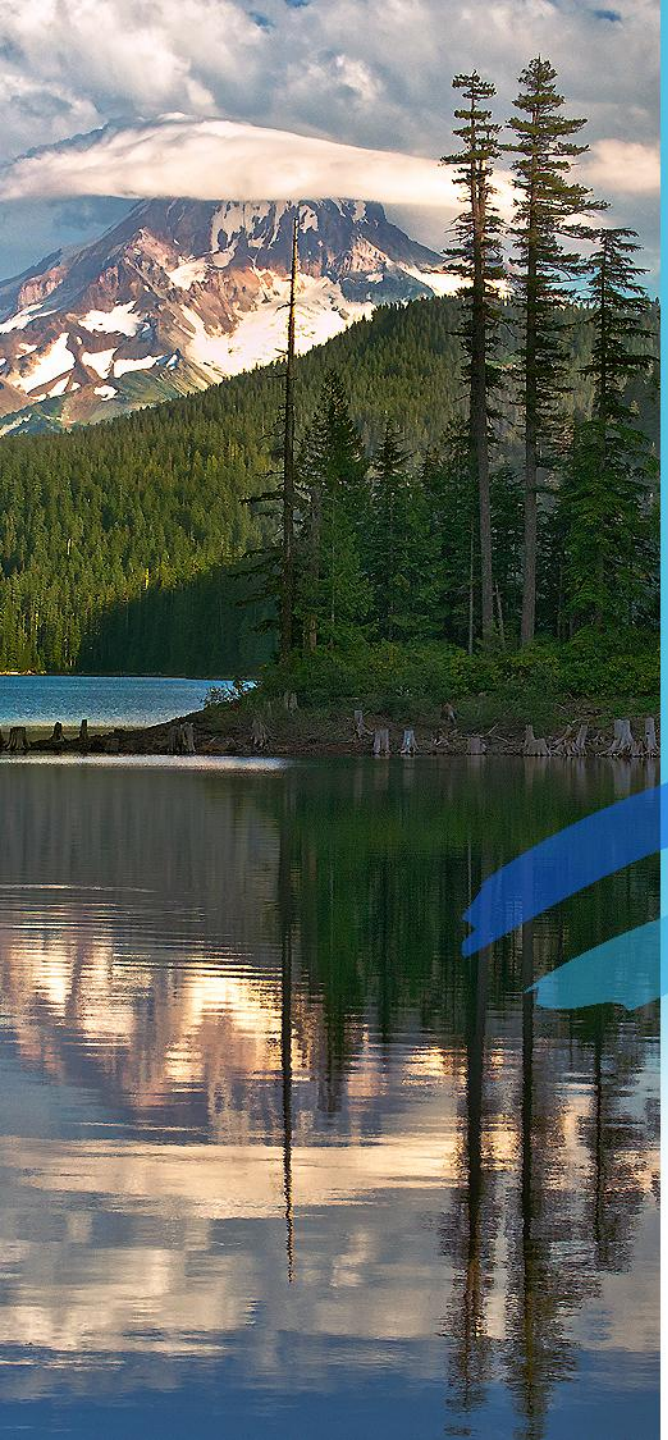


12 Month UV Fouling Study on Unfiltered Source Water

Chad Talbot, P.E.
Portland Water Bureau

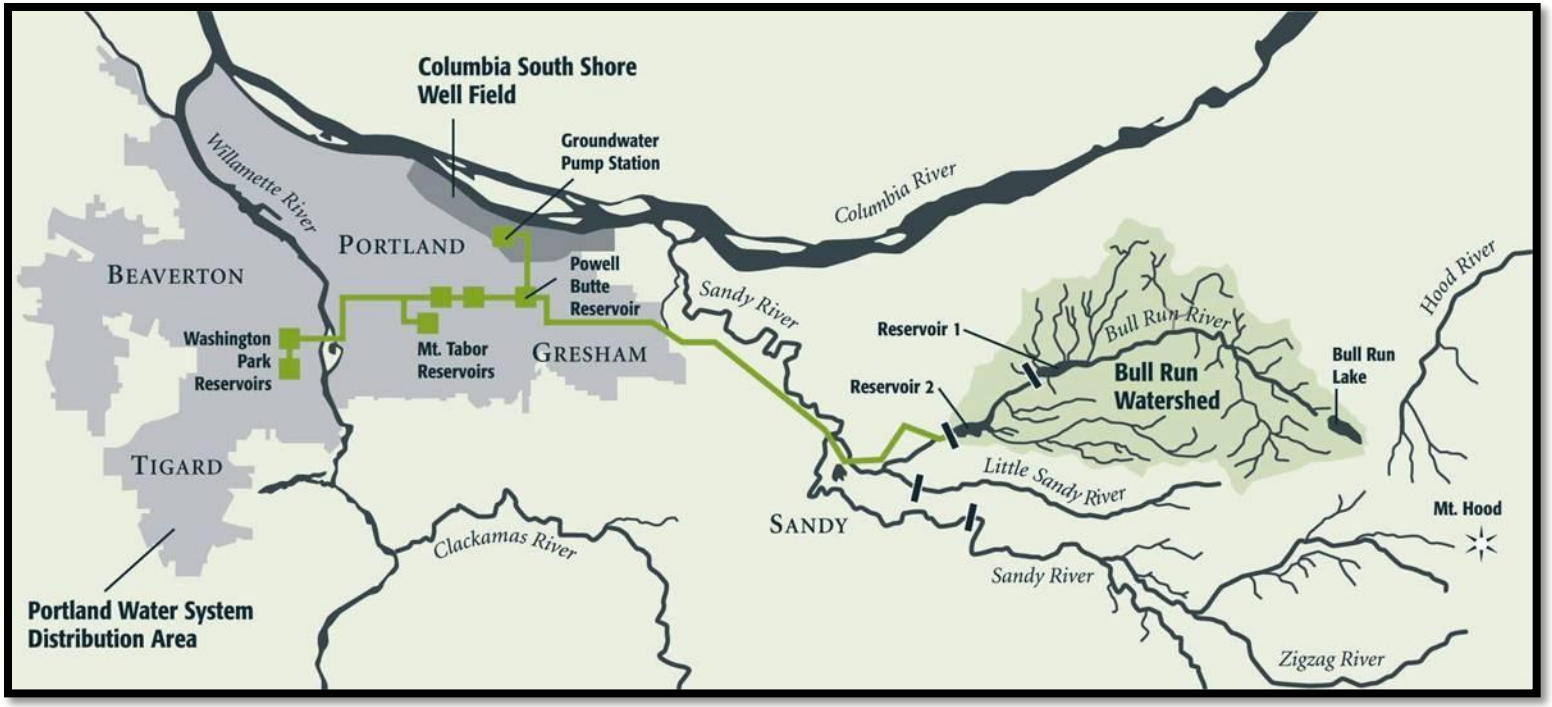
May 6, 2011

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

CITY OF PORTLAND, OREGON 1851

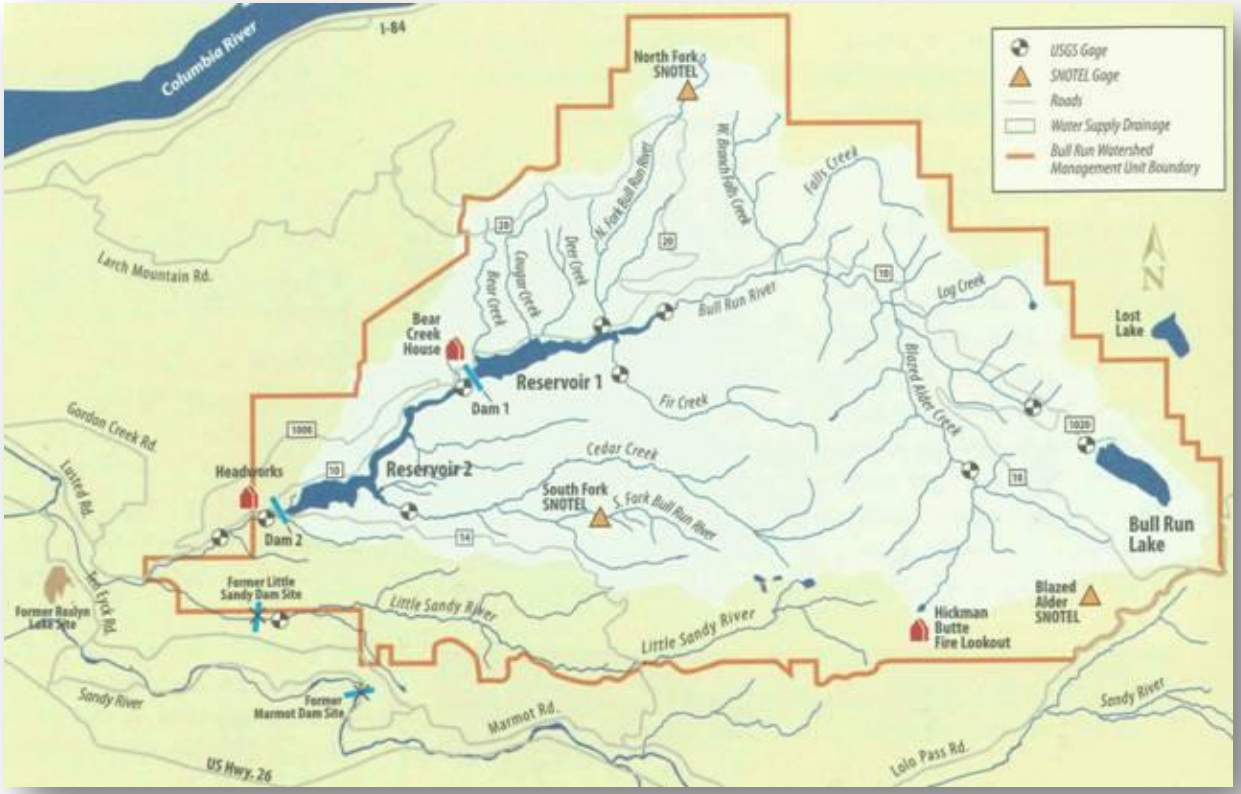
Portland Water Bureau

Portland, Oregon



PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Bull Run Watershed



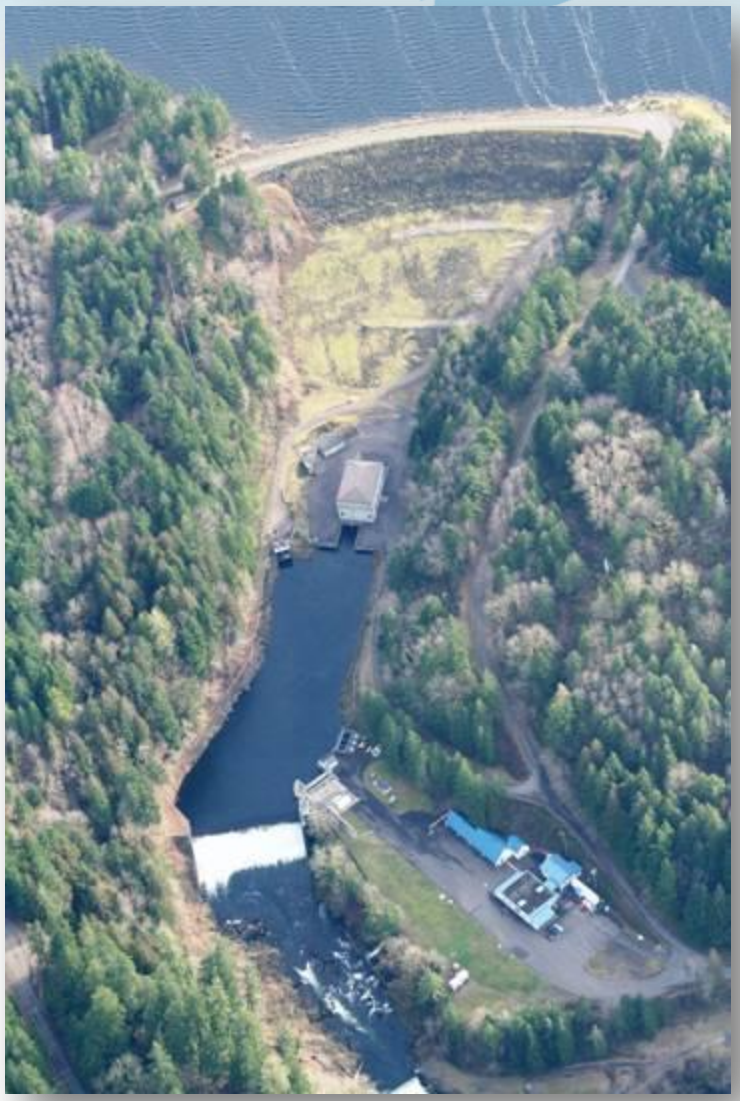
PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Bull Run Watershed

Dam 1

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Bull Run Headworks



Dam 2 and Headworks Intake Facility

Headworks Facility and Pilot Plant Discharge

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Bull Run Water Treatment

225 MGD Gravity Supply

Filtration Waiver

- Screening
- Chlorine Disinfection (Gas)
- Ammonia
- Sodium Hydroxide

LT2 Treatment Compliance: UV Disinfection

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Bull Run Water Quality

Parameter	Avg. Value	Range
pH	7.0	6.7 – 7.3
UVT, %	89	68 – 93
Turbidity	0.51	0.15 – 5.0+
Hardness, mg/l as $CaCO_3$	7.4	5.4 – 11.5
Alkalinity, mg/l as CaCO3	9.9	5.4 – 17.6
Total Organic Carbon, mg/l	1.5	1.0 – 2.8
Total Iron, mg/l	0.09	0.02 – 0.30
Manganese, mg/l	0.016	0.002 – 0.072
Zinc, ug/l	0.8	0.1 – 8.3
Magnesium, mg/l	0.73	0.48 – 1.21
Calcium, mg/l	1.78	1.29 – 2.62
Copper, mg/l	0.03	0.01 – 0.08

