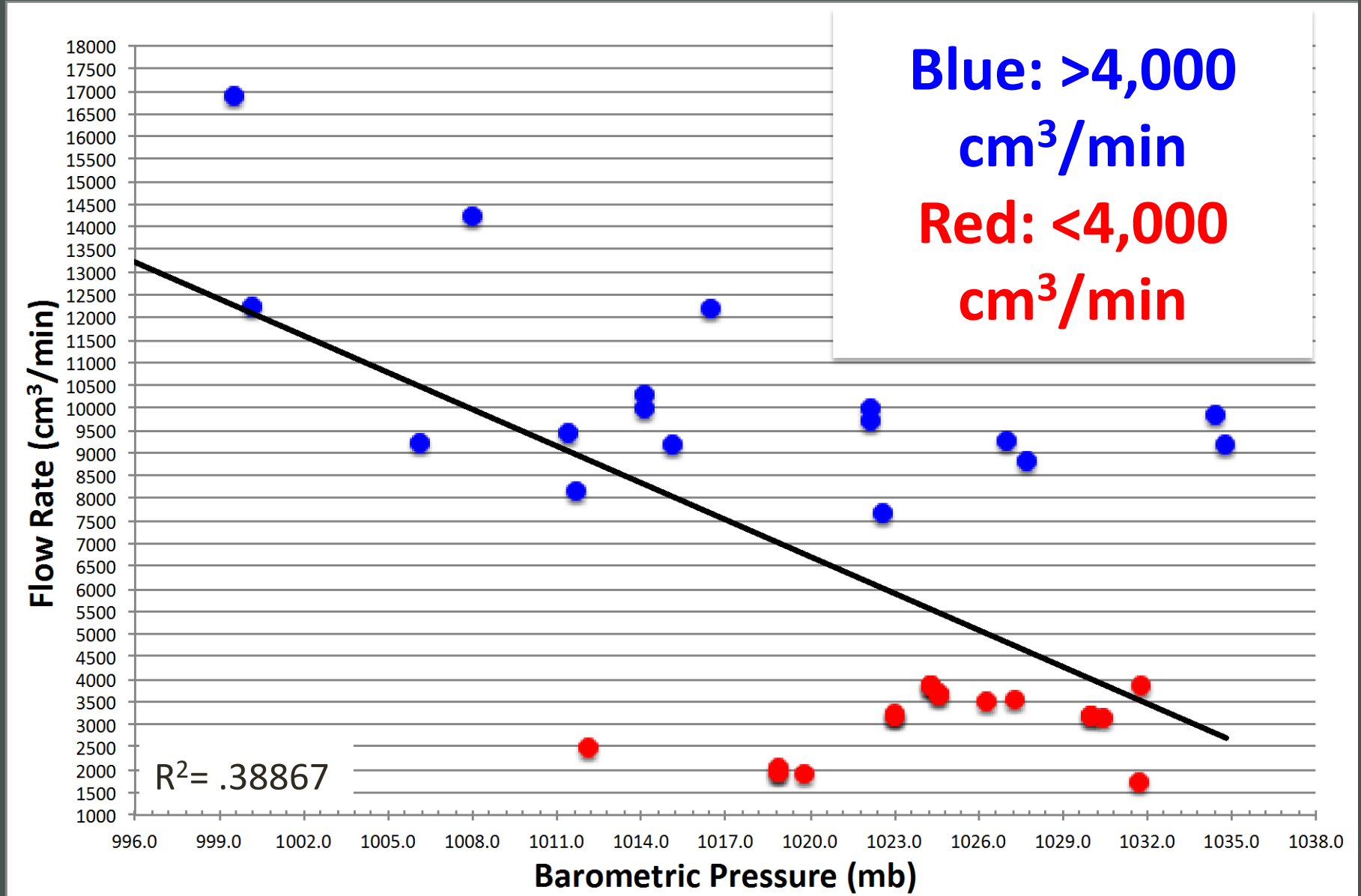
