This presentation premiered at WaterSmart Innovations

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INNOVATIONS

Understanding the Implications of Reduced Flows in Building Drains

ASFlow

Plumbing Efficiency Research Coalition

Alliance for Water Efficiency

ASPE

IAPMO

ICC INTERNATIONAL CODE COUNCIL

PHCC PLUMBING-HEATING-COOLING CONTRACTORS ASSOCIATION

pmi PLUMBING MANUFACTURERS INTERNATIONAL

What is PERC ?

- Formed in December of 2008
- MoU Signed at EPA HQ
- First Project: Drainline Transport
- MoU with AS-Flow in 2010
- Funding struggles

Why Drainline Transport?

- Toilet consumption reduced 3.5 gpf → 1.6 gpf →1.28 gpf → ?
- Commercial installations
  - Isolated bathrooms
  - Long horizontal run building drains
  - Reduced supplemental flows
    - Non-water consuming urinals, ultra low flow faucets (0.5 gpm)
    - Proliferation of other water efficient technologies; medical, food service, industrial and commercial processes
  - Toilets increasingly stressed
- Domestic installations
  - Reduced flow showerheads and appliances
  - Graywater reuse systems – long term potential to eliminate long duration flows

Past Research

- 2009 Dry Drains Forum at ISH Fair – 2009 CIB W062
  - Professor John Swaffield: No further research needed!
  - CIB Report Summarized Past Work
  - Discussions Followed
  - What makes the PERC study unique?
- ASFlow Research on Drainlines
  - Non-water Consuming Urinals
  - Horizontal Junctions
  - Impact of Toilet Paper Selection
- Lacking in Past Research
  - Very long duration test sequences that incorporate deformable media with toilet paper
  - Determine relative significance of controllable system variables

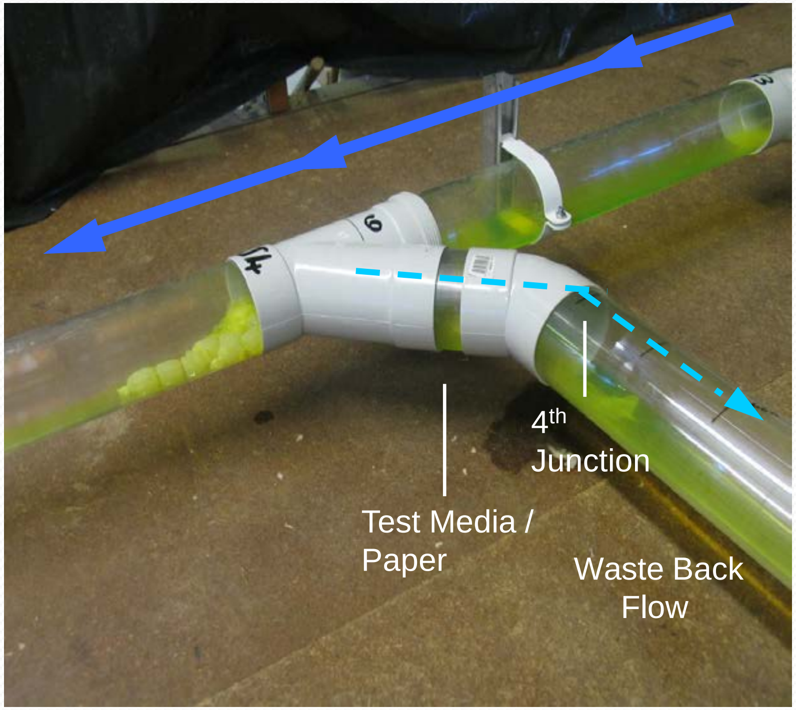


Photo: ASFlow research on horizontal junction fittings

The PERC Approach

- PERC Design of Experiment
  - The “Real World”: Too Variable to Duplicate / Characterize
  - Need to Understand What’s Really Important
  - Build a Perfect Drainline
- The Test Apparatus
  - 4” Clear PVC
  - 135 feet long (~41 M)
  - Slope Adjustable
- Why only 4-inch diameter? $
- Clearing Flush: Low Cost Solution?
  - Past research (Swaffield) cited potential
  - Low cost solution using flushometer-valves?

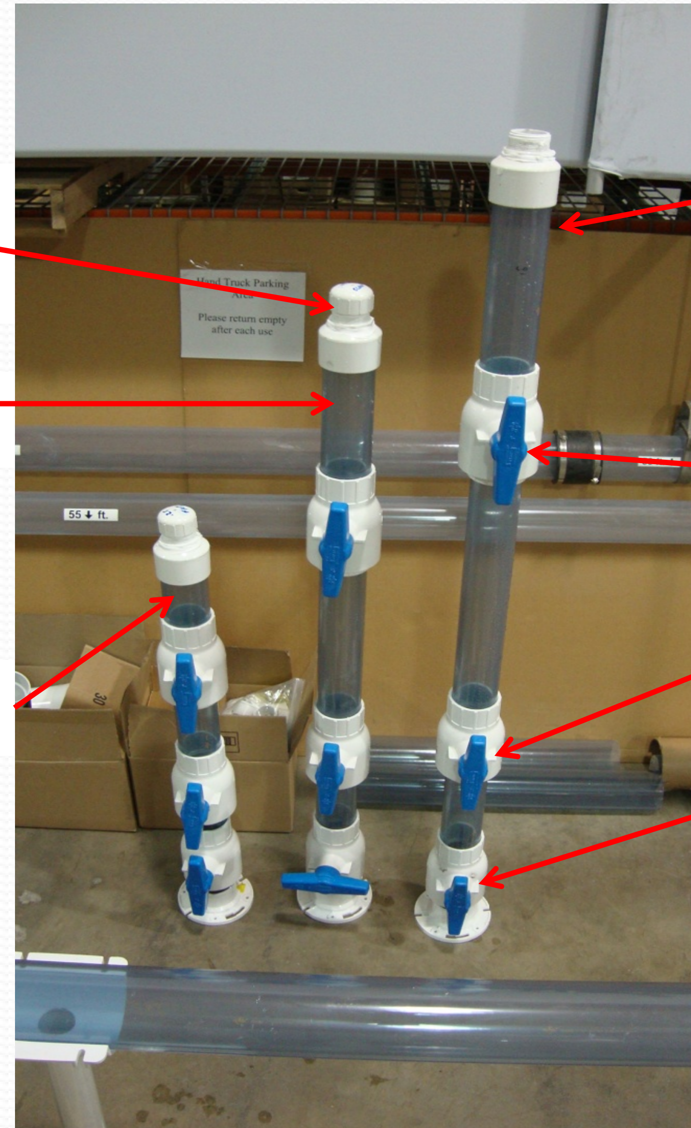
The PERC Approach

Test Apparatus viewed from Flush Stand

Two 90° Wide Sweep Bends at Far End

The PERC Approach

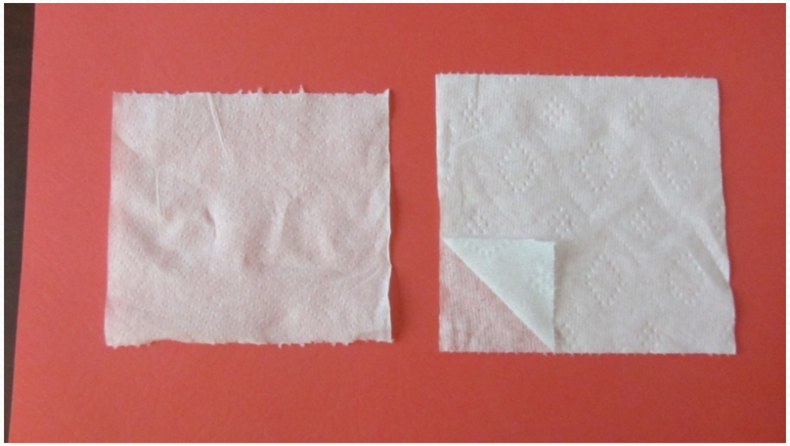
- Surge Injectors
  - More Consistent than Toilets
  - Control Flush Rate (2)
    - Threaded cap orifice
    - 2500 ml/sec
    - 3500 ml/sec
  - Control % Trailing Water (2)
    - 75%
    - 25%
  - Test Volumes (3)
    - 1.6, 1.28, 0.8 gpf
    - (6.0, 4.8, 3.0 Lpf)



Test Media

- Uncased "MaP" Test Media
  - Proven "Realistic" in Toilet Testing
  - Deformable, "breaks down"

- Toilet Paper
  - Two US Brands
    - Low Tensile Strength
    - High Tensile Strength



The PERC Test Plan

- Study Approach and Test Media Summary:
  - Lacking in Past Research
    - Very long duration test sequences that incorporate deformable media with toilet paper
    - Determine relative significance of controllable system variables
  - Cannot duplicate real world, run study on perfect apparatus
    - Only enough $ for one pipe diameter and two slopes
  - Develop a designed experiment that ranks controllable variables
  - Replace toilets with accurate Surge Injectors
    - Control toilet flush characteristics to determine significance
  - Use realistic Test Media
    - Uncased MaP Media / Toilet Paper