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

UV Pilot Fouling Study

12-Inch Trojan Swift

12-Inch Calgon Sentinel

8-Inch ITT Wedeco K

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

UV Pilot Setup

PWB UV Pilot Plant Views

Average Combined Flowrate: 4 MGD

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

UV Pilot Setup

PWB UV Pilot Plant Discharge to River

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Fouling Study Phase Summary

	Fouling Phase 1	Fouling Phase 1.5	Fouling Phase 2	Fouling Phase 3	Fouling Phase 4
	Aug 25-09 to Oct 16-09	Oct 16-09 to Oct 30-09	Oct 16-09 to Dec 5-09	Dec 5-09 to May 12-10	May 12-10 to Aug 1-10
Days of Operation	52	14	50	158	81
Power Settings Trojan: Calgon: Wedeco:	63% Med. High Full	63% Med. High Full	100% High Full	100% High Full	100% High Full
Avg. Raw Water Total Iron mg/l	0.206	0.245	0.089	0.030	0.040
Avg. Raw Water Manganese mg/l	0.058	0.039	0.011	0.002	0.006
Raw Water Pre-Chlorination Yes/No	No	No	No	No	Yes

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Combined Aging & Fouling Index
(CAF Index)

A Calculated Combined Aging and Fouling (CAF) Index can be used to quantify lamp aging and fouling by removing the effects of changing UV Transmittance and ballast power settings. This can be calculated by the equation:

$$CAF = \frac{S}{S_P}$$

S = Is the measured duty UV sensor reading

S_p = Is a predicted UV sensor reading that is a function of water UVT and lamp ballast power setting in a clean reactor with new lamps

S_p can be calculated by the equation below and through validation or on-site testing by varying the water UVT and ballast power settings.

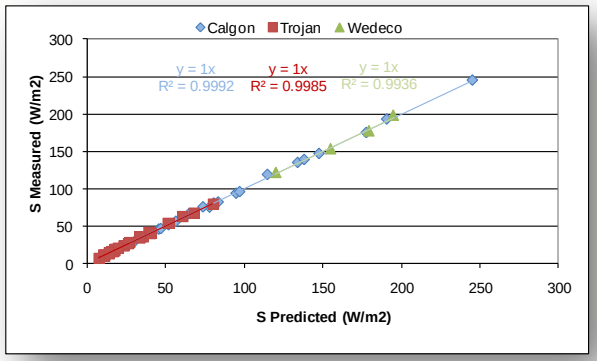
$$S(p) = A \times P^B \times e^{C \times UVT}$$

S_p = is the predicted sensor reading

P = is the ballast power setting

UVT = is the water UV Transmittance

A, B, & C = constants derived from the testing of the new lamps and the linear regressions of the data shown in the graph to the left.

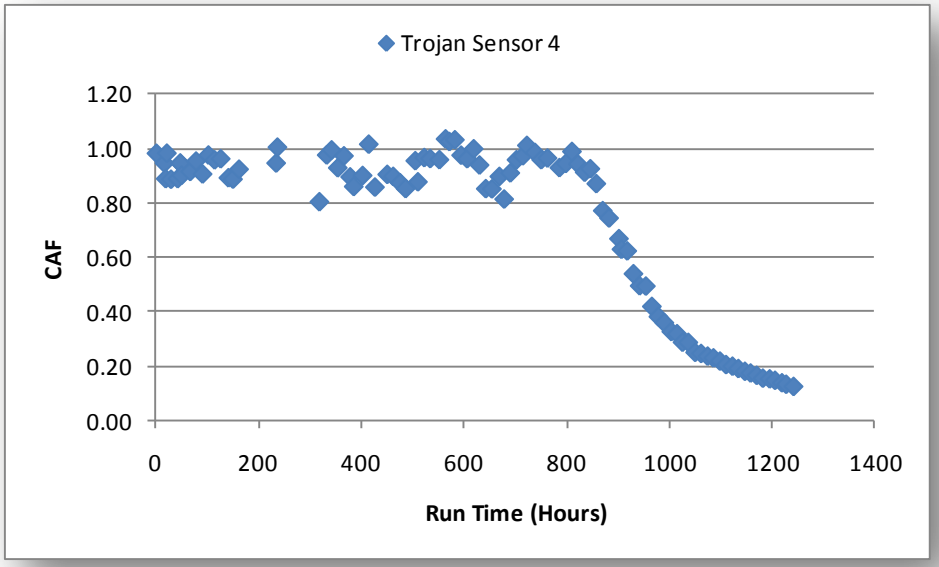


PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Fouling Study Results

Phase 1 Results 8/24/09 – 10/16/09

Trojan Swift Reactor



Un-wiped Trojan Sleeve CAF Index - Ph. 1

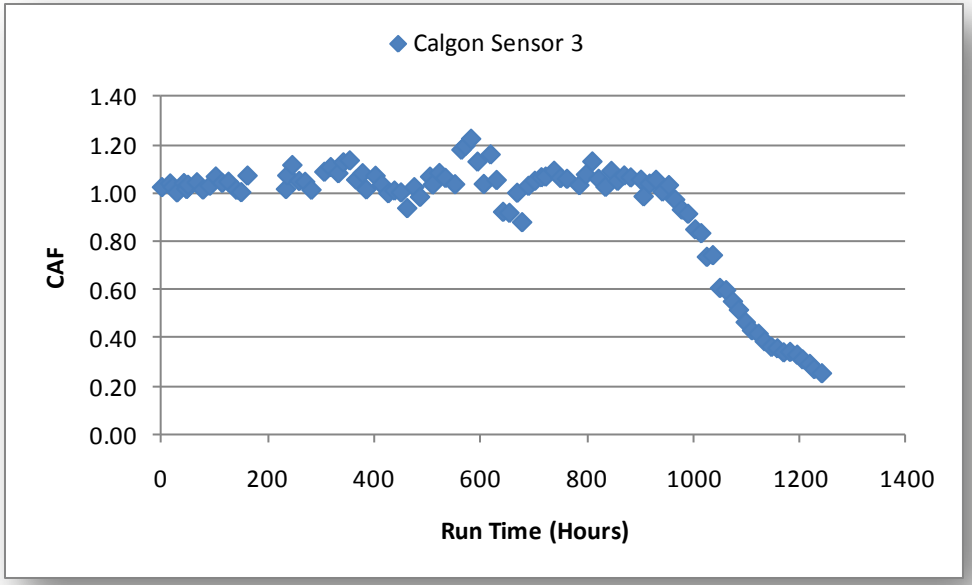
Trojan Sleeves: Top 2 = Wiped
Bottom 2 = Un-wiped