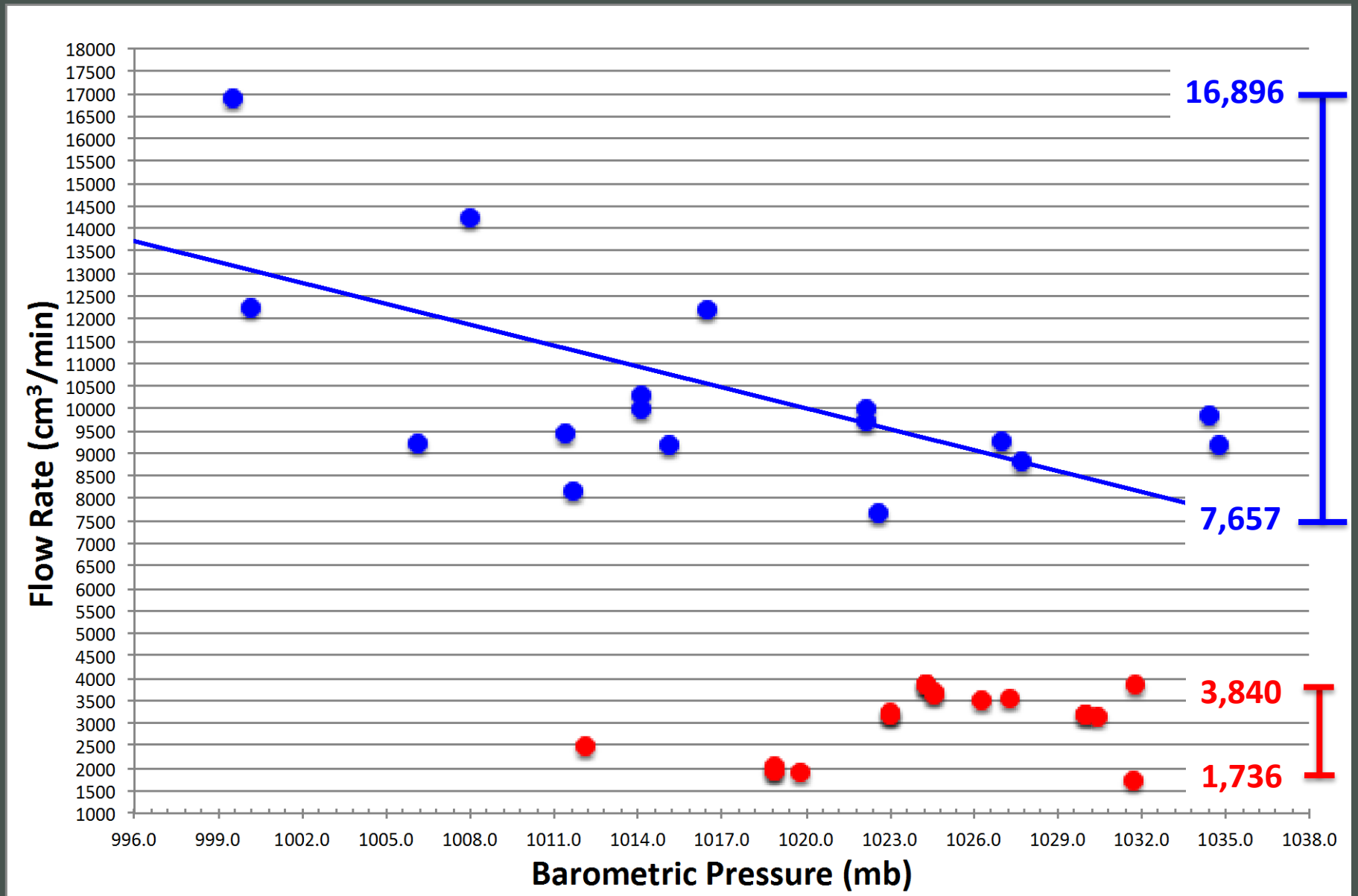


