# Baxter IMS Filter Study

## Analysis of Filter Performance 2010-2017

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1. Background
2. IMS Description
3. Run Turbidity
4. Ripening Period
5. TEP
6. Head Loss
7. Conclusion

# Background

- PWD Overview
- Plant Overview

# Philadelphia Water Department

Image from visitphilly.com (n.d.)

- **Water, wastewater, and stormwater**
- **3 WTP, 3 WPCP**
- **Consumers**
    - 1.7M drinking water
    - 2.2M wastewater
- **Green Stormwater Implementation**
- **Watershed Protection**

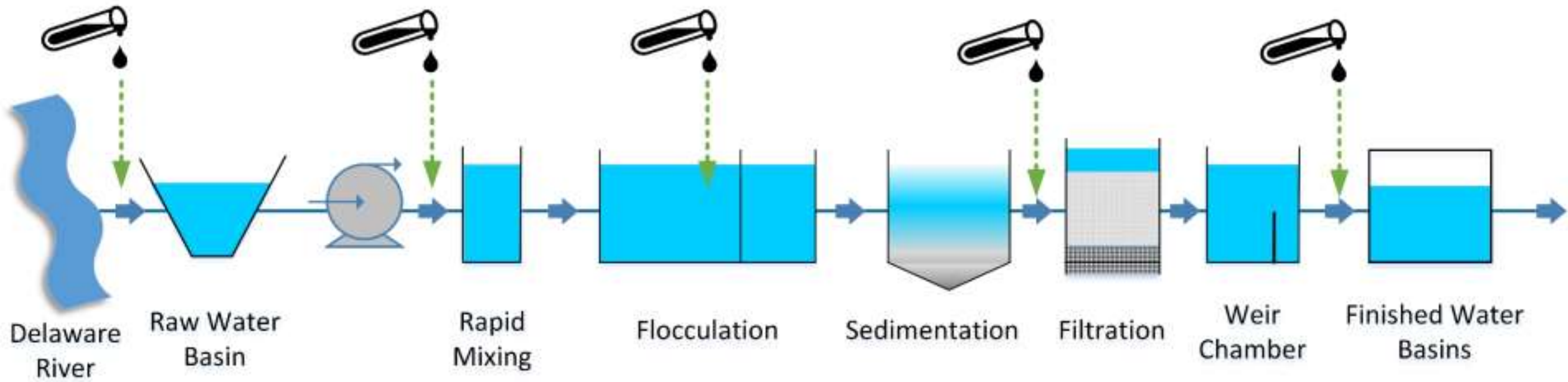
# PWD Water Districts


- **Two surface water sources**
  - Delaware River
  - Schuylkill River
- **3 WTPs**
- **13 Pressure Districts**
- **Over 3,000 miles of mains**
- **Supply over 250 mgd**
- **Chloramine residual**
- **PFSW since 1996**

# Baxter Water Treatment Plant

- **94 Filters**
- **282 mgd Design Capacity**
- **Turbidity Goal**
  - Max effluent turbidity: 0.10 NTU
  - Plant goal: < 0.05 NTU
- **Conventional Filter Depth**
  - 21” anthracite
  - 6” sand
  - 9” gravel
- **1.42 gpm/ft² filtration rate**

# Baxter Water Treatment Process




Alt:
PAC,
Hypo

Hypo, $FeCl_3$,
Lime,
PAC (alt)

Mid-floc
Hypo

Hypo,
Lime

$NH_3$,
Ortho,
Fluoride,
Hypo
(alt)