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

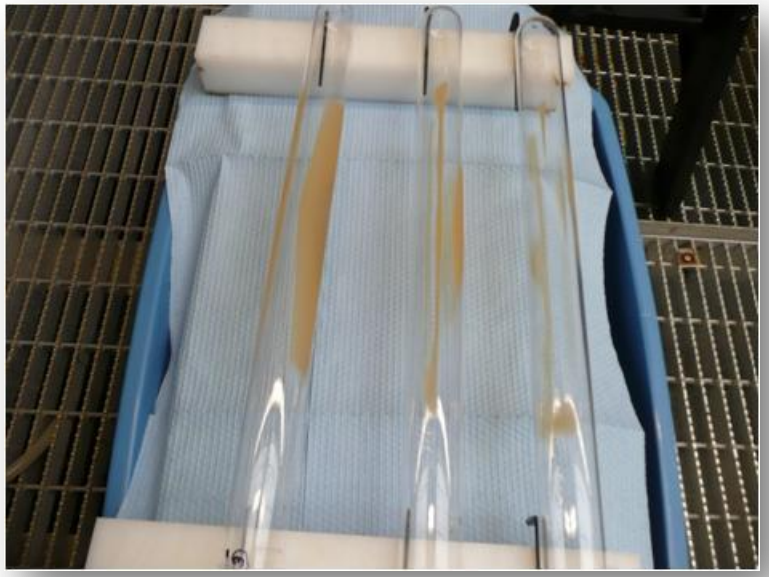
Fouling Study Results

Phase 1 Results 8/24/09 – 10/16/09

Calgon Sentinel Reactor



Un-wiped Calgon Sleeve CAF Index – Ph. 1



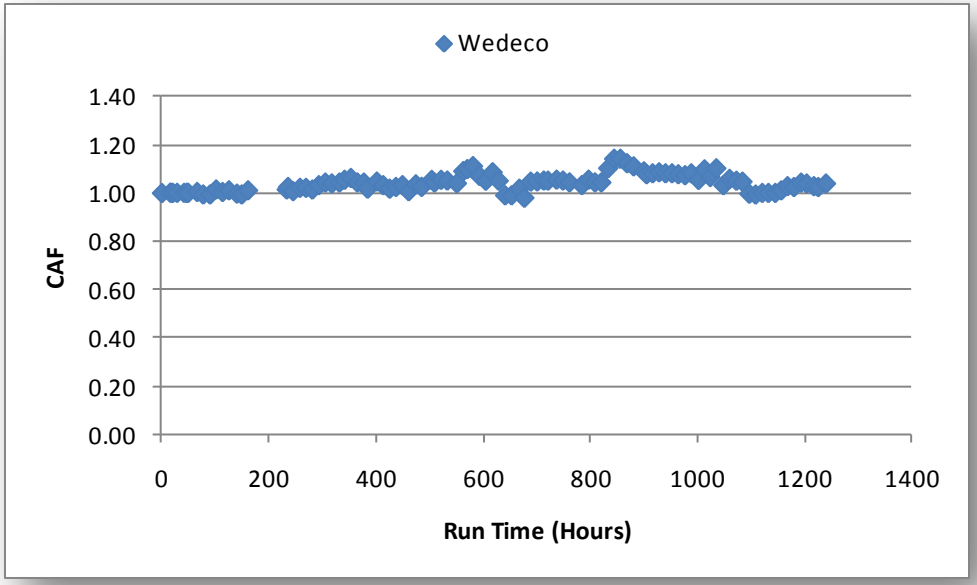
Calgon Sleeves: All Un-wiped

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

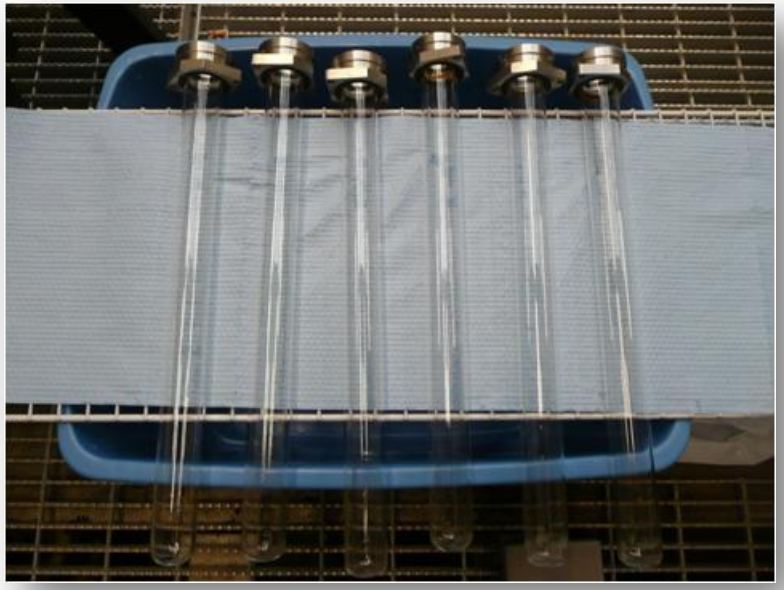
Fouling Study Results

Phase 1 Results 8/24/09 – 10/16/09

Wedeco K Reactor



Un-Wiped Wedeco Sleeve CAF Index – Ph. 1



Wedeco Sleeves: All Un-wiped

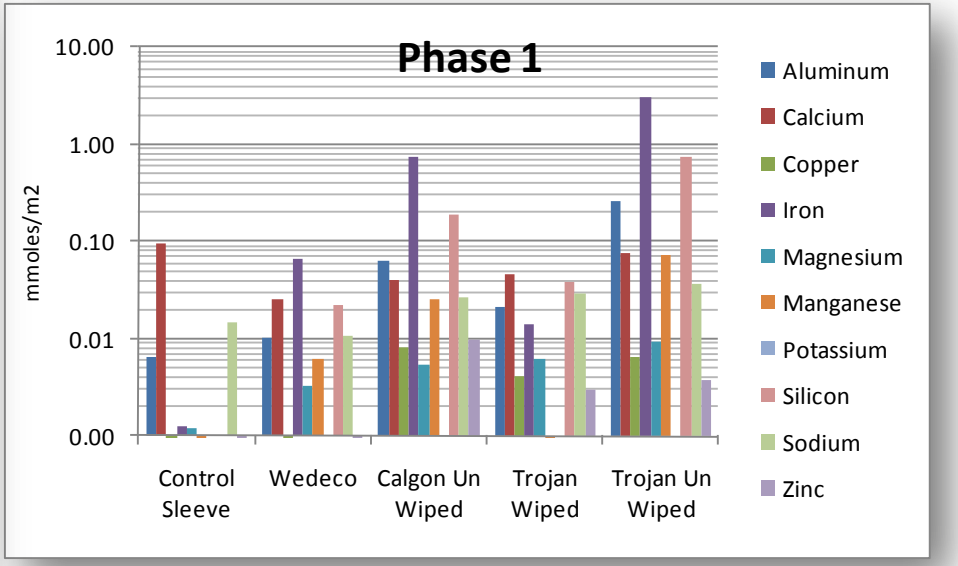
PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Fouling Study Results