Stronger control on high flows than low flows



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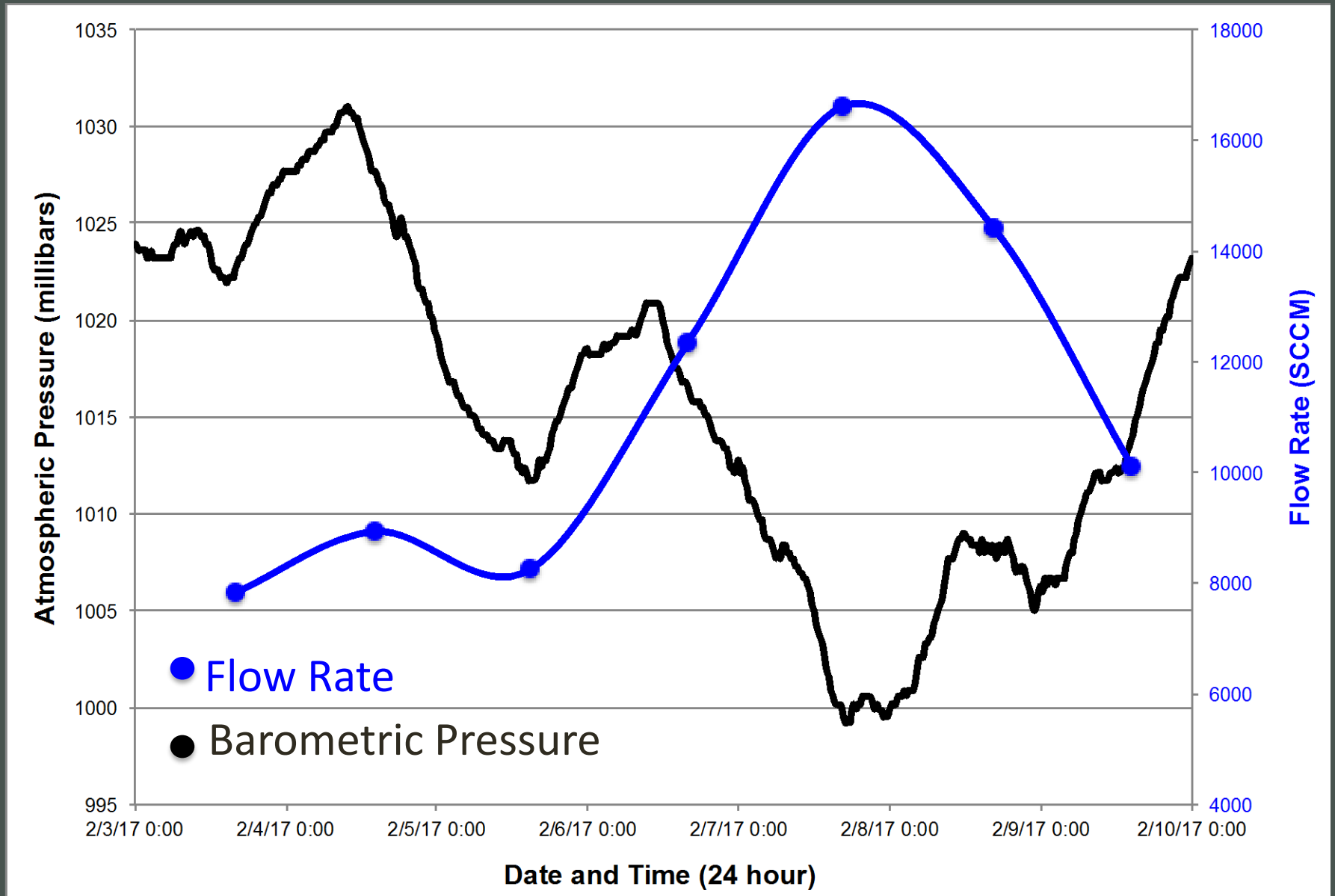
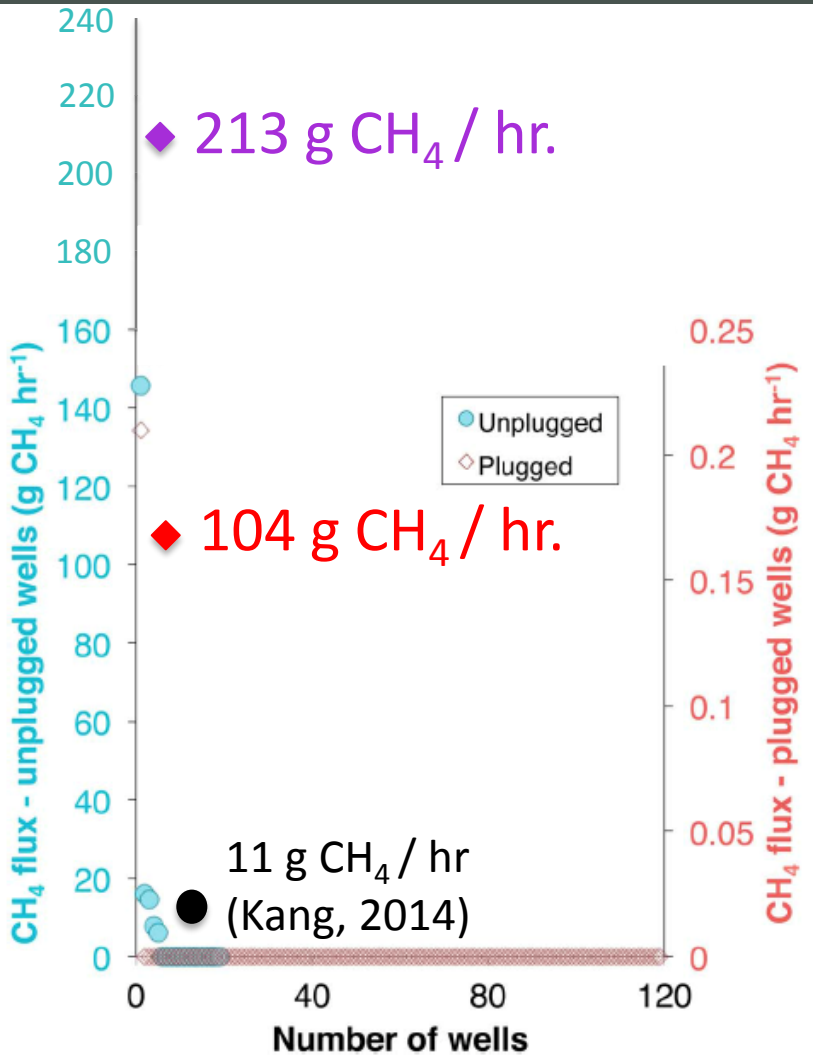