# Belmont and Queen Lane

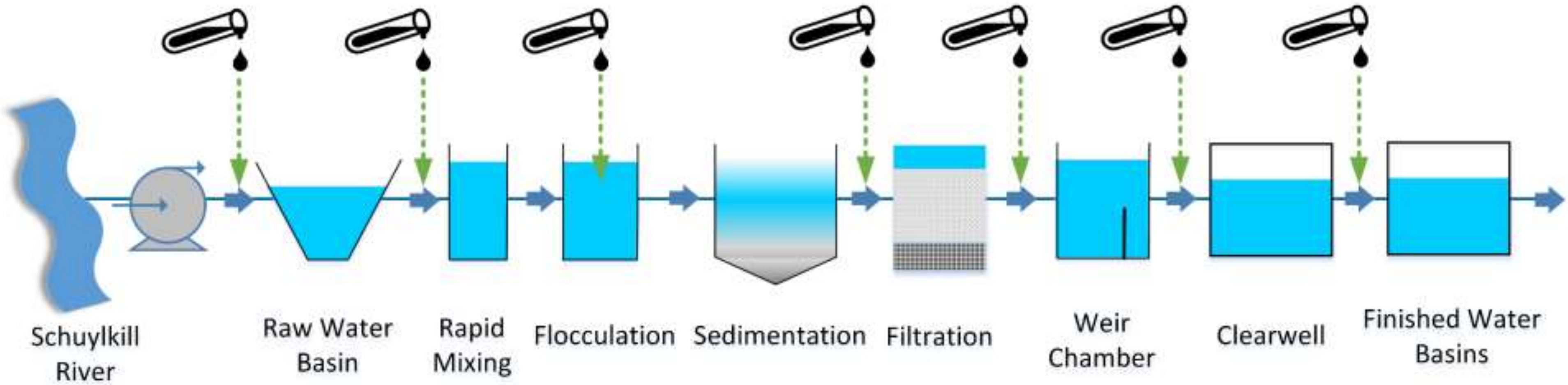
**Belmont WTP**

- **28 filters**
- **50 mgd average**
- **Schuylkill River**

**Queen Lane WTP**

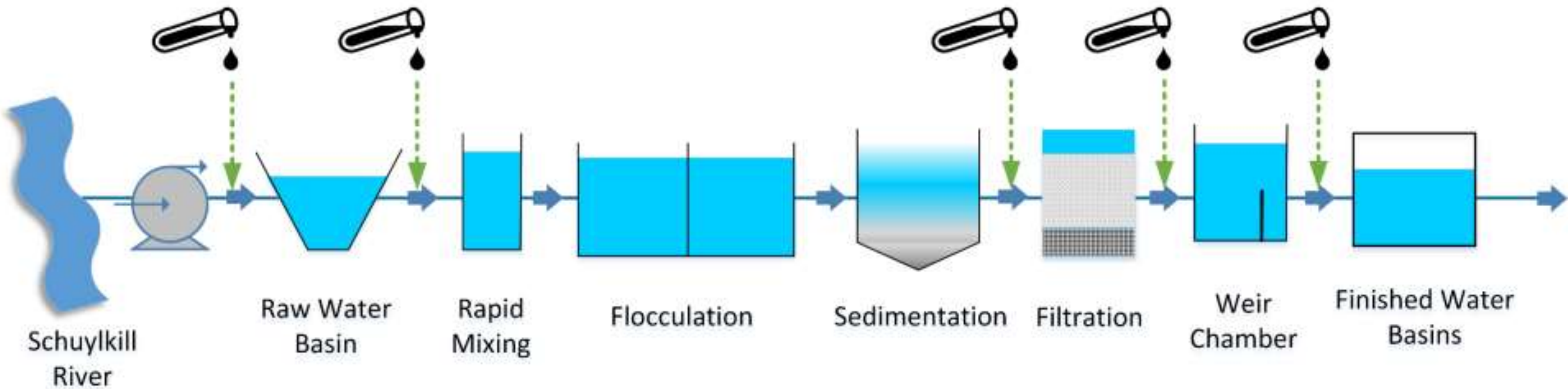
- **40 filters**
- **70 mgd average**
- **Schuylkill River**

# Belmont Treatment Process




| | | | | | | |
|---|---|---|---|---|---|---|
| Alt: PAC, $KMnO_4$, $CuSO_4$ | Hypo, $FeCl_3$, Lime Alt: $H_2SO_4$, Polymer, PAC, $KMnO_4$ | Alt: Hypo, Polymer | Hypo, Polymer (alt) | $NH_3$, Ortho, Fluoride, NaOH, Hypo (alt) | Alt: Hypo, $NH_3$ | Alt: Hypo, $NH_3$, NaOH |

# Queen Lane Treatment Process

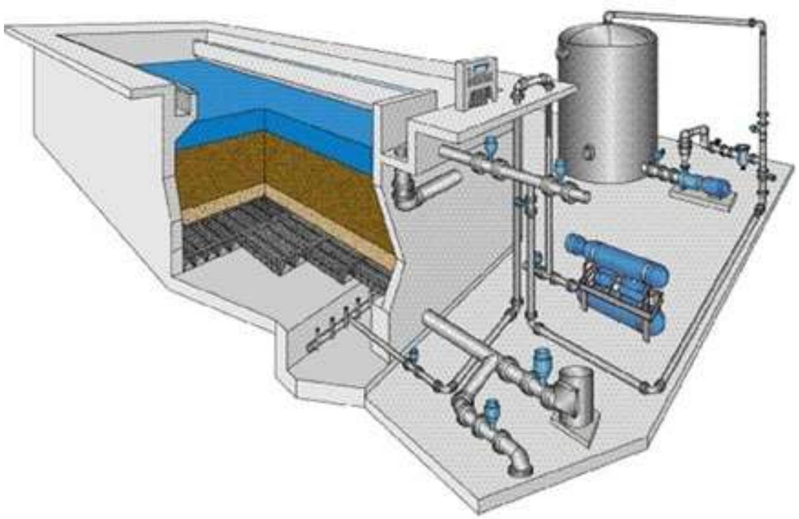



| | | | | |
|---|---|---|---|---|
| Alt: PAC, Hypo, $KMnO_4$ | Hypo, $FeCl_3$, Fluoride, Alt: Polymer, PAC, Lime, $H_2SO_4$ | Hypo, Lime, Polymer (alt) | $NH_3$, Ortho | Alt: Fluoride, Hypo |

# IMS Description

- Description of Integral Media Support (IMS) system
- Potential Advantages
- IMS at Baxter

# IMS Description



- **Xylem product**
- **Leopold Underdrain**
- **Replace gravel layer**
- **Can be used with air scour**
- **Modified Filter Depth**
    - 26” anthracite
    - 10” sand

Image from Xylem (n.d.)