Phase 1 Results 8/24/09 – 10/16/09

Acid Digestion of Foulant

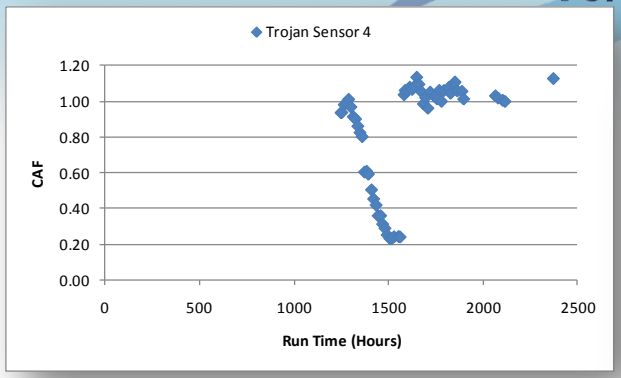
Foulant Cleaning with 10% HCl Solution



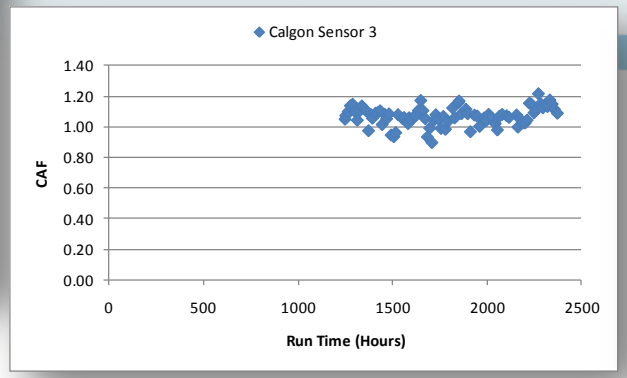
PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Phase 2 Results

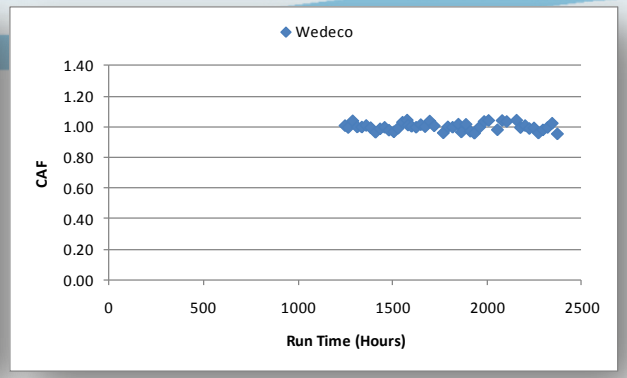
10/16/09 – 12/04/09 - All Reactors



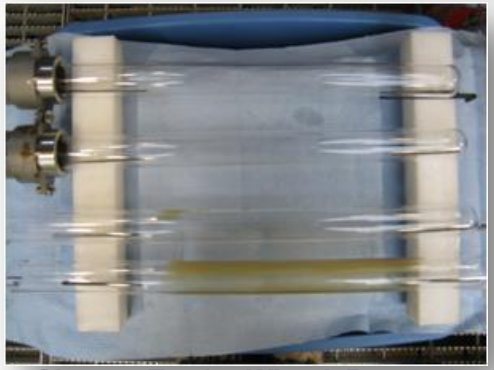
Un-wiped Trojan Sleeve CAF Index – Phase 2



Un-wiped Calgon Sleeve CAF Index – Ph. 2



Un-wiped Wedeco Sleeve CAF Index – Ph. 2



Trojan Sleeves Top2 = Wiped, Bottom2 = Un-wiped

Un-wiped Calgon Sleeves – Ph. 2

Un-wiped Wedeco Sleeves – Ph. 2

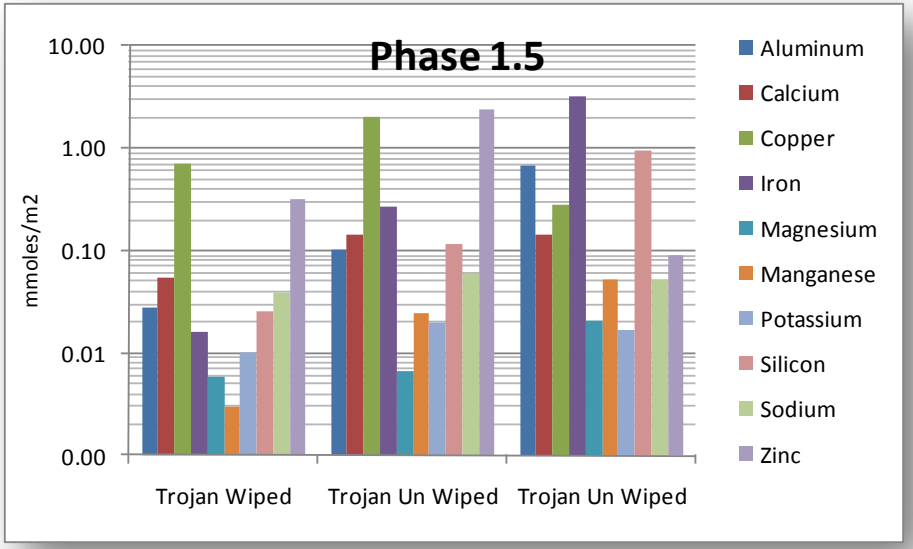
Trojan Sleeves Top2 = Wiped, Bottom2 = Un-wiped