Concentrations of venting gas

Flow Rate (cm^3/min)
x
Methane Concentration
x
Density of methane (g/cm^3)
x
60 min
=
g CH_4 / hr

- **CH_4- 87%**
- **CO_2- 4%**
- **Undetermined- 9%**

Well is a super - emitter compared to previous studies



- Average Flow
- Low Flow Average
- High Flow Average: **358 g CH_4 / hr.**
- (Kang, 2014) Average

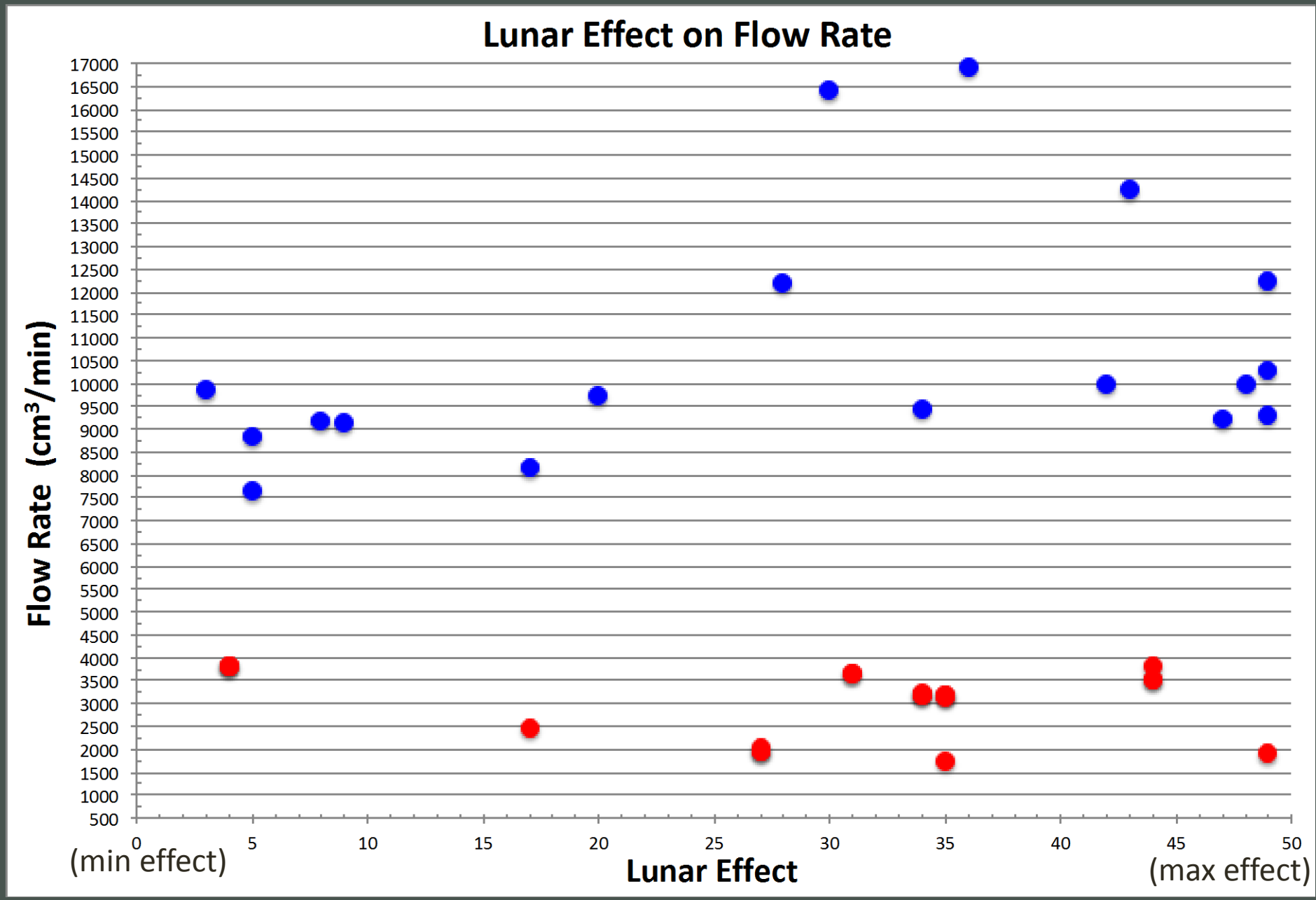
Modified from Townsend-Small et al., 2016