The PERC Test Plan

- The Designed Experiment (DOE)
  - What is a designed experiment?
    - Groups test variables
    - Assigns random test sequence
    - Improves accuracy and reduces test duration
    - Determine the relative significance of the test variables
    - Uses pre-determined statistical model to analyze data
    - Able to differentiate between “signal” (impact of the variables on the system) and “noise” (random occurrences in the system not attributed to the test variables)
  - Analysis of Variance “ANOVA”
    - Statistical model best suited to rank test variables
    - Significance determined by low “P-value”

The PERC Test Plan

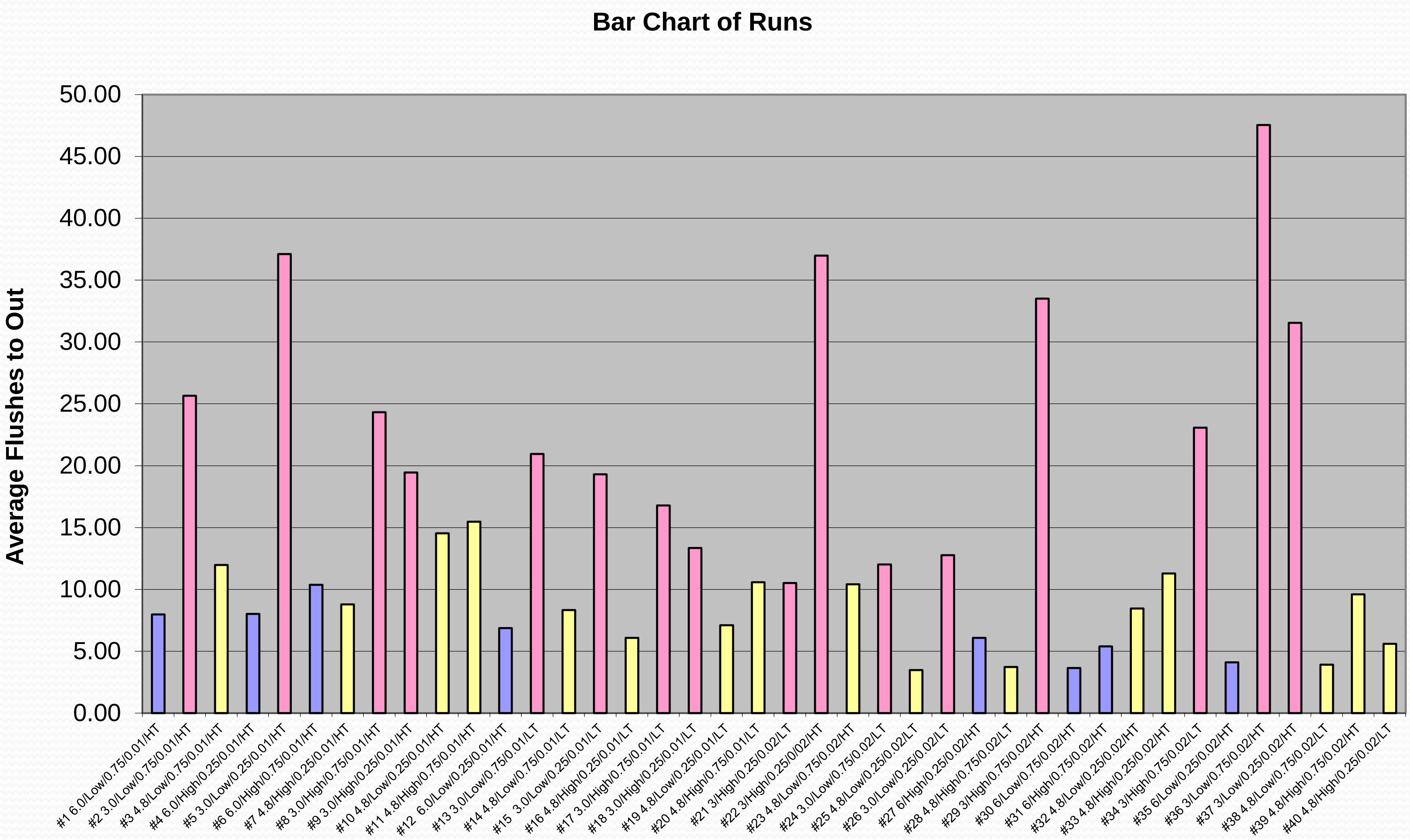
- Deliverables
  1. Clearing flush at the end of each Test Run
     - Is this a reliable low cost solution?

  2. Ranking of test variables
     - ✓ *1 Pipe Diameter: 4-inch / ~100* mm
     - ✓ *2 Pipe Slopes/Pitches: 1.00%; 2.00%*
     - ✓ *3 Flush Volumes: 6.0/1.6; 4.8/1.3; 3.0/0.8 (Lpf / gpf)*
     - ✓ *2 Flush Rates: 3500; 2500 (ml/sec –peak flow)*
     - ✓ *2 Percent Trailing Water Levels: 75%; 25%*
     - ✓ *2 Toilet Paper Tensile Strengths: High; Low*

The PERC Test Plan

- Execution of the DOE
  - Test Sequence
    - Total of 40 - 100 cycle ***Test Runs*** that capture the test variables
    - Random test sequence determined by computer
  - How do we measure?
  - ***Flushes to Out***: *the number of flushes it took for an individual injection of test media to run the 135 foot Test Apparatus course of in a Test Run*
  - ***Average Flushes to Out (AVO):*** *the average Flushes to Out value in a Test Run after 100 flush cycles*
  - **IMPORTANT** - The AVO scores were used to calculate all results