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

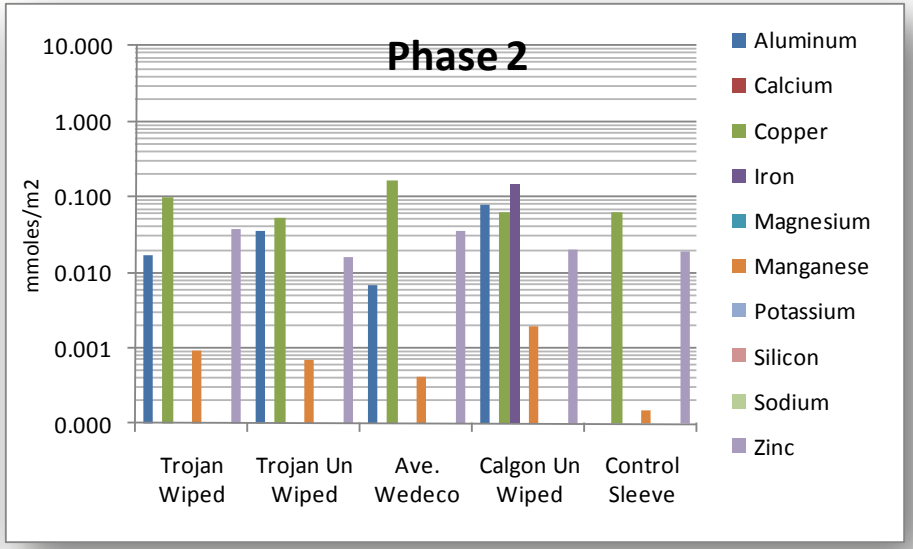
Phase 2 Results

10/16/09 – 12/04/09

Acid Digestion of Foulant



Acid Digestion of Trojan Sleeves on 10/30/09

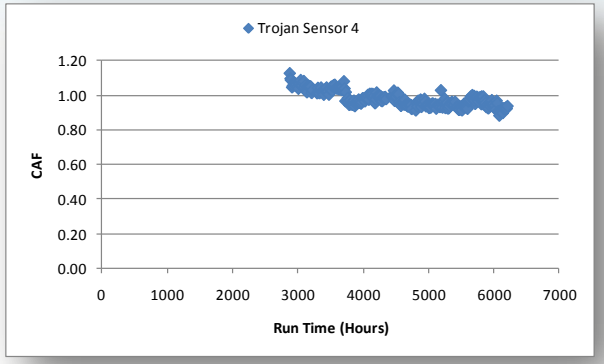


Acid Digestion of All Sleeves on 12/04/09

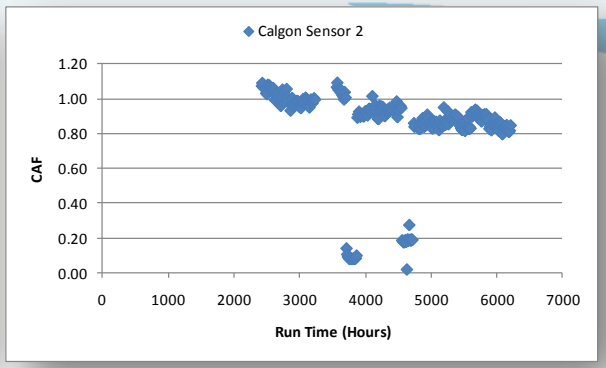
PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Phase 3 Results

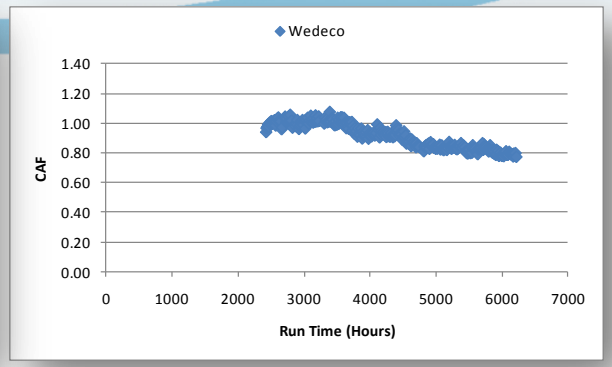
12/04/09 – 05/12/10 - All Reactors



Un-wiped Trojan Sleeve CAF Index – Phase 3



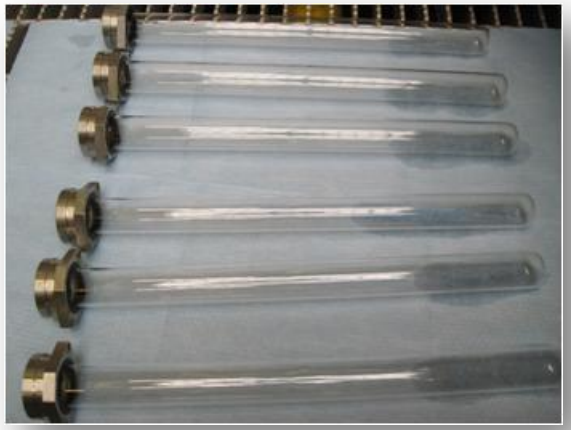
Un-wiped Calgon Sleeve CAF Index – Ph. 3