# IMS Description

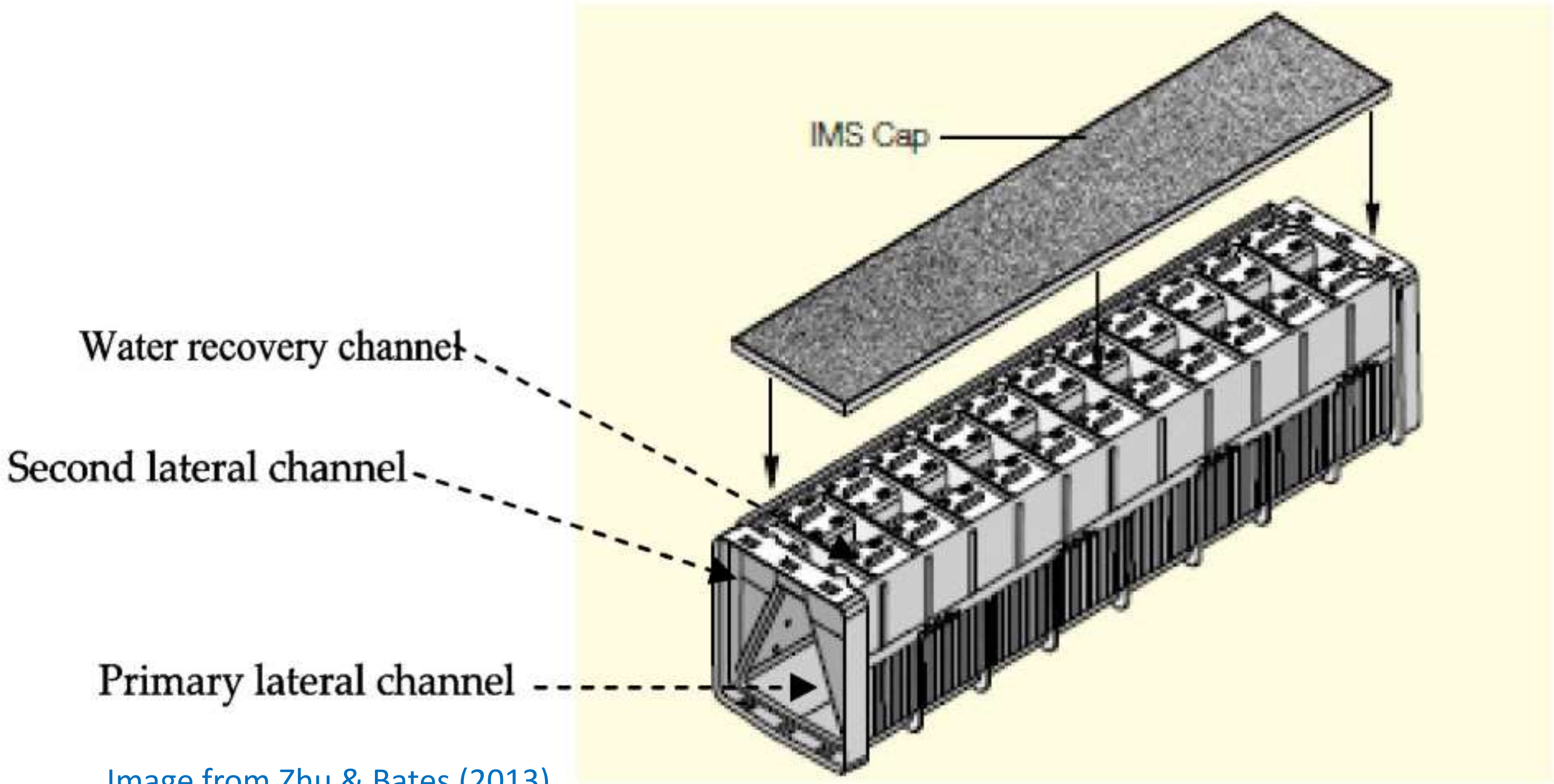



Image from Zhu & Bates (2013)

# IMS Description

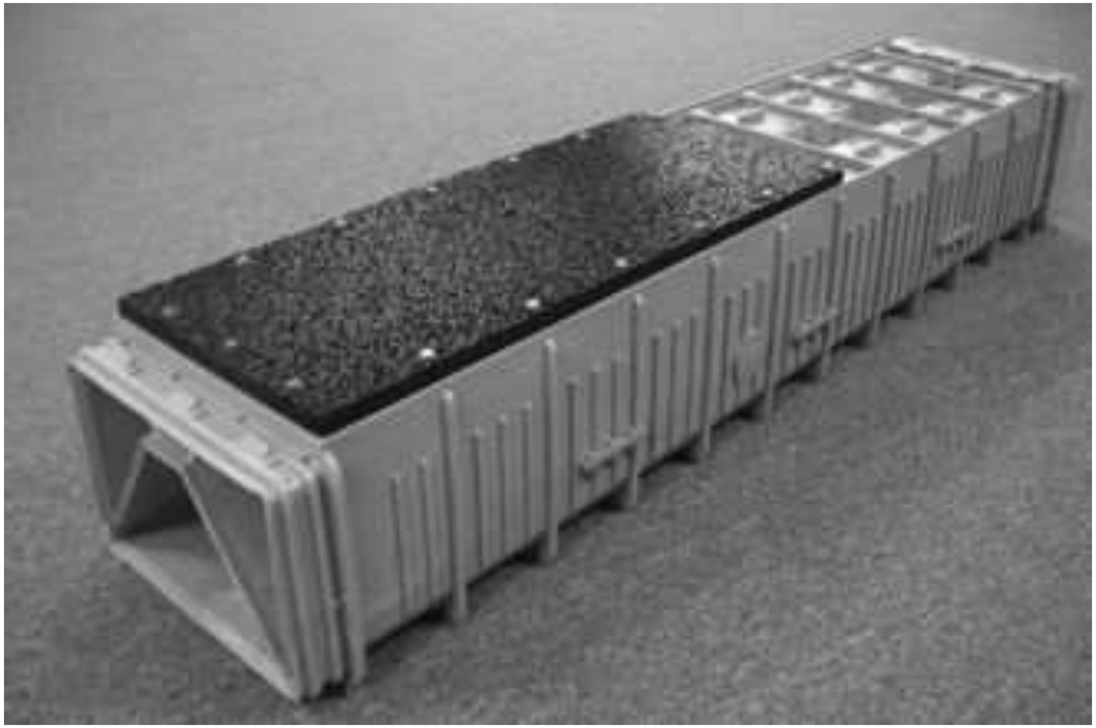


Image from WaterWorld.com

# Potential Benefits of IMS

- **Additional Media**
  - Increased particle capture
  - Increased resilience (i.e. fewer wasting events)
- **Prevents "short-circuiting" potential of gravel**
- **Decrease maintenance costs (e.g. gravel replacement)**

# Analyzed Filters

- **20 Filters Replaced**
- **4 IMS (Type SL)**
- **2 Renovated**
- **14 Non-IMS**
- **68 months of turbidity data**
- **12 months of head loss data**

# Filter Types

**IMS Filters**

- **5 & 7**
- **45 & 47**

**Non-IMS Filters**

- **17 & 19**
- **25 & 27**
- **42 & 44**
- **43**
- **49 & 51**
- **54 & 56**
- **60**
- **63**
- **68**
- **83 & 85 (renovated)**

# Filter Types

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# Research Goals

- **Evaluate Filter Performance**
  - Frequency Histograms
  - Population Statistics
  - Comparison to Non-IMS filters (Z-test)
  - Time Variations
- **Inform Future Filter Installations**