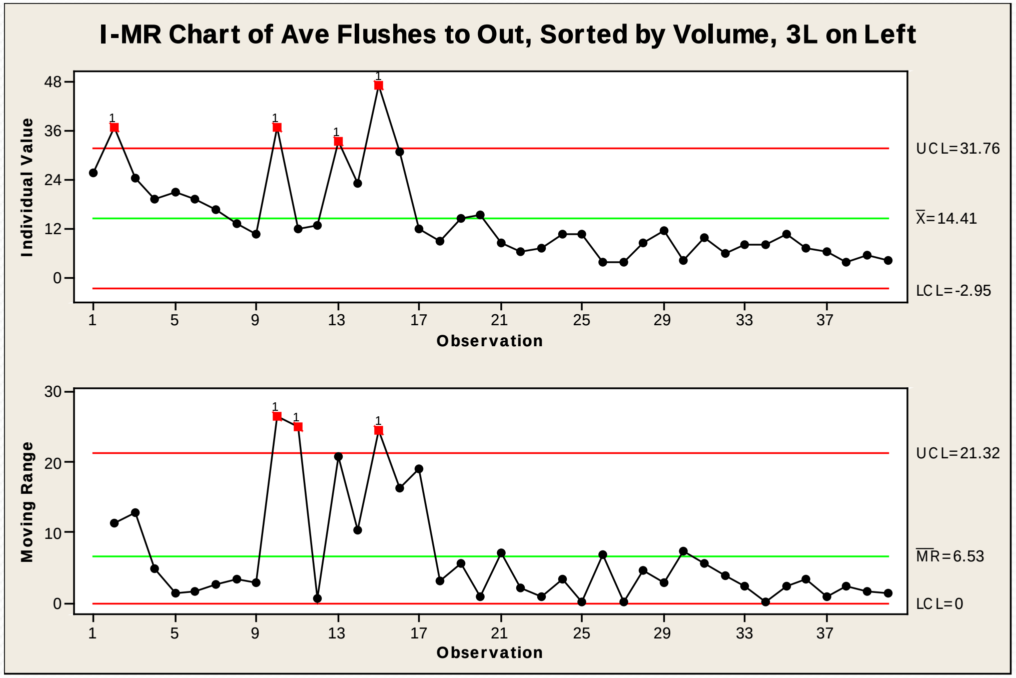
Data Review



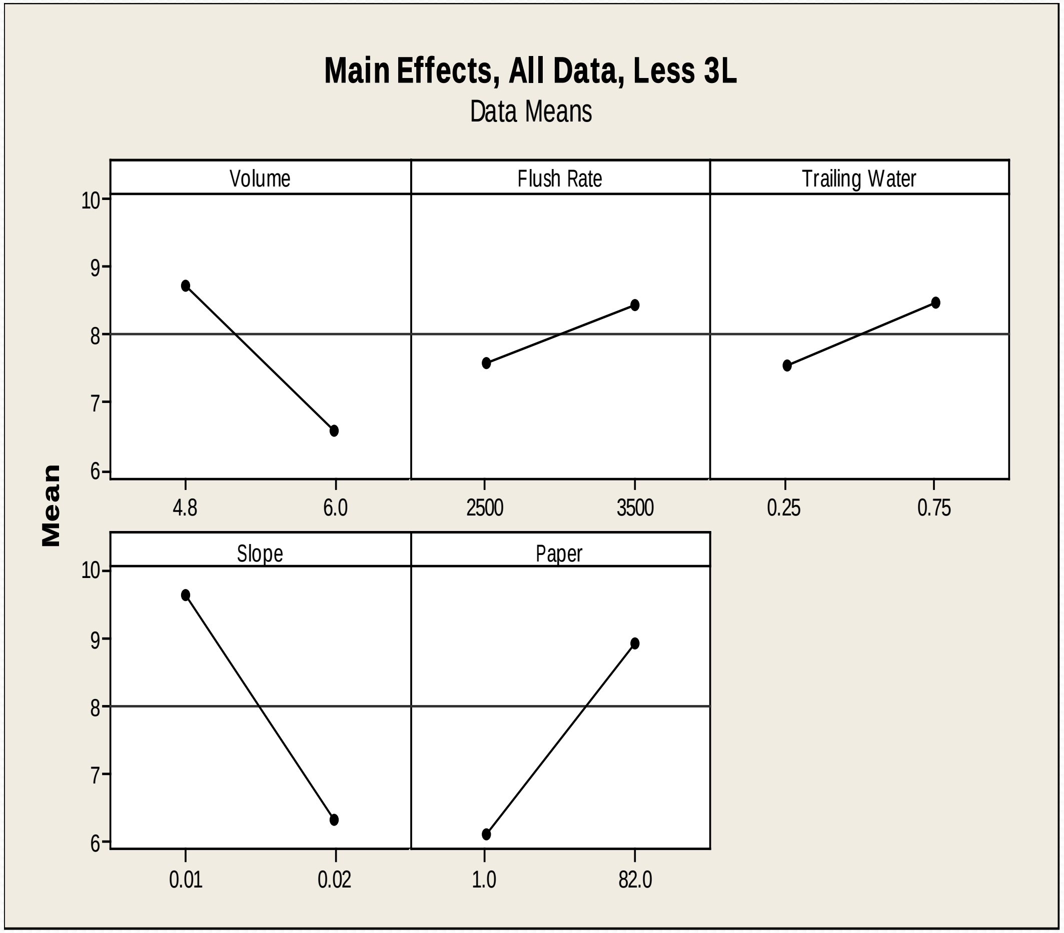
Bar Chart of Runs
Average Flushes to Out
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
#1 6.0/Low/0.75/0.01/HT
#2 3.0/Low/0.75/0.01/HT
#3 4.8/Low/0.75/0.01/HT
#4 6.0/High/0.25/0.01/HT
#5 3.0/Low/0.25/0.01/HT
#6 6.0/High/0.75/0.01/HT
#7 4.8/High/0.25/0.01/HT
#8 3.0/High/0.75/0.01/HT
#9 3.0/High/0.25/0.01/HT
#10 4.8/Low/0.25/0.01/HT
#11 4.8/High/0.75/0.01/HT
#12 6.0/Low/0.25/0.01/HT
#13 3,0/Low/0.75/0.01/LT
#14 4.8/Low/0.75/0.01/LT
#15 3.0/Low/0.25/0.01/LT
#16 4.8/High/0.25/0.01/LT
#17 3.0/High/0.75/0.01/LT
#18 3.0/High/0.25/0.01/LT
#19 4.8/Low/0.25/0.01/LT
#20 4.8/High/0.75/0.01/LT
#21 3/High/0.25/0.02/LT
#22 3/High/0.25/0/02/HT
#23 4.8/Low/0.75/0.02/HT
#24 3.0/Low/0.75/0.02/LT
#25 4.8/Low/0.25/0.02/LT
#26 3.0/Low/0.25/0.02/LT
#27 6/High/0.25/0.02/HT
#28 4.8/High/0.75/0.02/LT
#29 3/High/0.75/0.02/HT
#30 6/Low/0.75/0.02/HT
#31 6/High/0.75/0.02/HT
#32 4.8/Low/0.25/0.02/HT
#33 4.8/High/0.25/0.02/HT
#34 3/High/0.75/0.02/LT
#35 6/Low/0.25/0.02/HT
#36 3/Low/0.75/0.02/HT
#37 3/Low/0.25/0.02/HT
#38 4.8/Low/0.75/0.02/LT
#39 4.8/High/0.75/0.02/HT
#40 4.8/High/0.25/0.02/LT

Data Review

- Trouble with 0.8 gallon (3.0 L) data
  - Observation during Test Runs
    - 0.8 gallon test runs chaotic
    - Very high variability in AVO scores
  - Statistical review of 0.8 gallon data indicates:
    - Results are random and not attributed to the test variables
    - Skews the overall test results significantly
    - 0.8 Test Run results are “out of control”



Data Review



Factor	Type	Levels	Values
Volume	fixed	2	4.8, 6.0
Flush Rate	fixed	2	2500, 3500
Trailing Water	fixed	2	0.25, 0.75
Slope	fixed	2	0.01, 0.02
Paper	fixed	2	1, 82

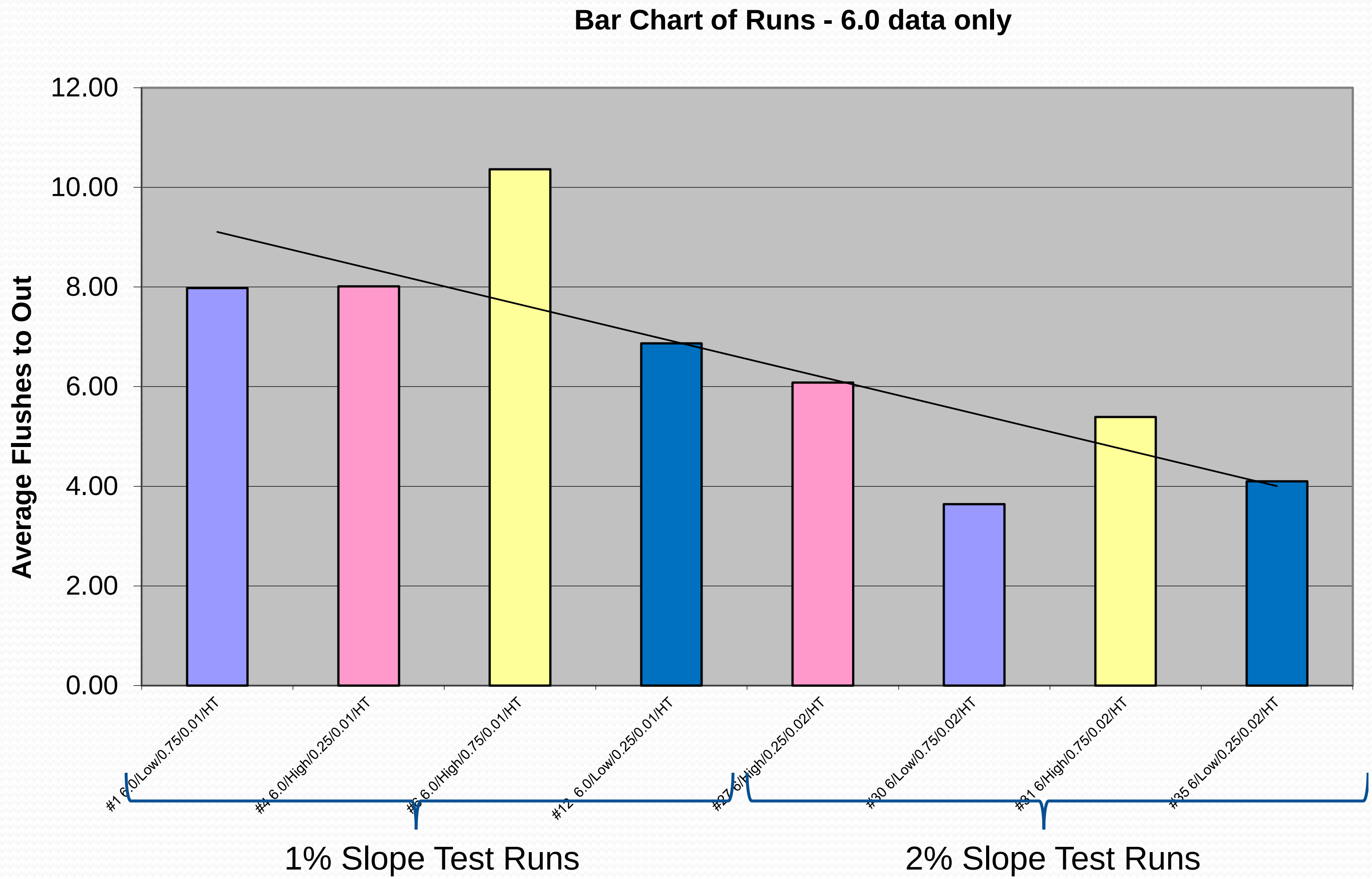
Variable	P Value
Volume	0.000*
Flush Rate	0.216
Trailing Water	0.185
Slope	0.000*
Paper	0.000*