Un-wiped Wedeco Sleeve CAF Index – Ph. 3

Trojan Sleeves, Wiped and Un-wiped - Ph. 3

Un-wiped Calgon Sleeves – Ph. 3



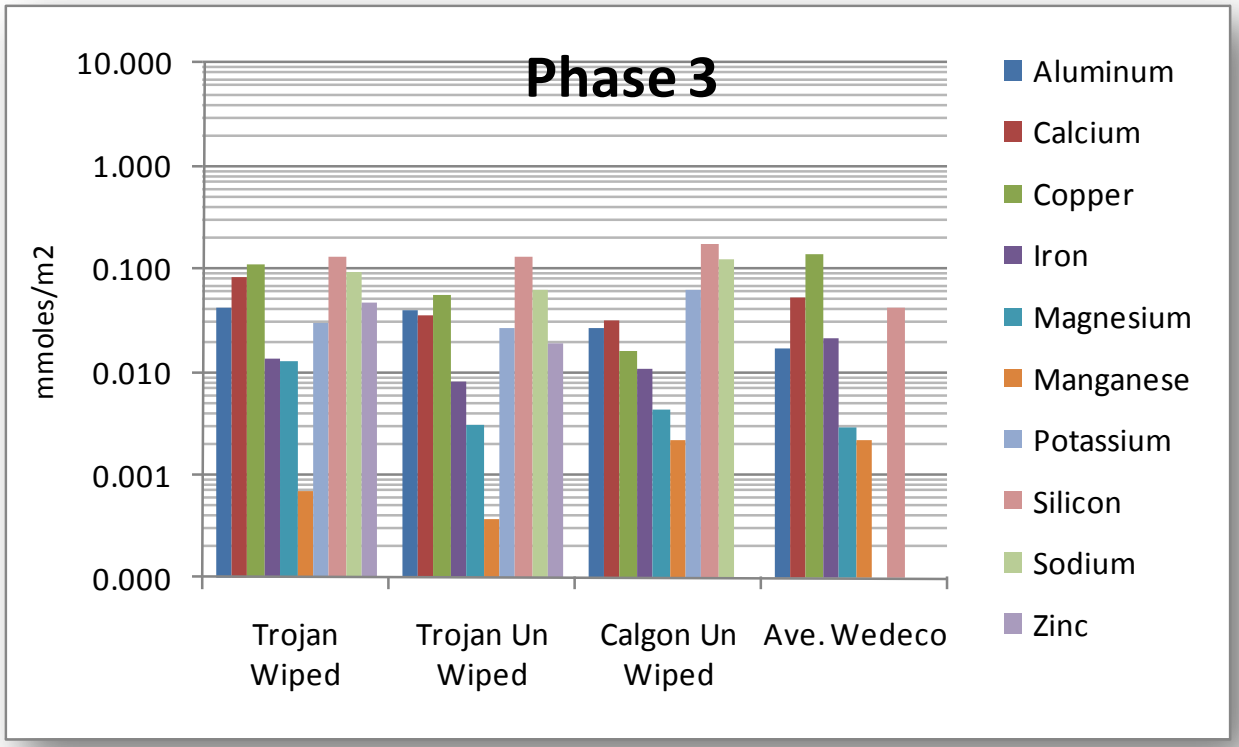
Un-wiped Wedeco Sleeves – Ph. 3

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Phase 3 Results

12/04/09 – 05/12/10

Acid Digestion of Foulant



Acid Digestion of All Sleeves on 05/12/10

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Phase 4 CAF Indexes

05/13/10 – 08/01/10 - All Reactors - With Bulk Cl_2 Addition

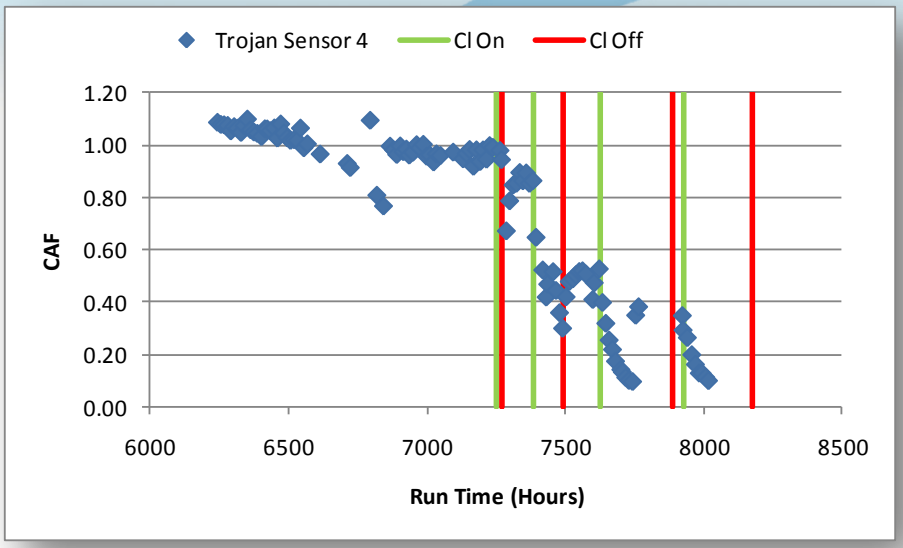
Bulk Hypochlorite Injection Equipment

Bulk Calcium Thiosulphate Injection Equipment

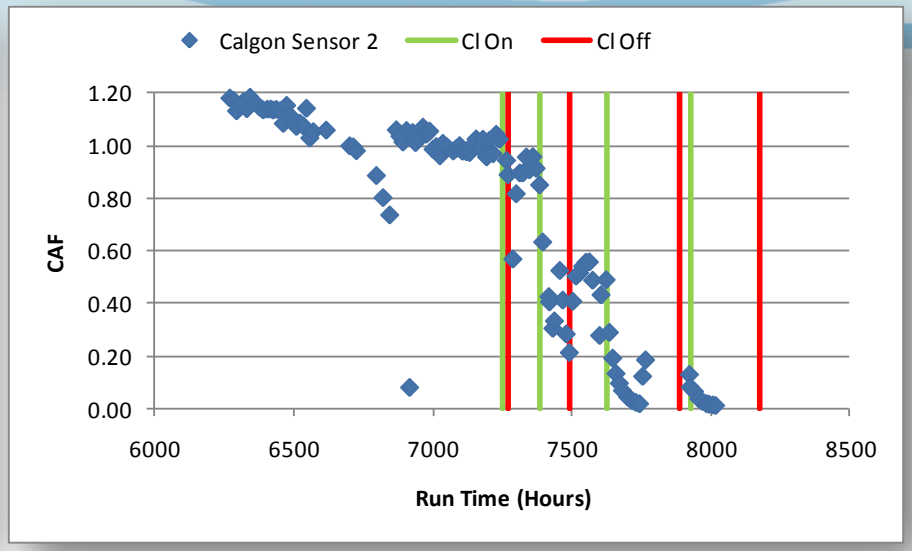
PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Phase 4 CAF Indexes

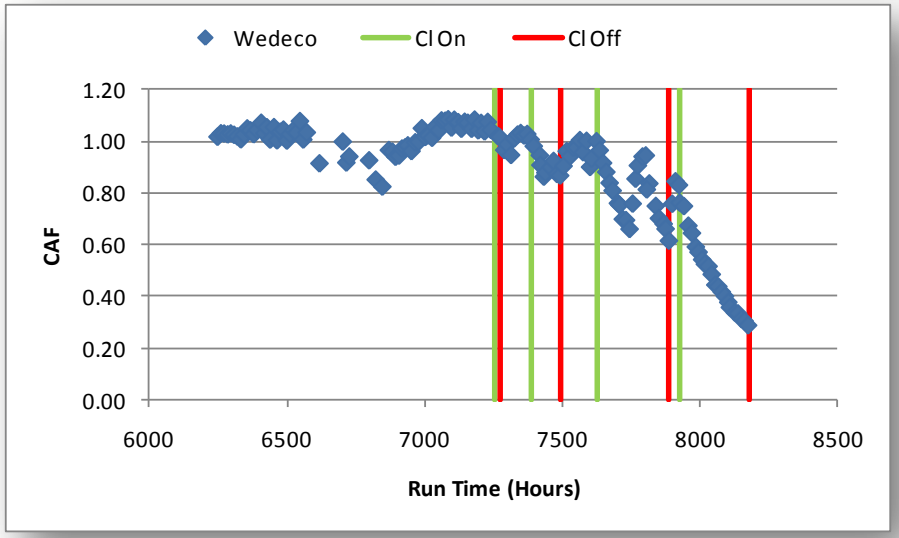
05/13/10 – 08/01/10 - All Reactors - With Bulk Cl_2 Addition