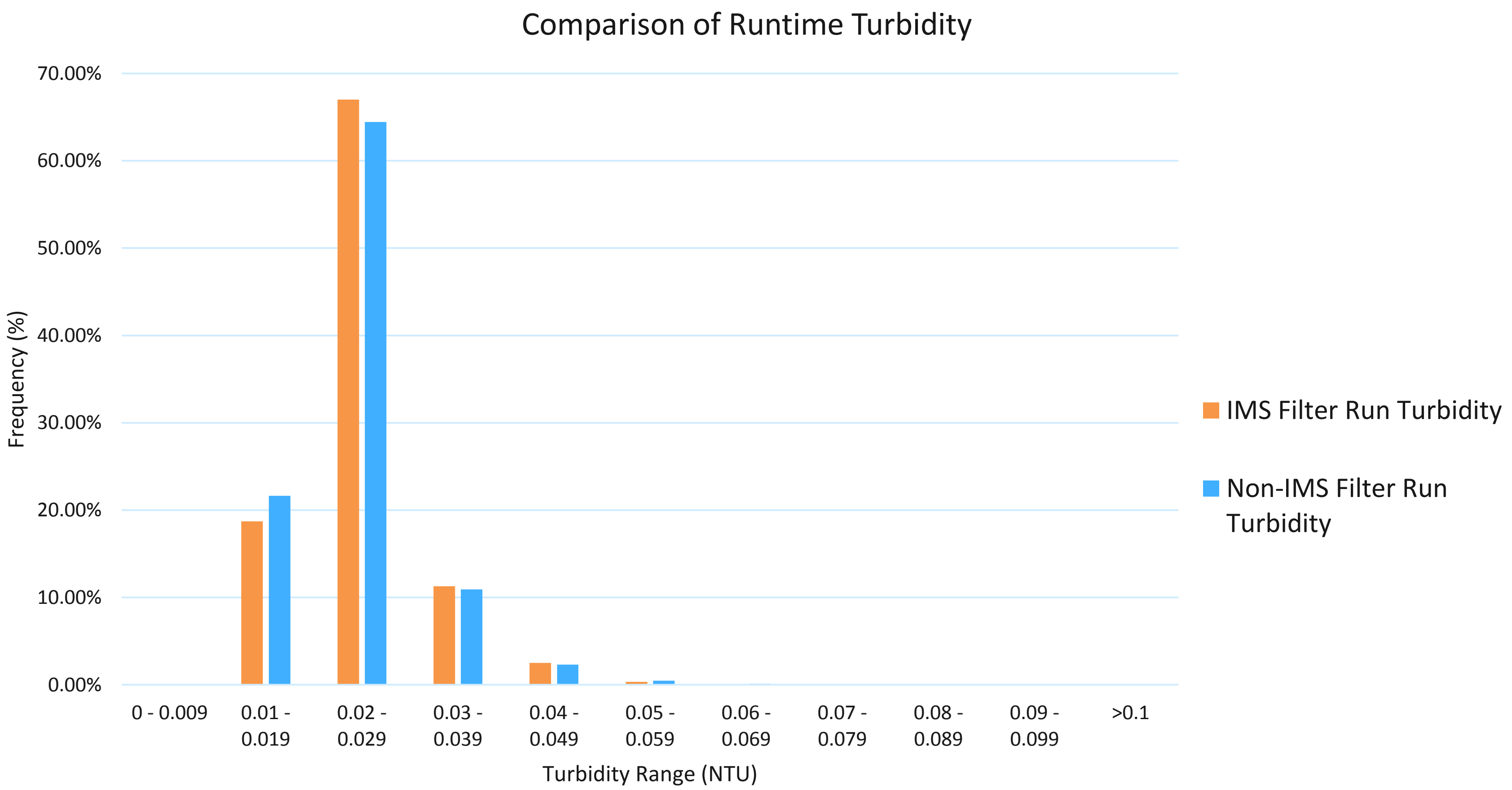
# Runtime Turbidity

- Results of Analysis of Runtime Turbidity Data

# Runtime Turbidity Analysis Strategy

- **Approximately 42.4 million data points**
    - Minute-by-minute readings for 68 months
- **Frequency Histograms**
- **Population Statistics**
- **Examine Peak Range**

# Overall Runtime Turbidity



# Population Statistics

| PARAMETER | IMS FILTERS | NON-IMS FILTERS |
|---|---|---|
| COUNT (NON-ZERO) | 10988254 | 31452239 |
| MAX (NTU) | 0.463 | 1.33 |
| MEAN (NTU) | 0.024 | 0.024 |
| STANDARD DEVIATION (NTU) | 0.008 | 0.008 |
| SKEWNESS | 0.614 | 1.62 |
| KURTOSIS | 6.70 | 142.4 |
| COUNT (> 0.05) | 52532 | 201420 |
| FREQUENCY (> 0.05) | 0.48 % | 0.64% |
| $95^{TH}$ PERCENTILE | 0.0361 | 0.0356 |

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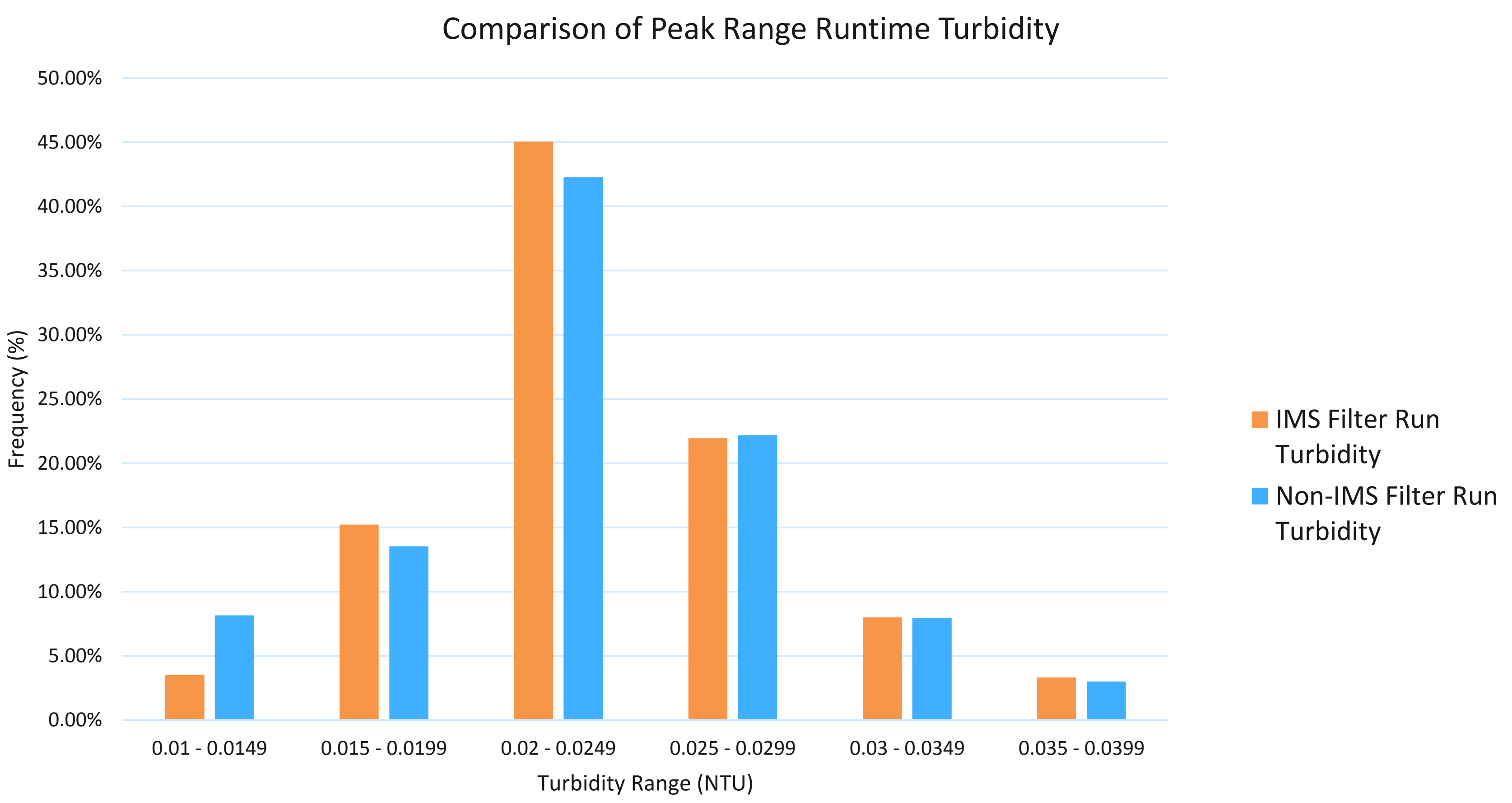
# Runtime Turbidity 0.01 – 0.04 NTU