* P-values below 0.05 indicate significance of the test variable

R-Sq = 81.61percent

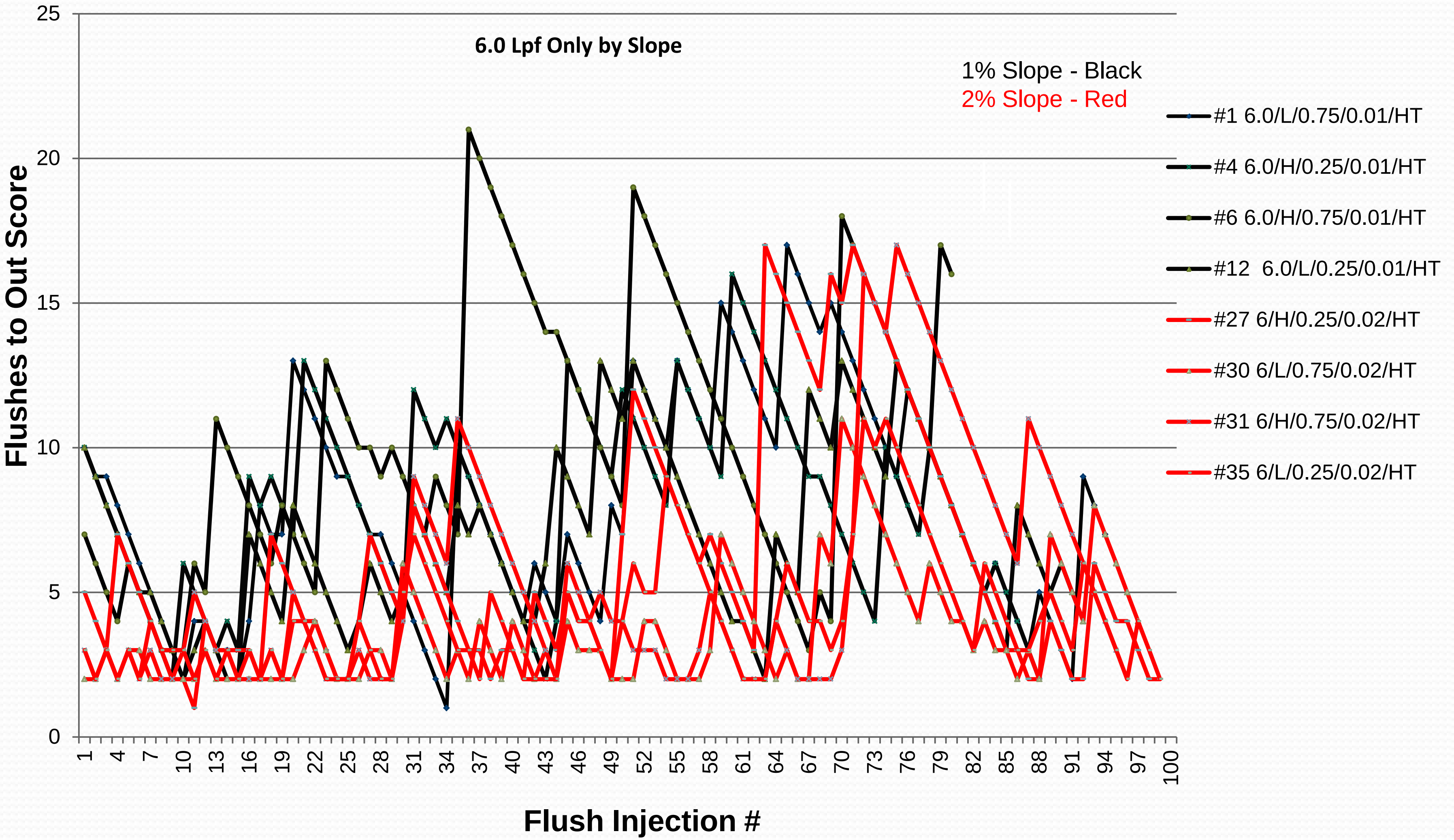
Data Review

- How can we tell if the statistical model is telling us the right answers? Let's look at traditional charts!