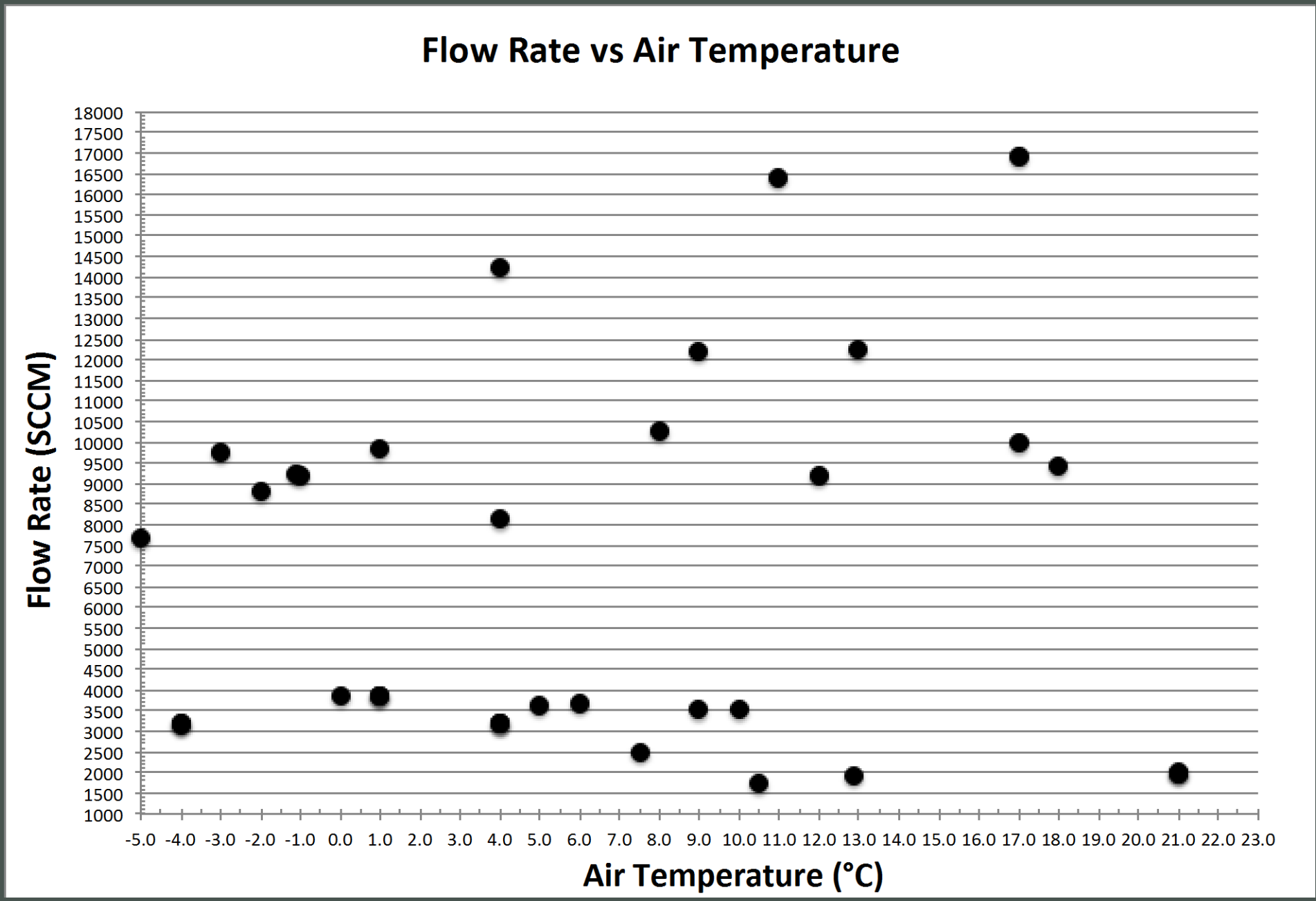
Conclusions

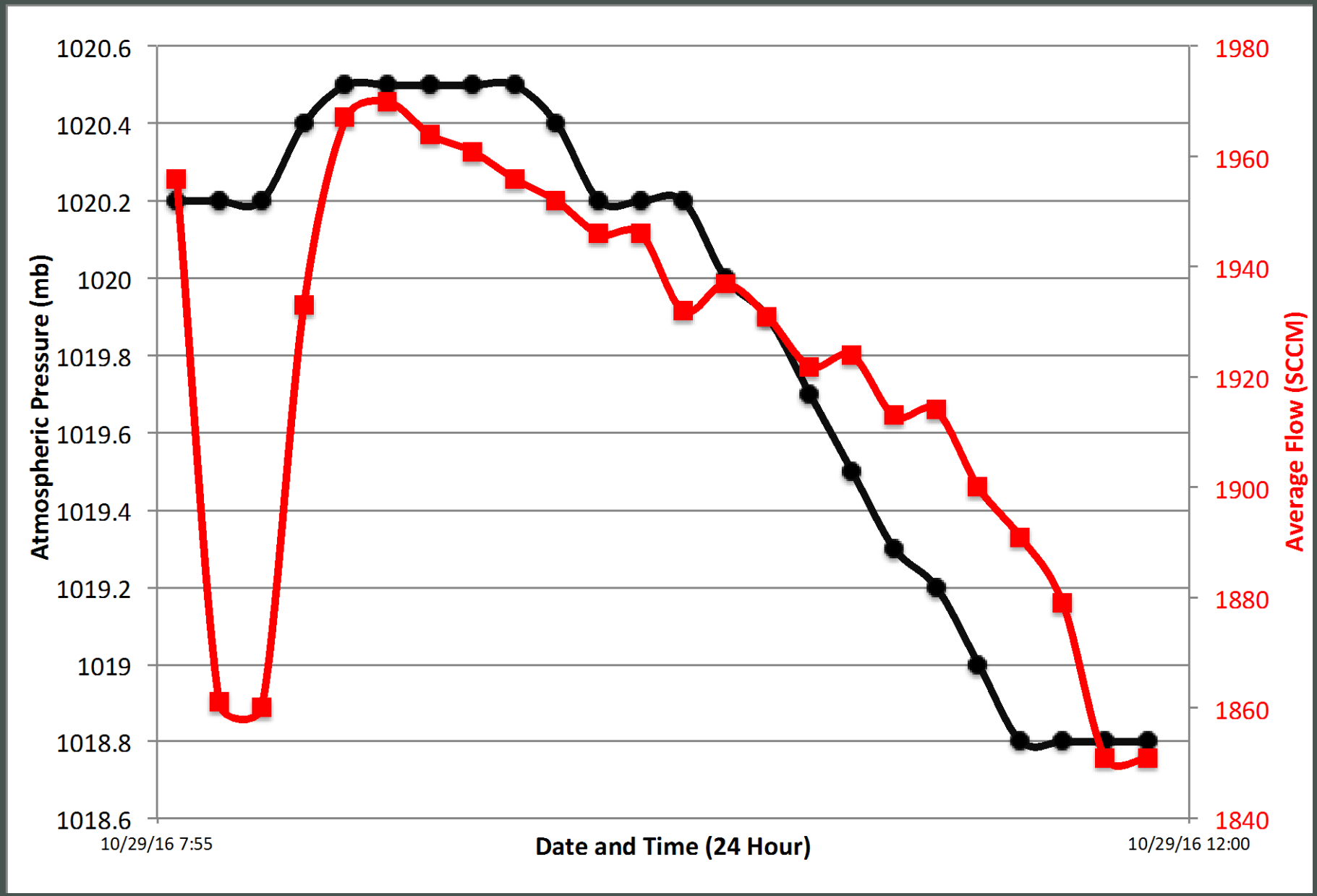
- A single measurement will not accurately quantify venting flow
- Barometric pressure appeared to have the strongest control on flow
- This large emitter well is not representative of most plugged wells
- Further investigation of multiple wells is needed