# Ripening Period

- Results of Analysis of Ripening Period Data

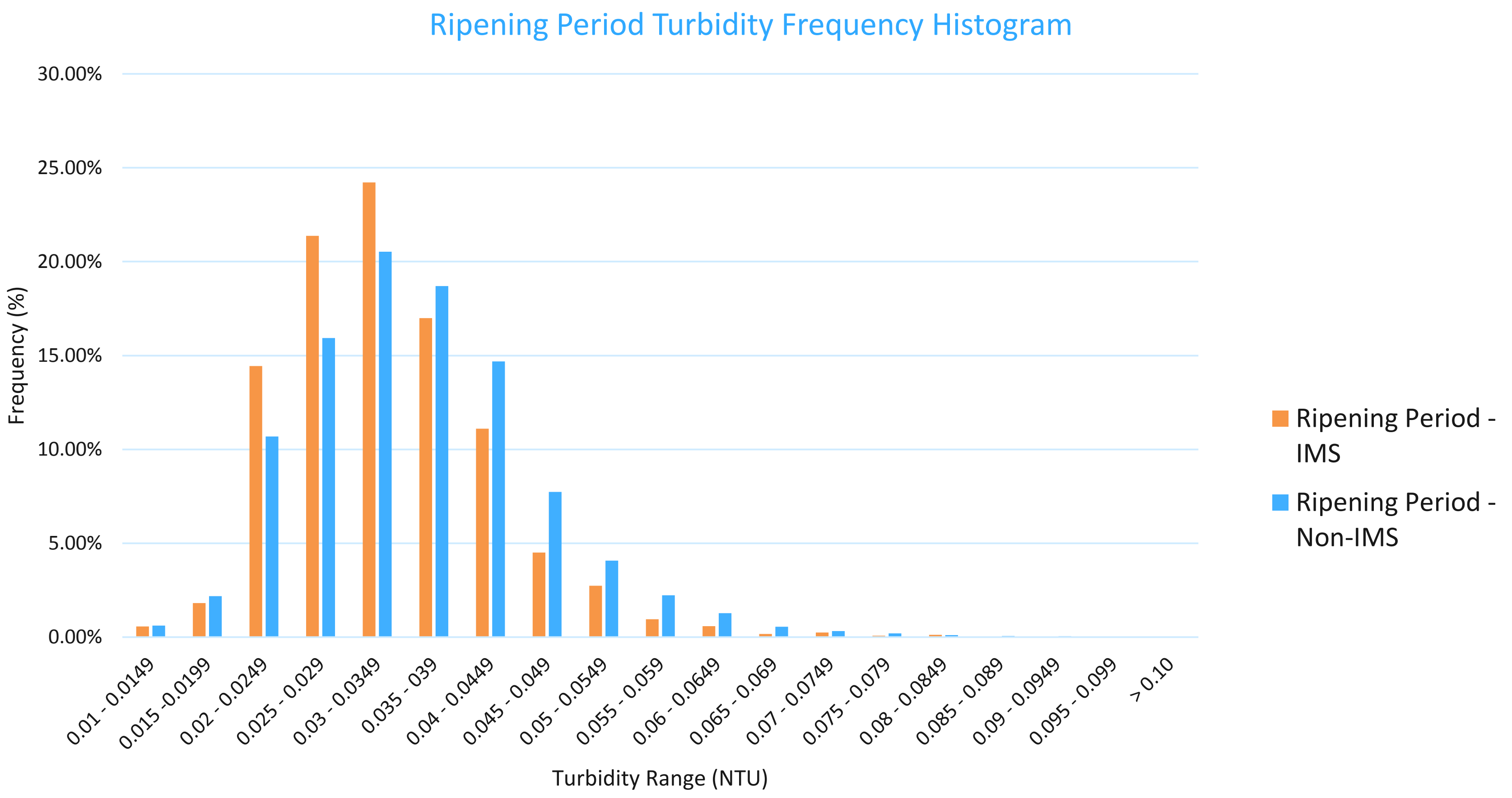
# Ripening Period Analysis Strategy

- **4-hour Period after Backwash**
- **Frequency Histograms**
- **Population Statistics**
- **Time Dependent Analysis**

# Number of Backwashes

| FILTER | NO. RIPENING PERIODS |
|---|---|
| 5 (IMS) | 662 |
| 7 (IMS) | 662 |
| 17 | 644 |
| 19 | 645 |
| 45 (IMS) | 636 |
| 47 (IMS) | 636 |
| 54 | 639 |
| 56 | 639 |