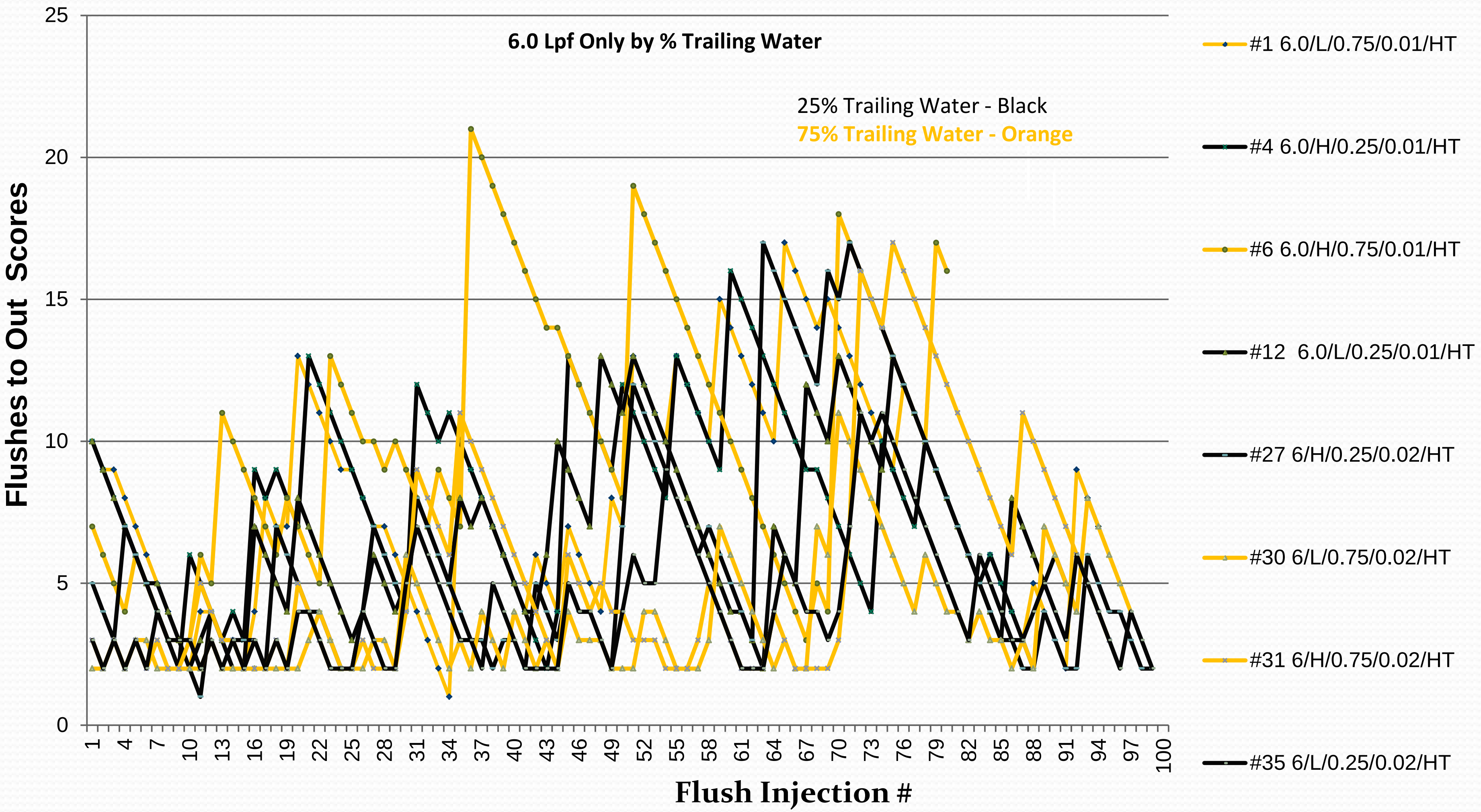
Data Review

- 6.0 L (1.6 gal) data broken down by Slope



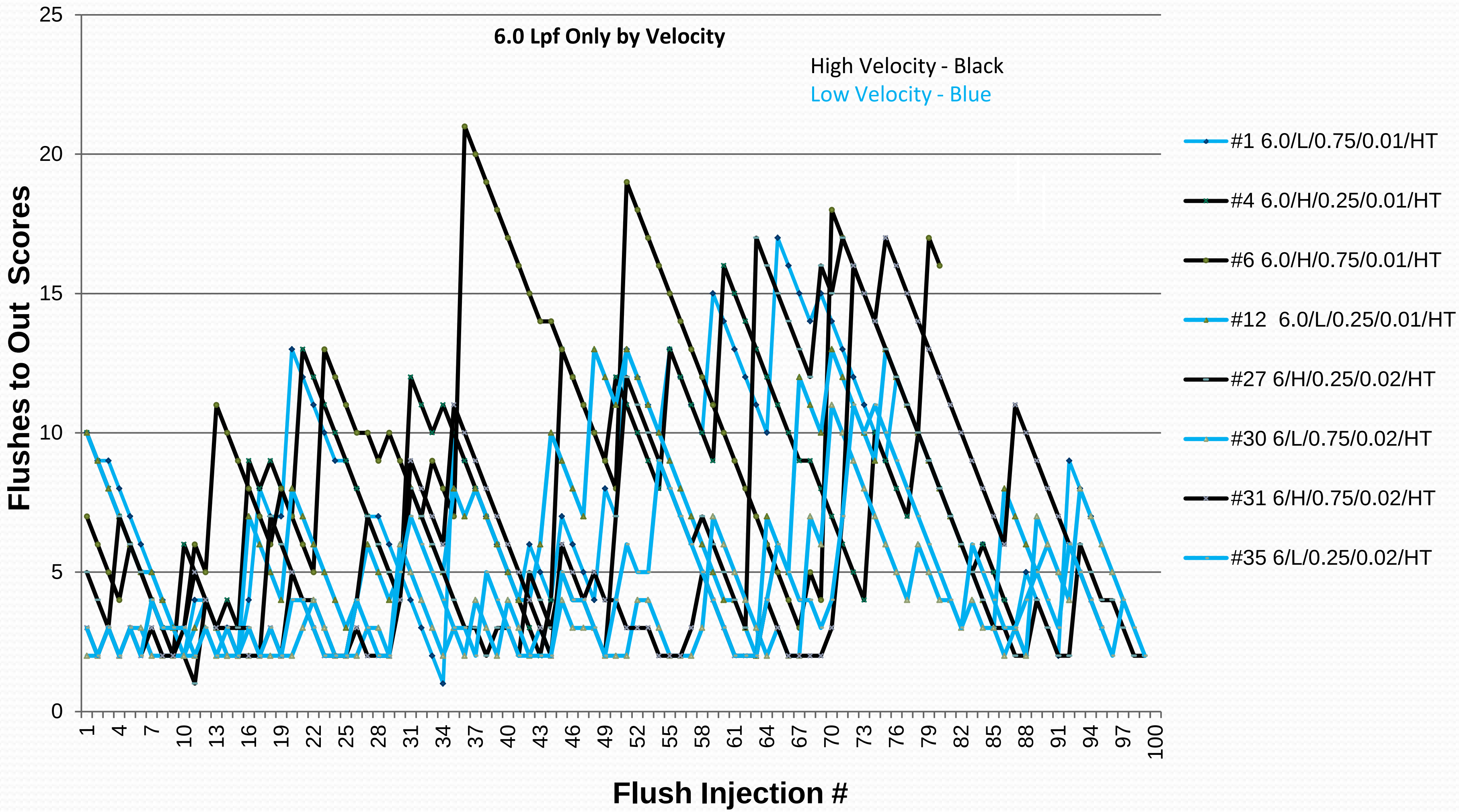
Data Review

- 6.0 L (1.6 gal) data broken down by % Trailing Water



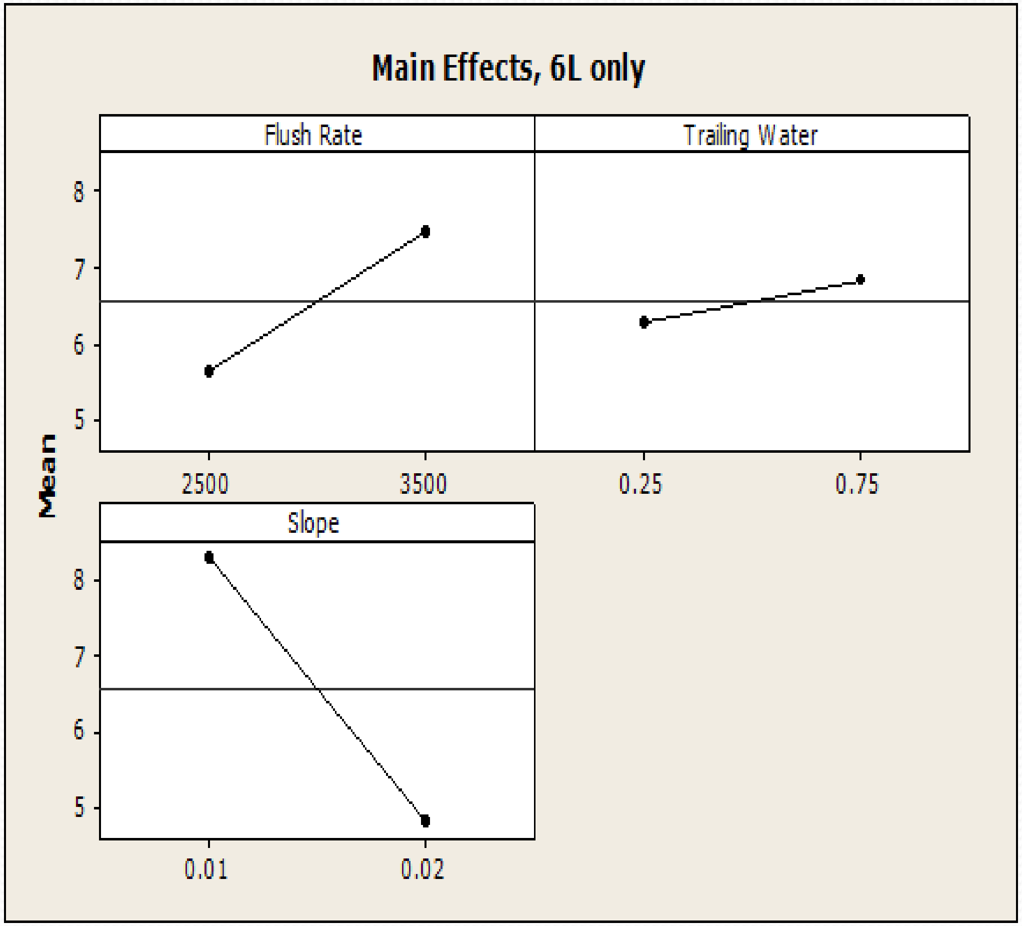
Data Review

- 6.0 L (1.6 gal) data broken down by Flush Rate



Data Review

- 6.0 L (1.6 gal) data – Main Effects Plots



Factor	Type	Levels	Values
Flush Rate	fixed	2	2500, 3500
Trailing Water	fixed	2	0.25, 0.75
Slope	fixed	2	0.01, 0.02

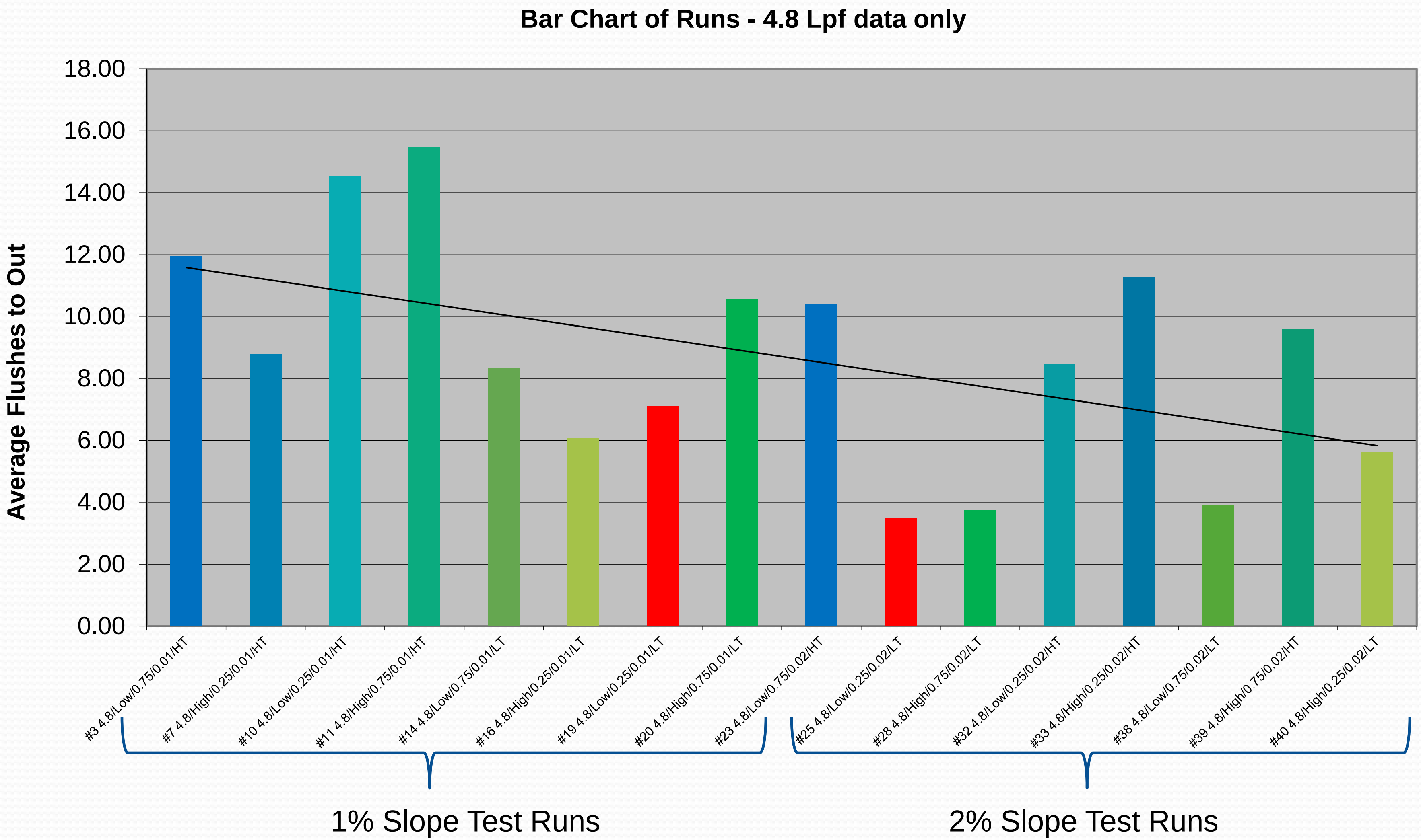
Variable	P Value
Flush Rate	0.043*
Trailing Water	0.404
Slope	0.005*