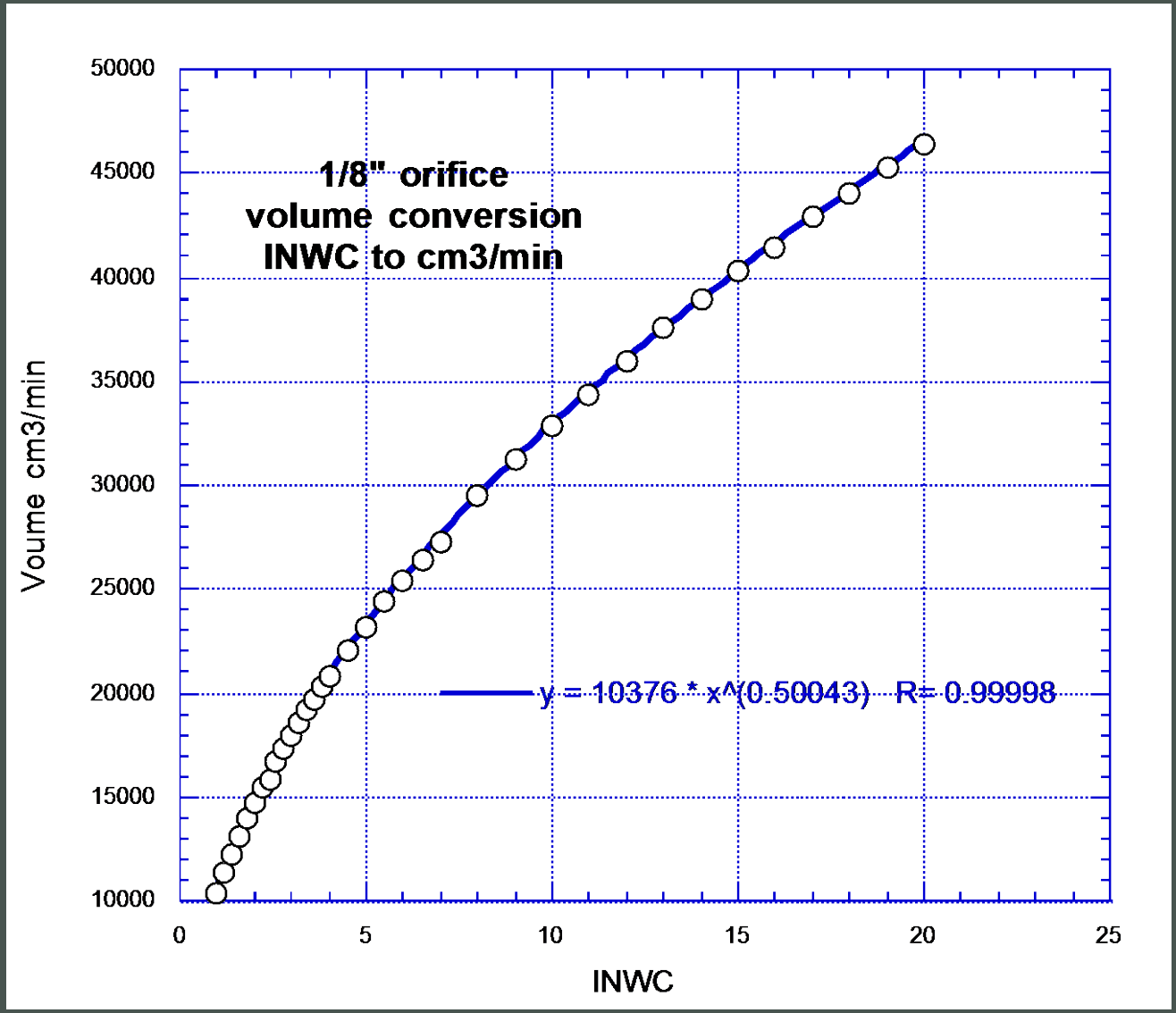
Acknowledgments

- Dominion Higher Educational Partnership
- IUP
- IUP Geoscience Department
- Dr. Greg Mount
- Dr. Steve Hovan


Lunar Effect on Flow Rate
Flow Rate (cm³/min)
17000
16500
16000
15500
15000
14500
14000
13500
13000
12500
12000
11500
11000
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
5
10
15
20
25
30
35
40
45
50
(min effect)
Lunar Effect
(max effect)


Flow Rate vs Air Temperature
Flow Rate (SCCM)
18000
17500
17000
16500
16000
15500
15000
14500
14000
13500
13000
12500
12000
11500
11000
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
-5.0 -4.0 -3.0 -2.0 -1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0
Air Temperature (°C)


1020.6
1020.4
1020.2
1020
1019.8
1019.6
1019.4
1019.2
1019
1018.8
1018.6
Atmospheric Pressure (mb)
1980
1960
1940
1920
1900
1880
1860
1840
Average Flow (SCCM)
10/29/16 7:55
Date and Time (24 Hour)
10/29/16 12:00


1/8" orifice
volume conversion
INWC to cm3/min
y = 10376 * x^(0.50043) R= 0.99998
Voume cm3/min
INWC
50000
45000
40000
35000
30000
25000
20000
15000
10000
0
5
10
15
20
25