# Ripening Turbidity



# Population Statistics

| PARAMETER | IMS FILTERS | NON-IMS FILTERS |
|---|---|---|
| COUNT | 619105 | 611439 |
| MIN (NTU) | 0.013 | 0.011 |
| MAX (NTU) | 0.117 | 0.159 |
| MEAN (NTU) | 0.033 | 0.036 |
| STANDARD DEVIATION (NTU) | 0.009 | 0.011 |
| SKEWNESS | 1.27 | 0.958 |
| KURTOSIS | 4.01 | 2.61 |

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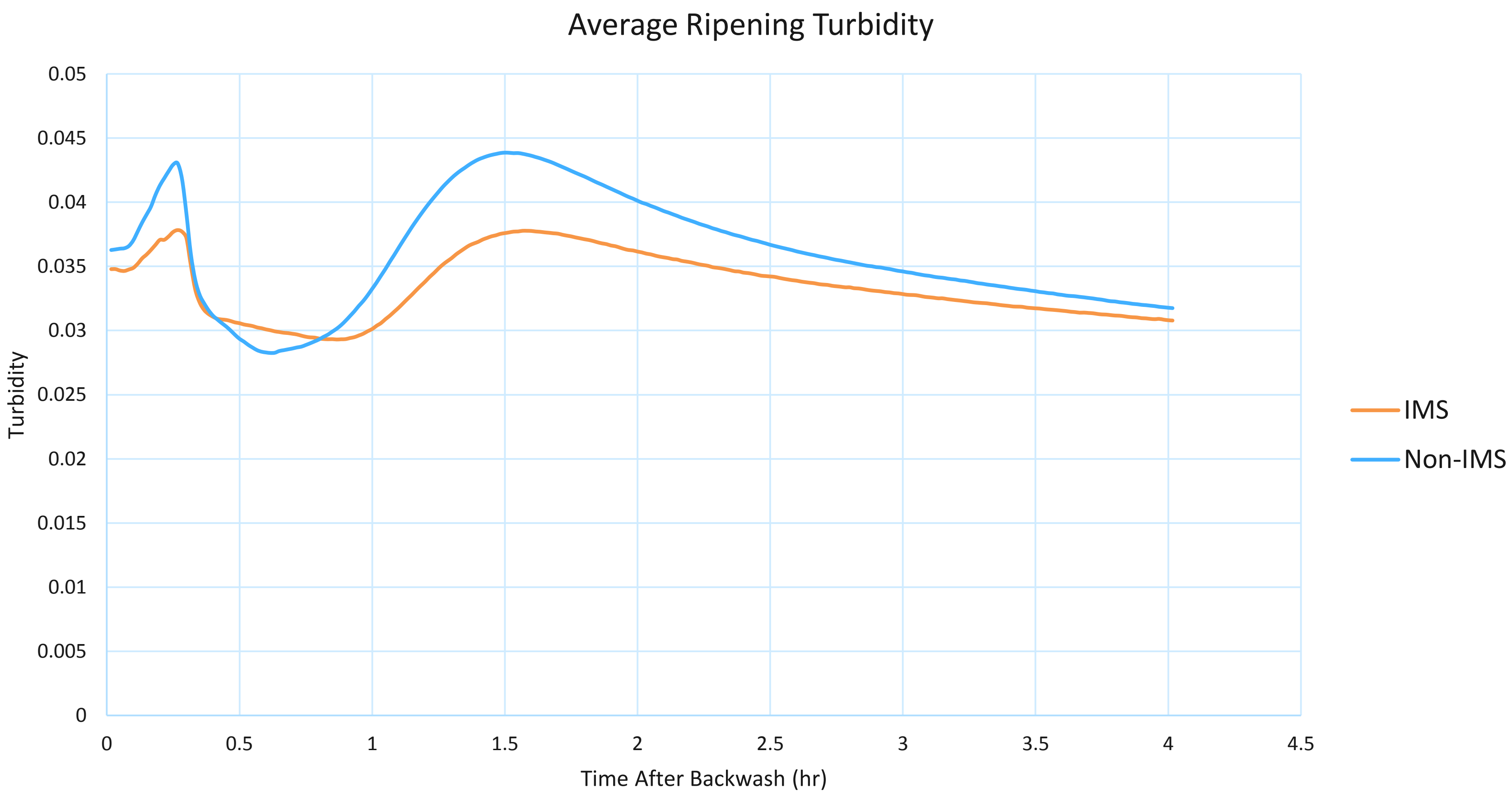
# Time Variation