* P-values below 0.05 indicate significance of the test variable

R-Sq = 91.2%

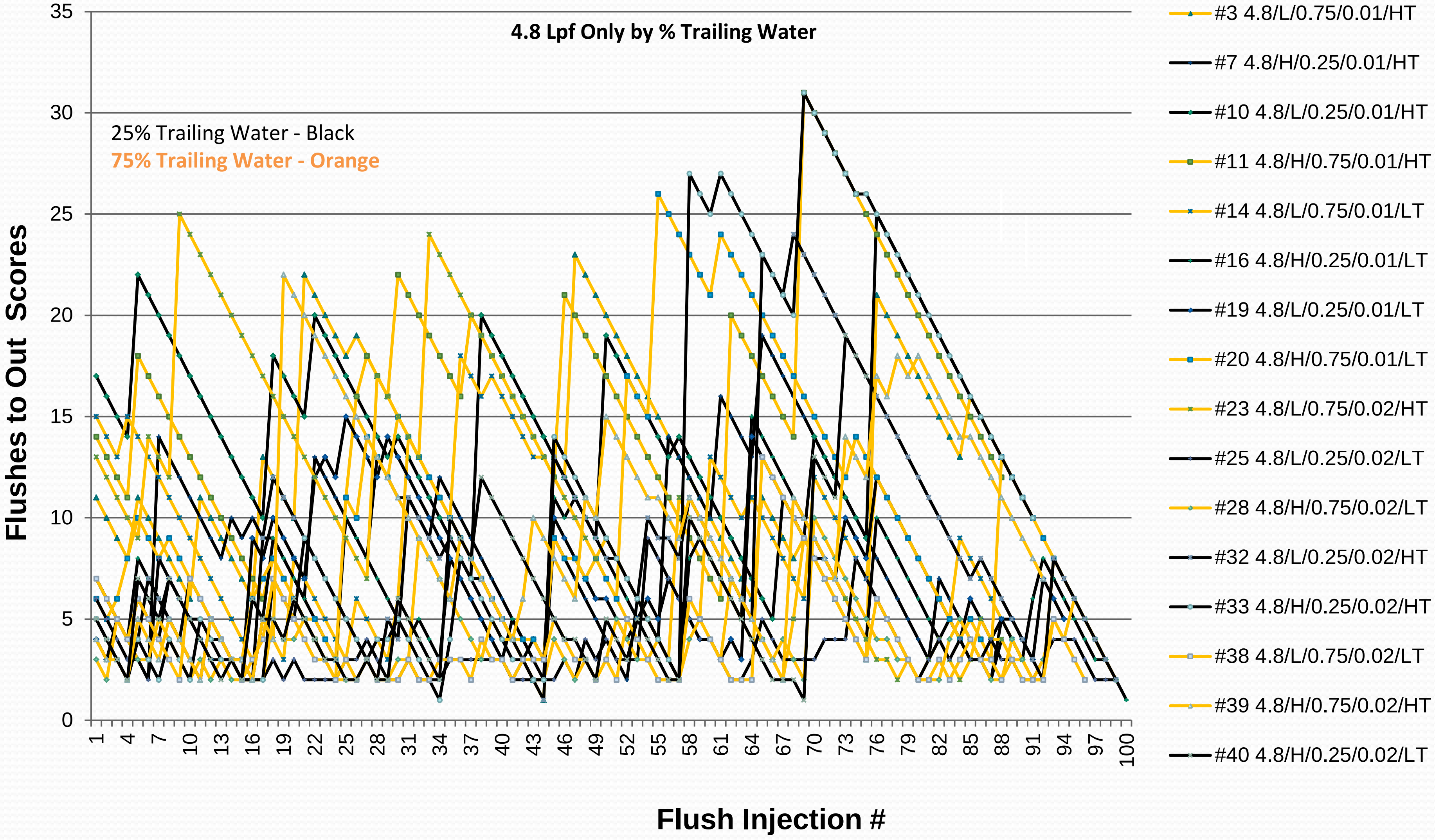
Data Review

- 4.8 L (1.28 gal) data only by slope



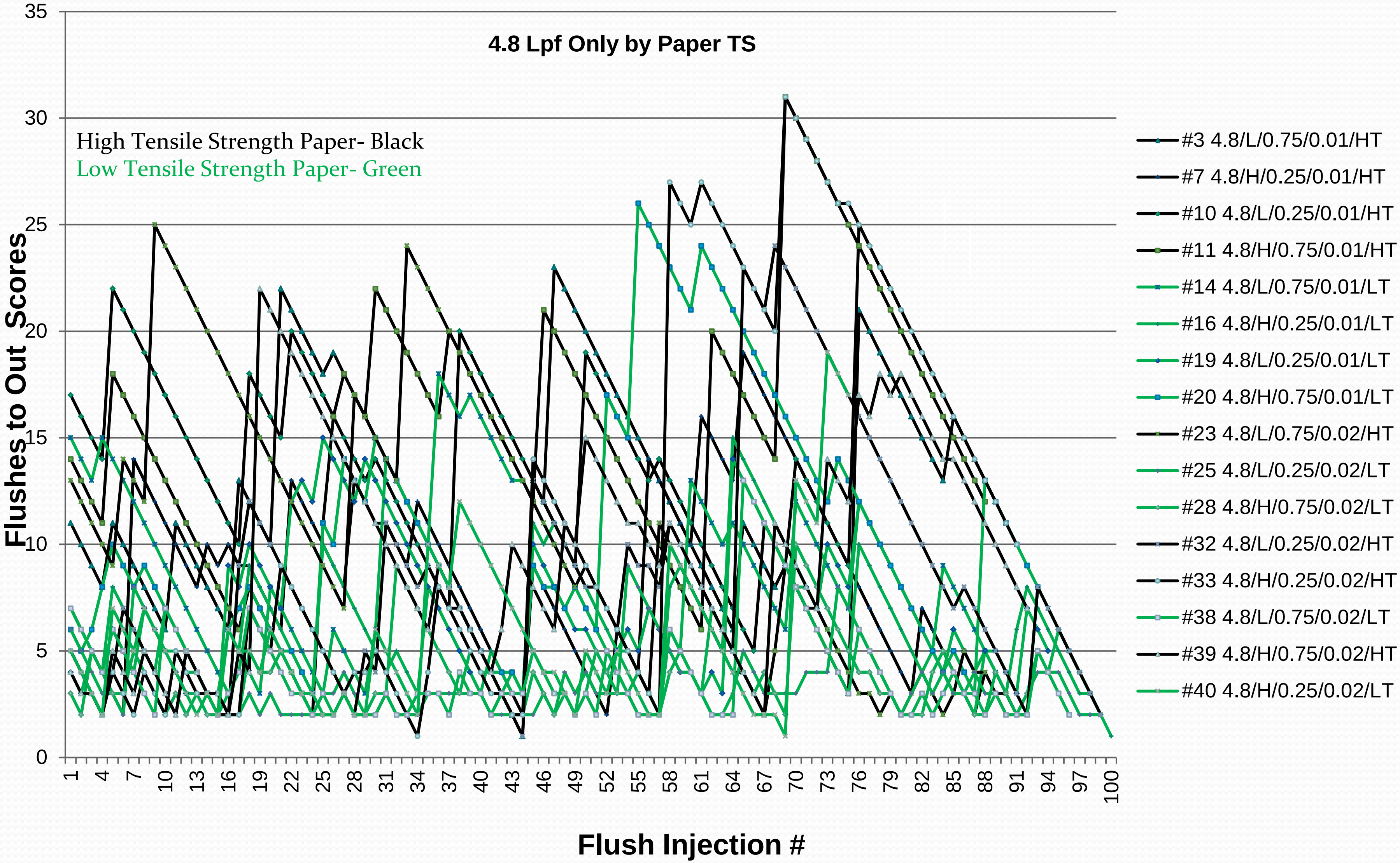
Data Review

- 4.8 L (1.28 gal.) data broken down by % Trailing Water



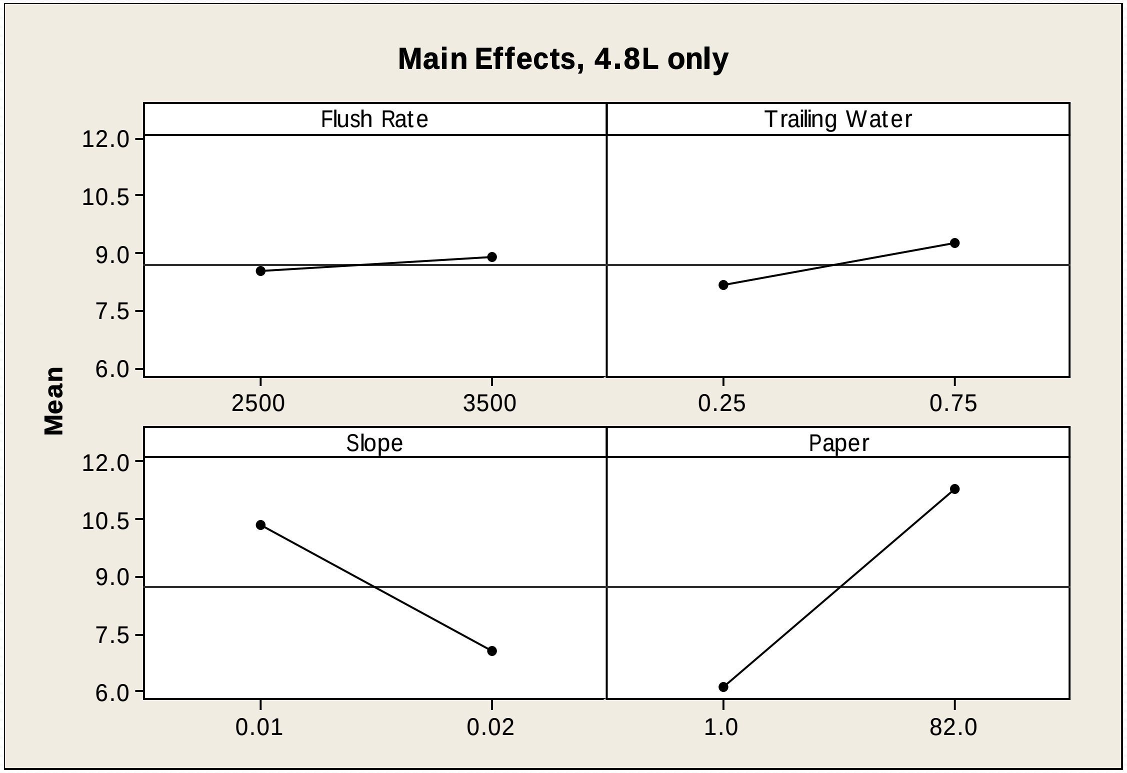
Data Review

- 4.8 L (1.28 gal) data broken down by Paper Tensile Strength



Data Review

- 4.8 L (1.28 gal) data – Main Effects Plots



Factor	Type	Levels	Values
Flush Rate	fixed	2	2500, 3500
Trailing Water	fixed	2	0.25, 0.75
Slope	fixed	2	0.01, 0.02
Paper	fixed	2	1, 82

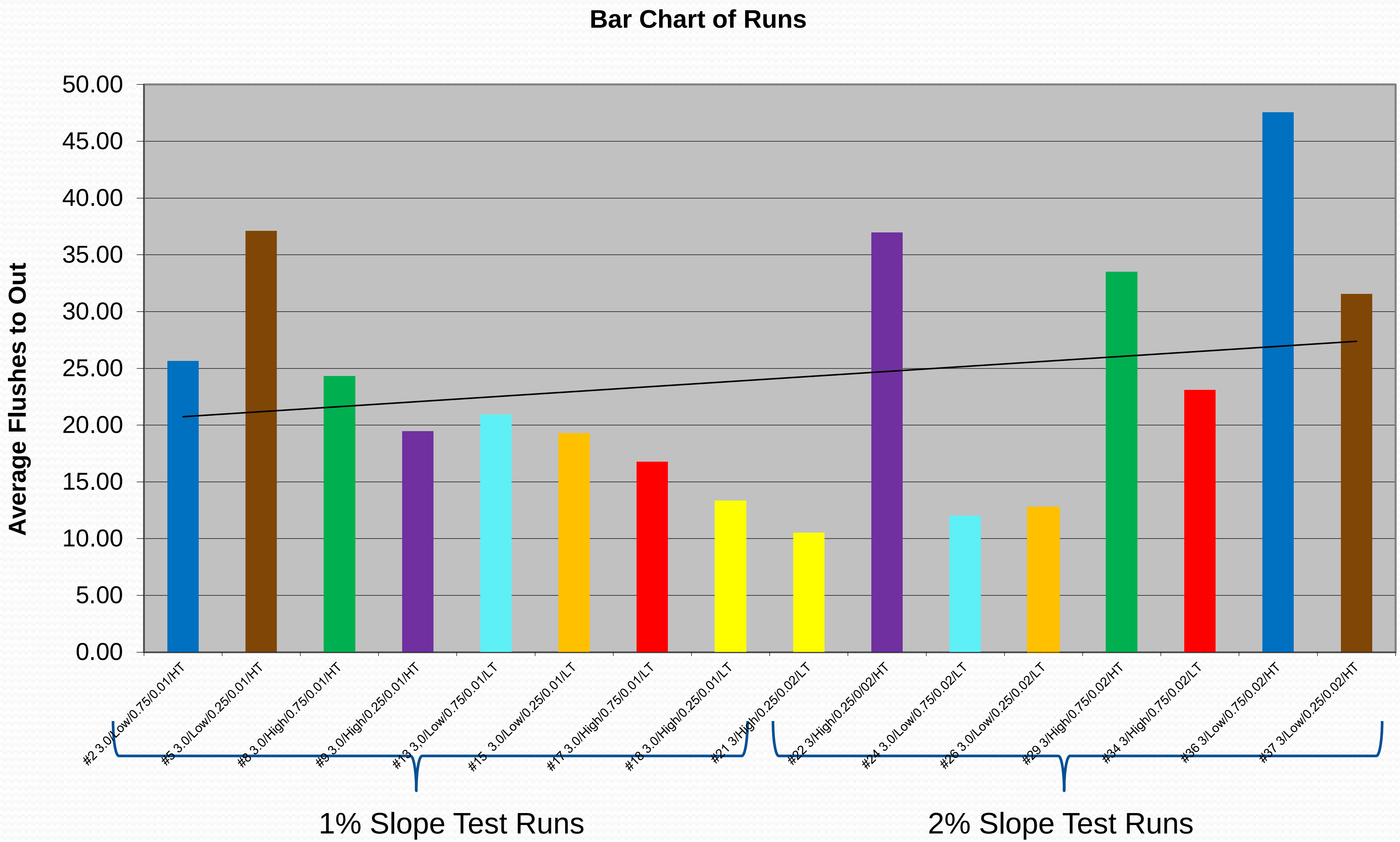
Variable	P Value
Flush Rate	0.712
Trailing Water	0.288
Slope	0.006*
Paper	0.000*