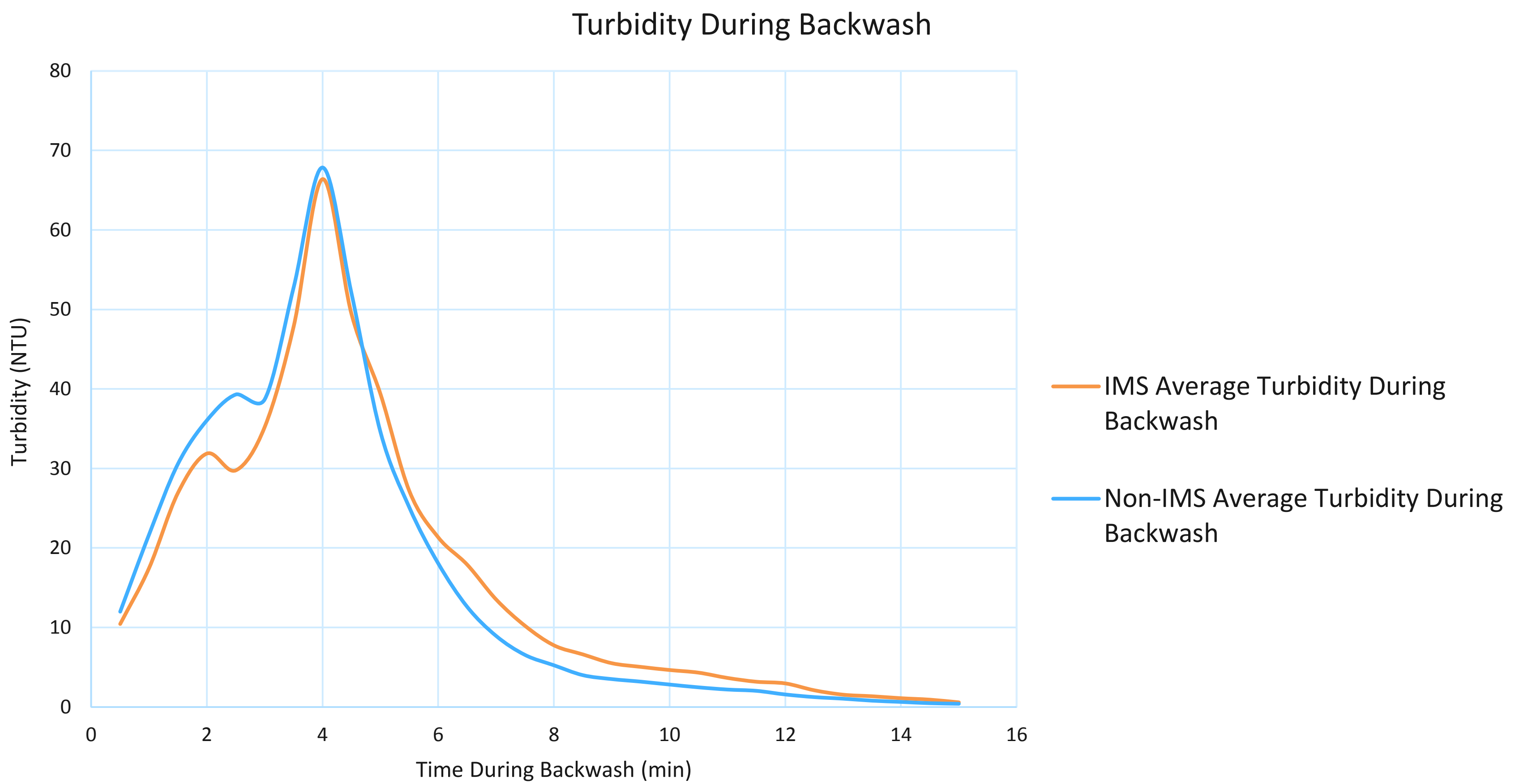
# Turbidity Expansion Profile

- Results of Analysis of TEP Data for Turbidity and Expansion

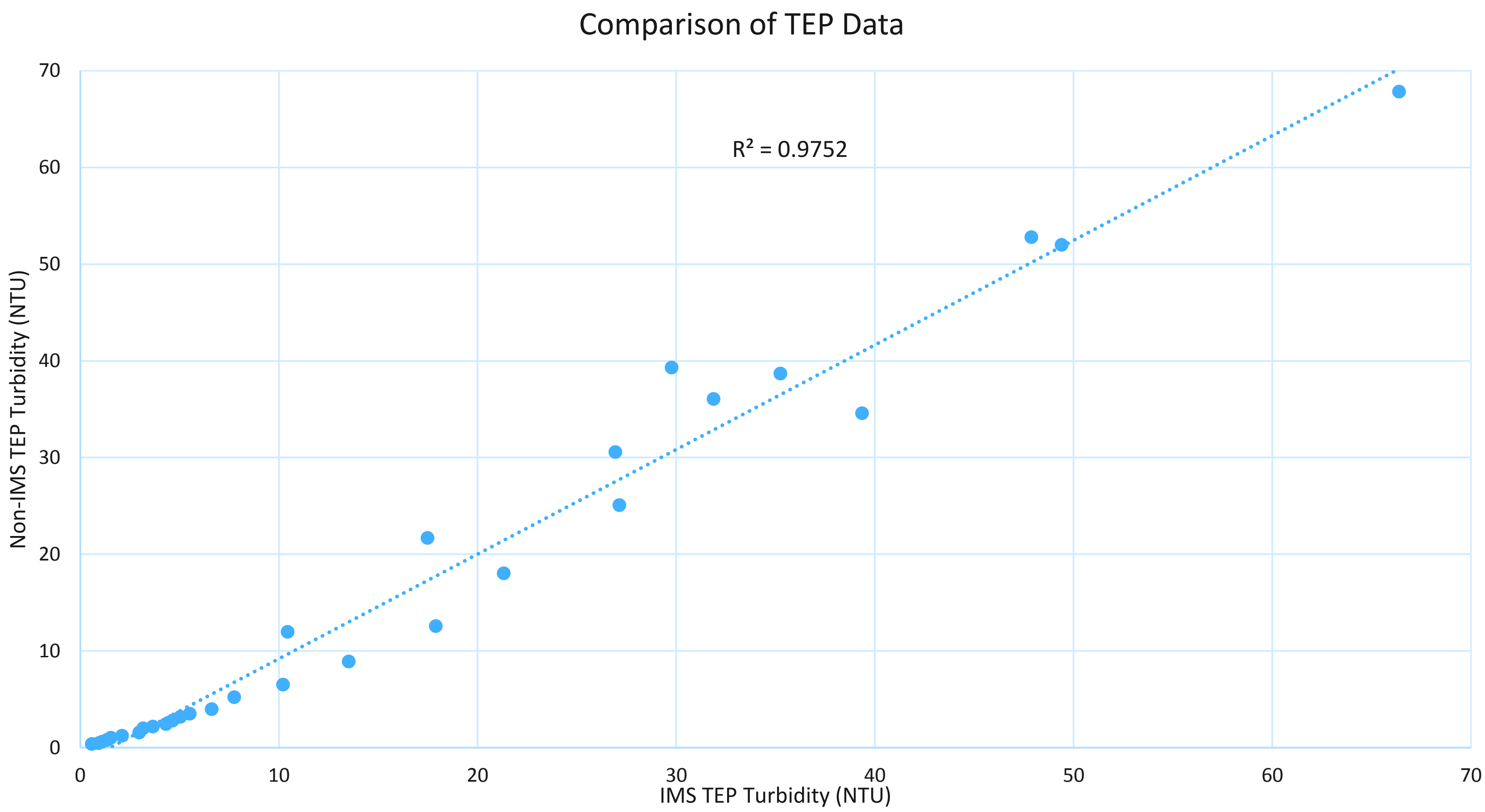
# TEP Procedure

# TEP Procedure

# Turbidity During Backwash



# Turbidity During Backwash



# Expansion

| FILTER | AVERAGE EXPANSION (IN) |
|---|---|
| 5 | 4.52 (± 1.42) |
| 7 | 4.81 (± 1.55) |
| 45 | 5.39 (± 1.66) |
| 47 | 5.61 (± 1.62) |
| 17 | 4.31 (± 1.52) |
| 19 | 4.37 (± 1.42) |
| 25 | 4.46 (± 1.45) |
| 27 | 3.52 (± 1.31) |
| 42 | 3.21 (± 1.75) |
| 43 | 3.60 (± 1.80) |
| 44 | 5.11 (± 1.24) |
| 49 | 6.50 (± 1.30) |
| 51 | 6.39 (± 1.44) |
| 54 | 3.86 (± 1.53) |
| 56 | 3.75 (± 1.62) |
| 60 | 2.90 (± 1.59) |
| 63 | 3.29 (± 1.82) |
| 68 | 4.88 (± 1.86) |
| IMS | 5.05 (± 1.59) |
| NON-IMS | 4.32 (± 1.84) |
| ALL | 4.53 (± 1.80) |

# Head Loss

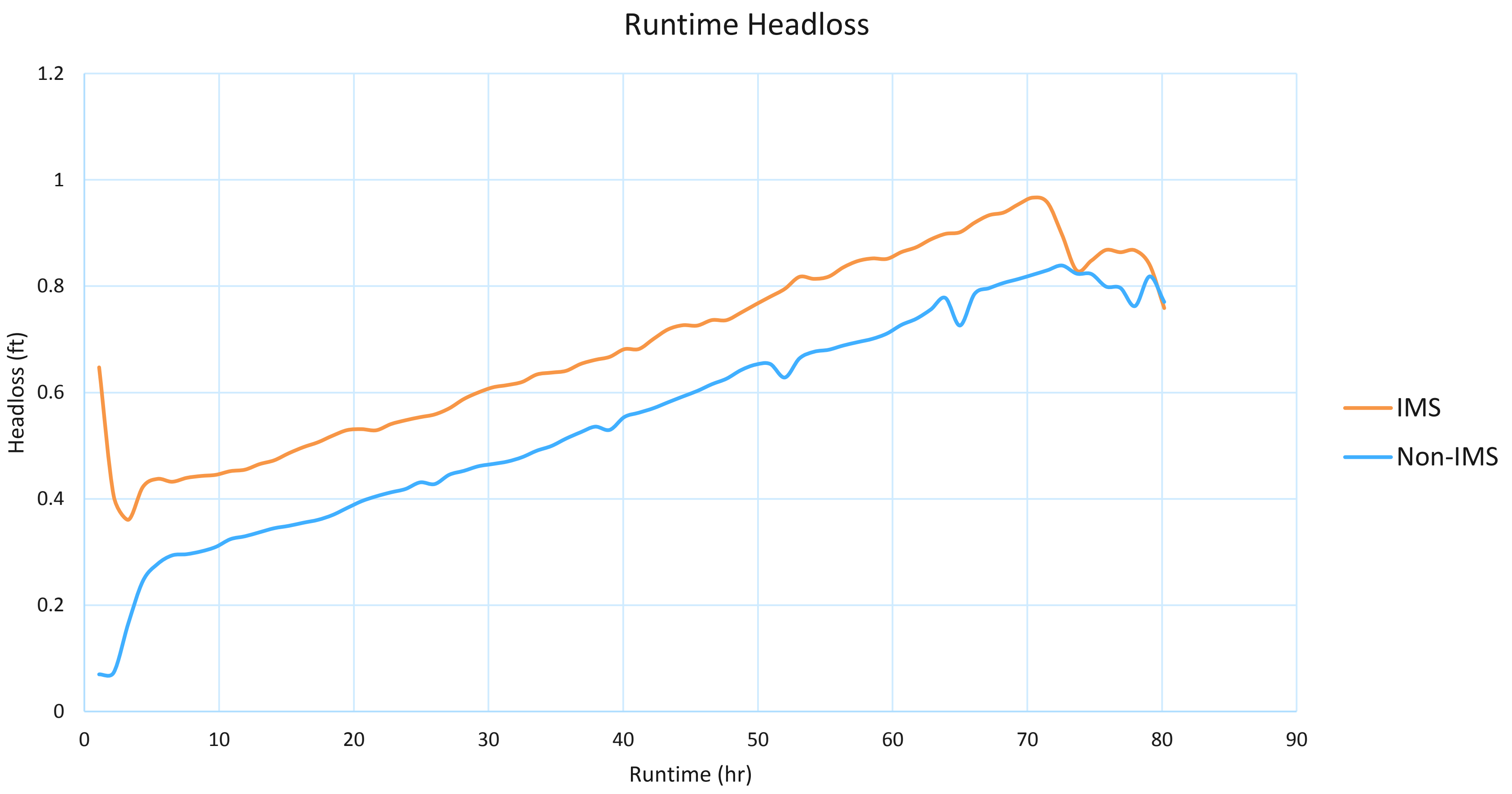
- Results of Analysis of Head Loss Data

# Rose Equation

$$h_L = \frac{1.067 v_a^2 D}{\varphi g \epsilon^4} * \sum_{i=1}^{n} \frac{C_D f}{d}$$

- $\mathrm{v_a}$ = approach velocity $\left(\frac{\mathrm{m}}{\mathrm{s}}\right)$
- D = filter depth (m)
- $\mathrm{C_D}$ = drag coefficient
- f = mass frac. of sand particle of diam d
- d = diameter of sand
- φ = shape factor
- ϵ = porosity
- $\mathrm{C_D} = \frac{24}{\mathrm{Re}} + \frac{3}{\mathrm{Re}^{\frac{1}{2}}} + 0.34$
- $\mathrm{Re} = \frac{\varphi \mathrm{d} \mathrm{v_a}}{\nu}$

# Head Loss



Runtime Headloss
1.2
1
0.8
0.6
0.4
0.2
0
Headloss (ft)
0
10
20
30
40
50
60
70
80
90
Runtime (hr)
IMS
Non-IMS

# Conclusion

- Key Takeaways from Analysis

# Conclusions

- **Slight advantage in overall runtime turbidity**
- **Advantage in ripening turbidity**
- **No difference in final turbidity before backwash**
- **Similar TEP Performance**
- **Minor Increase in Head Loss**

# References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# Questions?

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