* P-values below 0.05 indicate significance of the test variable

R-Sq = 79.23%

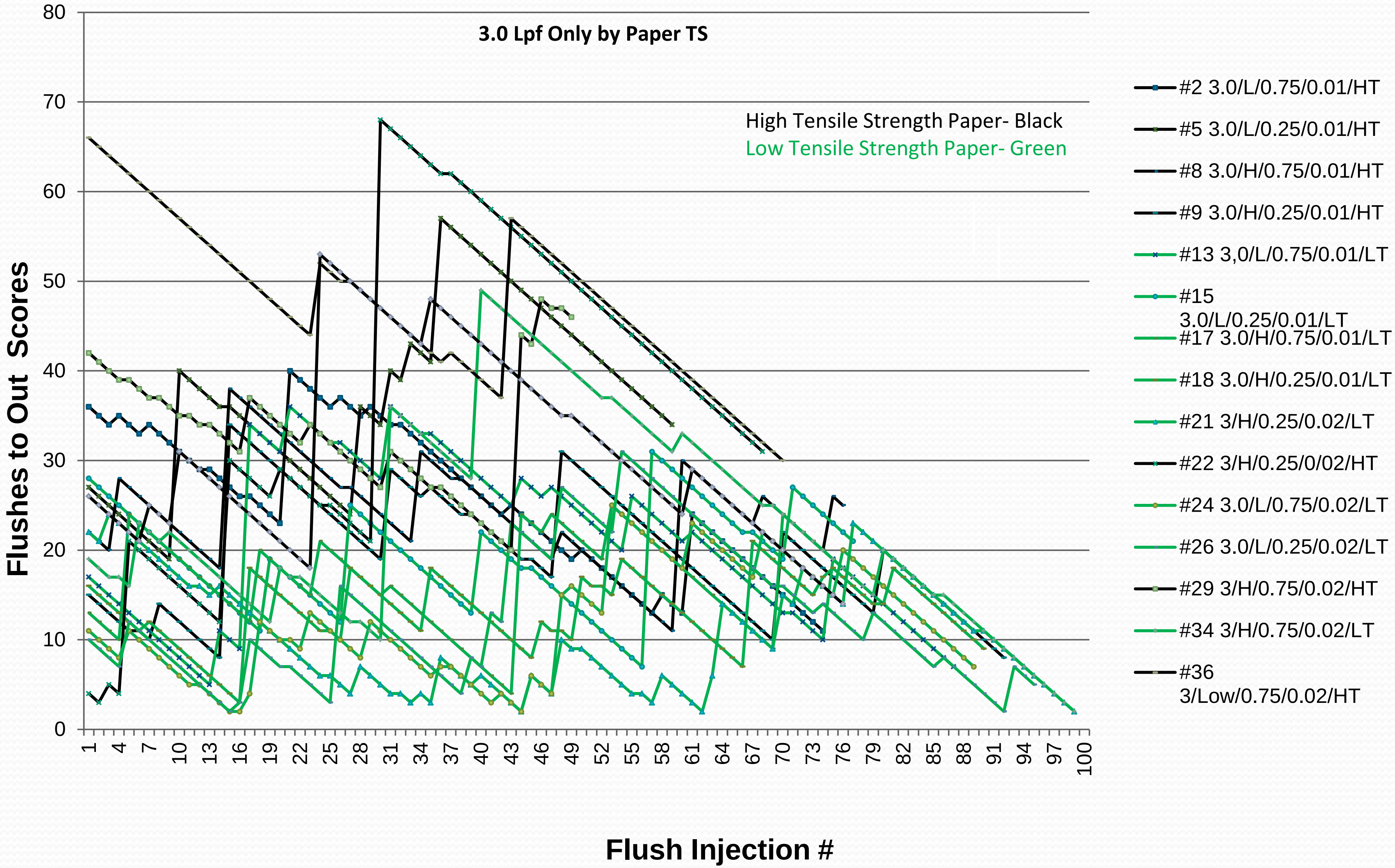
Data Review

- 3.0 L (0.8 gal) data only by slope



Data Review

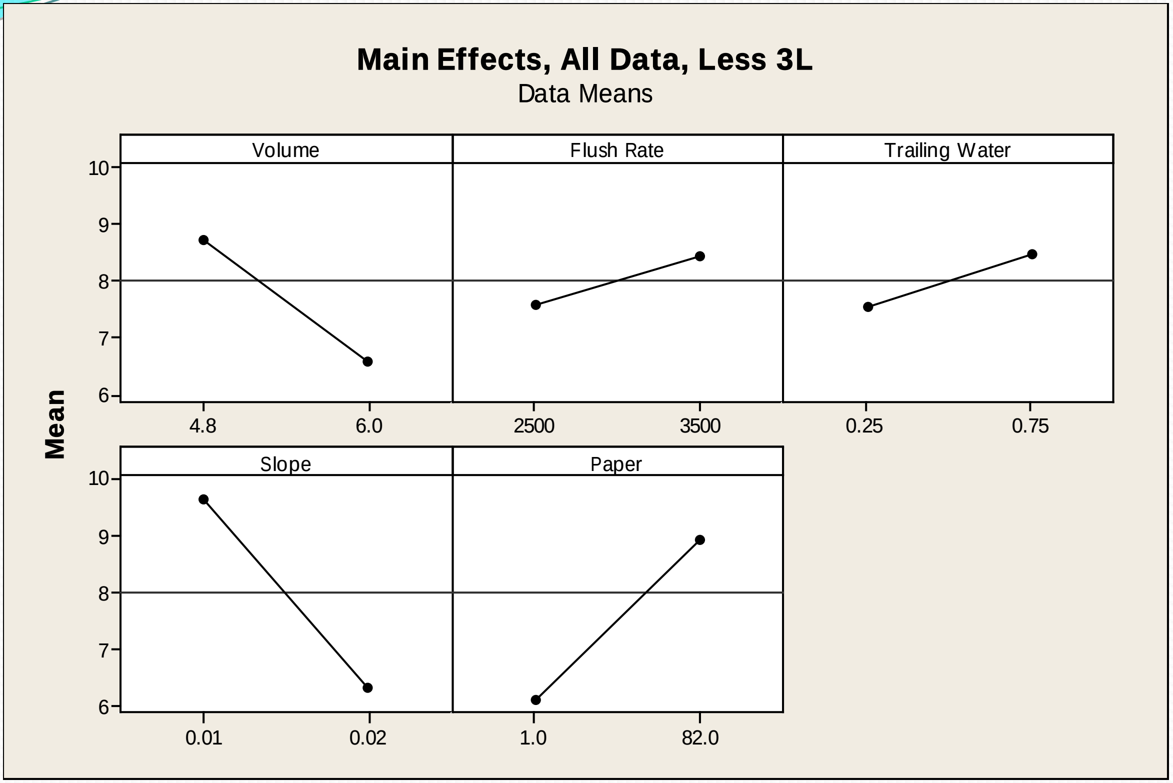
- 3.0 L (0.8 gal) data broken down by Paper Tensile Strength



- Deliverables
  1. Clearing flush at the end of each Test Run
     - Reliable solution? **No**
     - 5 gallon clearing flush failed to clear line in 7 of 39 trials
     - Further study warranted
       - Shorter intervals
       - Requires separate experiment
  2. Ranking of test variables

Significant Variables	**Insignificant Variables**
Slope > Paper > Volume >	**% Trailing Water > Flush Rate**

Findings



Factor	Type	Levels	Values
Volume	fixed	2	4.8, 6.0
Flush Rate	fixed	2	2500, 3500
Trailing Water	fixed	2	0.25, 0.75
Slope	fixed	2	0.01, 0.02
Paper	fixed	2	1, 82

Variable	P Value
Volume	0.000*
Flush Rate	0.216
Trailing Water	0.185
Slope	0.000*
Paper	0.000*

* P-values below 0.05 indicate significance of the test variable

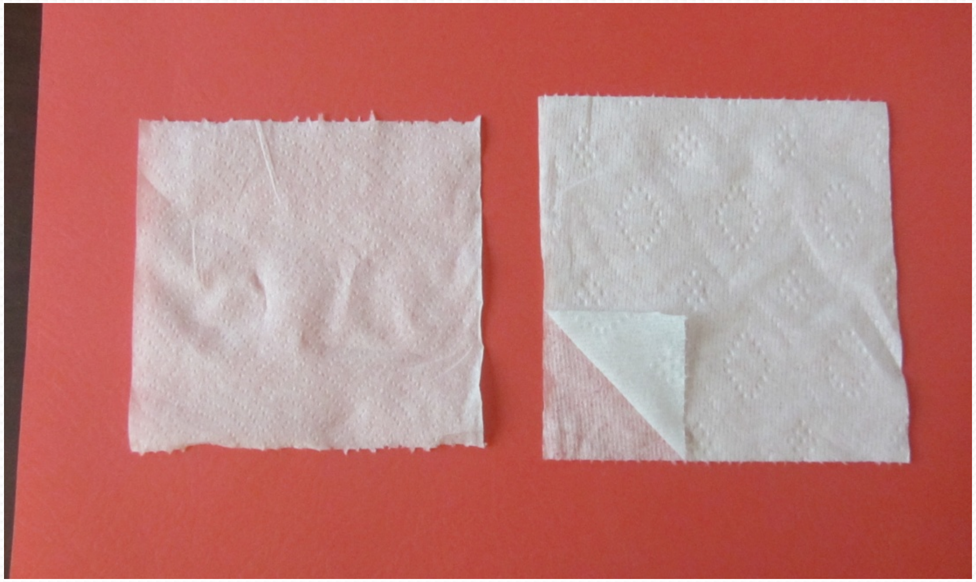
Level	Volume	Flush Rate	%Trailing Water	Slope	Paper
1	8.710	7.567	7.535	9.671	6.104
2	6.554	8.416	8.448	6.311	8.935
Delta	2.156	0.849	0.913	3.360	2.831
Rank	**3**	**5**	**4**	**1**	**2**

Additional Findings

- <u>0.8 gpf / 3.0 Lpf Toilets</u>*: Chaotic conditions resulted in the test apparatus at this discharge volume.*
- <u>1.28 gpf / 4.8 Lpf HET's</u>: *The behavior of the Test Apparatus at this volume level indicates satisfactory performance at this discharge volume.*
- Impact of Toilet Flush Characteristics: *Not significant factors in drain line performance in this study (further study req'd)*
  - Will present finding to ASME / CSA Standards Committees
  - Is there a need for a DLT test in the industry toilet standards?
  - Good news regarding future long term research needs

Additional Findings

- Significance of Toilet Paper: *Toilet paper characteristics have the potential to drastically impact DLT distances*
  - Strong inverse correlation between wet tensile strength and DLT distances
  - Caution: Potential demonstrated in the PERC DOE characterizes the extremes of toilet paper influence
  - Easy test to determine relative wet tensile strength developed
  - Possible low-cost solution to mitigate DLT related blockages



Future Study Opportunities

- Different diameter pipe: 3-inch and 6-inch
- Intermediate slope and flush volume levels
  - Effect of slope as solids to water ratio increases
- Consumer “flushables” other than toilet paper
  - Toilet seat covers
  - Moisturized wipes
- Other pipe materials and simulated aging of pipes
  - Cast iron
  - “Bellies”, FOG, Corrosion
- Explicit experiment for Clearing Flush at lower intervals
  - Tipping and siphonic devices: Reliability? Code compliance potential?
  - Flushometer-valve approach: Will it save water?
  - Cost effective?

PERC's Future

- PERC was founded to align industry research efforts
  - Diverse and impressive technical skill sets
  - Other entities considered based on ability to contribute
- Ability to obtain funding will drive future activities
- Regarding future Drainline Transport Study
  - American Standard Brands remains a partner
    - This will make future DLT study extremely cost effective
- Funding
  - Hopeful that this study elevates interest in PERC
- How can YOU contribute?

Recognition of Contributors

American Standard

- Without American Standard Brands contributions, this study would not have been possible
  - Allowing PERC to conduct study at Product Development Center in NJ
  - Allowing access by PERC Personnel
  - Expanding their DLT Test Apparatus to PERC specifications
  - Financial and In-kind Contributions
  - Assistance in obtaining experienced technicians
  - Assistance with the DOE development and data analysis
- Mr. C.J. Lagan – Many hours of work

Recognition of Contributors

- Alliance for Water Efficiency
- American Society of Plumbing Engineers
- American Society of Sanitary Engineers
- Best Management Partners
- City of Calgary, Alberta
- Delta Faucet Company
- Donald Roberts, P.E.
- Duravit USA, Inc.
- Fort Collins Utilities
- Gerber Plumbing Fixtures LLC, a subsidiary of Globe Union Group, Inc.
- Hansgrohe, Inc.
- Hulsey Engineering

Recognition of Contributors

- International Association of Plumbing and Mechanical Officials
- International Code Council
- Koeller and Company
- Kohler Company
- Natural Resources Defense Council
- PlumbTech, LLC
- Plumbing – Heating – Cooling Contractors National Association
- Plumbing Manufacturers International
- Portland Water Bureau
- Sloan Valve Company
- Sonoma County Water Agency
- Southern Nevada Water Authority
- Veritec Consulting, Inc.
- Waterless Company

THANK YOU

QUESTIONS?

Plumbing Efficiency Research Coalition

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