Un-wiped Trojan Sleeve CAF Index – Phase 4



Un-wiped Calgon Sleeve CAF Index – Ph. 4



Un-wiped Wedeco Sleeve CAF Index – Ph. 4

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

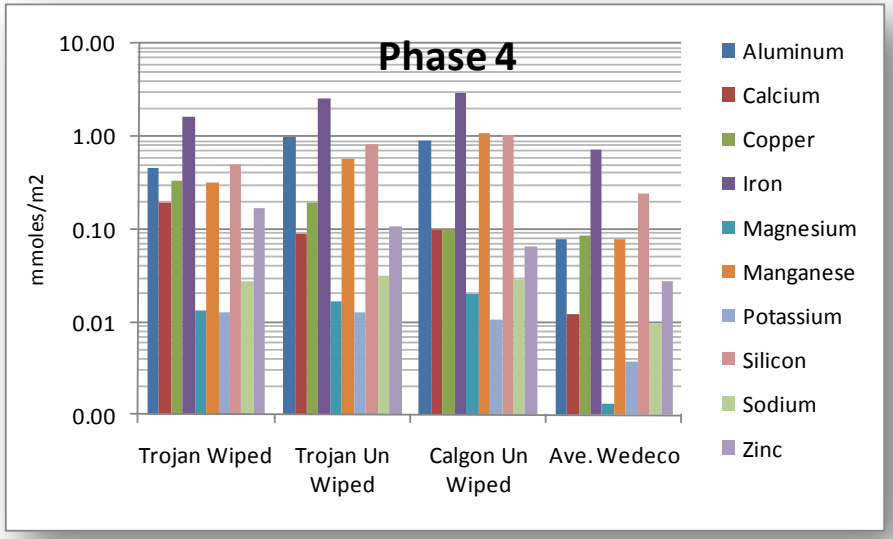
Phase 4 Fouling

05/13/10 – 08/01/10 - All Reactors - With Bulk Cl_2 Addition

Trojan Sleeves, Un-wiped - Ph. 4

Un-wiped Calgon Sleeves – Ph. 4

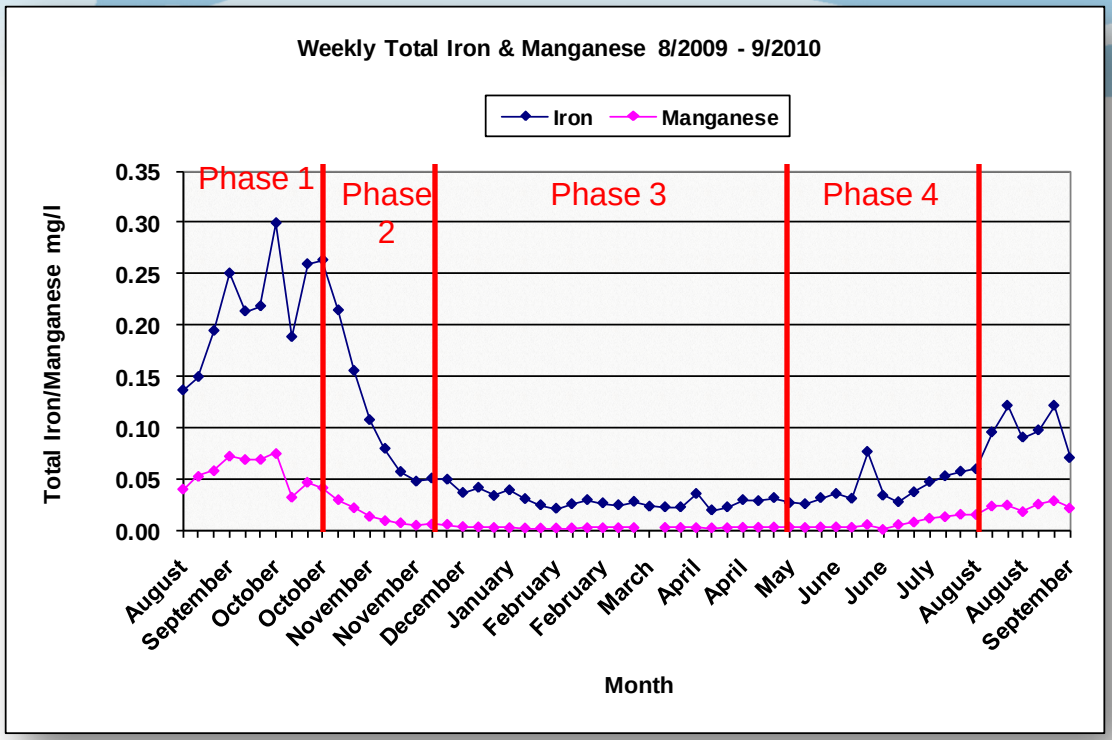
Un-wiped Wedeco Sleeves – Ph. 4

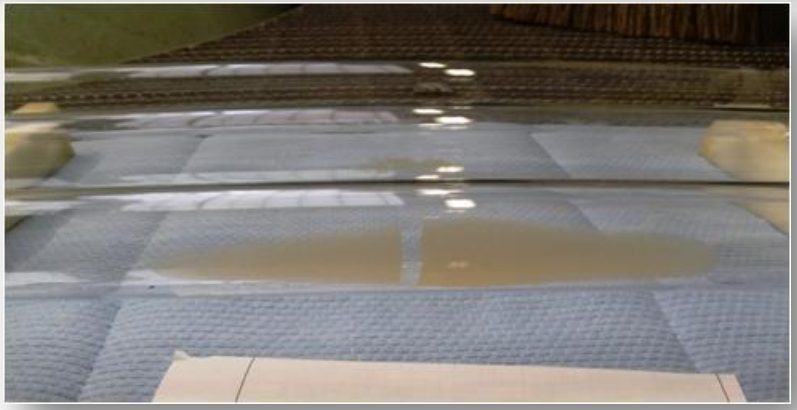


Phase 4 Metals Content of Foulant

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Key Water Quality Data





PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Optics Bench Measurements

Quartz Sleeve Optical UVT Measurement

Fouled sleeve optically measured for UVT at the end of each phase.

Sleeve optically re-measured for UVT after acid cleaning.

Optical Fouling Factor "*ff*" *is calculated by the following:*

$$ff\,(sleeve) = \left(\frac{I_{Dirty}}{I_{Clean}}\right)^{1/2} \qquad ff\,(sensorport) = \frac{I_{Dirty}}{I_{Cleaned}}$$

$$ff\,(overall) = ff\,(sleeve) \times ff\,(sensorport)$$

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Optics Bench Results

Testing Phase	Vendor	Lamp Type	Wipers ?	Direct Sleeve Measurements: Sleeve FF	Direct Sleeve Measurements: Sensor FF	Direct Sleeve Measurements: Overall FF	Sensor Based CAF Index
1	ITT Wedeco	LPHO	None	0.99	0.96	0.95	1.04
1	Calgon	MP	Not Active	0.71	1.00	0.71	0.62
1	Trojan	MP	Yes	1.00	0.98	0.98	NA[1]
1	Trojan	MP	Not Active	0.05	0.98	0.05	0.13
1.5	Trojan	MP	Yes	0.98	1.00	0.98	NA[1]
1.5	Trojan	MP	Not Active	0.15	1.00	0.15	0.24
2	ITT Wedeco	LPHO	None	1.01	0.96	0.97	0.96
2	Calgon	MP	Not Active	0.93	1.00	0.93	1.04
2	Trojan	MP	Yes	1.01	1.00	1.01	NA[1]
2	Trojan	MP	Not Active	1.02	1.00	1.02	1.13
3	ITT Wedeco	LPHO	None	1.00	1.01	1.01	0.77
3	Calgon	MP	Not Active	0.95	1.00	0.95	0.79
3	Trojan	MP	Yes	1.00	0.95	0.95	NA[1]
3	Trojan	MP	Not Active	0.99	1.00	0.99	0.94
4	ITT Wedeco	LPHO	None	0.40	0.53	0.21	0.29
4	Calgon	MP	Not Active	0.05	0.06	0.00	0.01
4	Trojan	MP	Not Active	0.14	0.39	0.05	0.15

[1] Sensor Based CAF index not calculated since Trojan pilot reactor was originally delivered with only on sensor installed, so initial reactor characterization only included Sensor #4 for the first three testing phases.

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

UV Fouling Study Conclusions

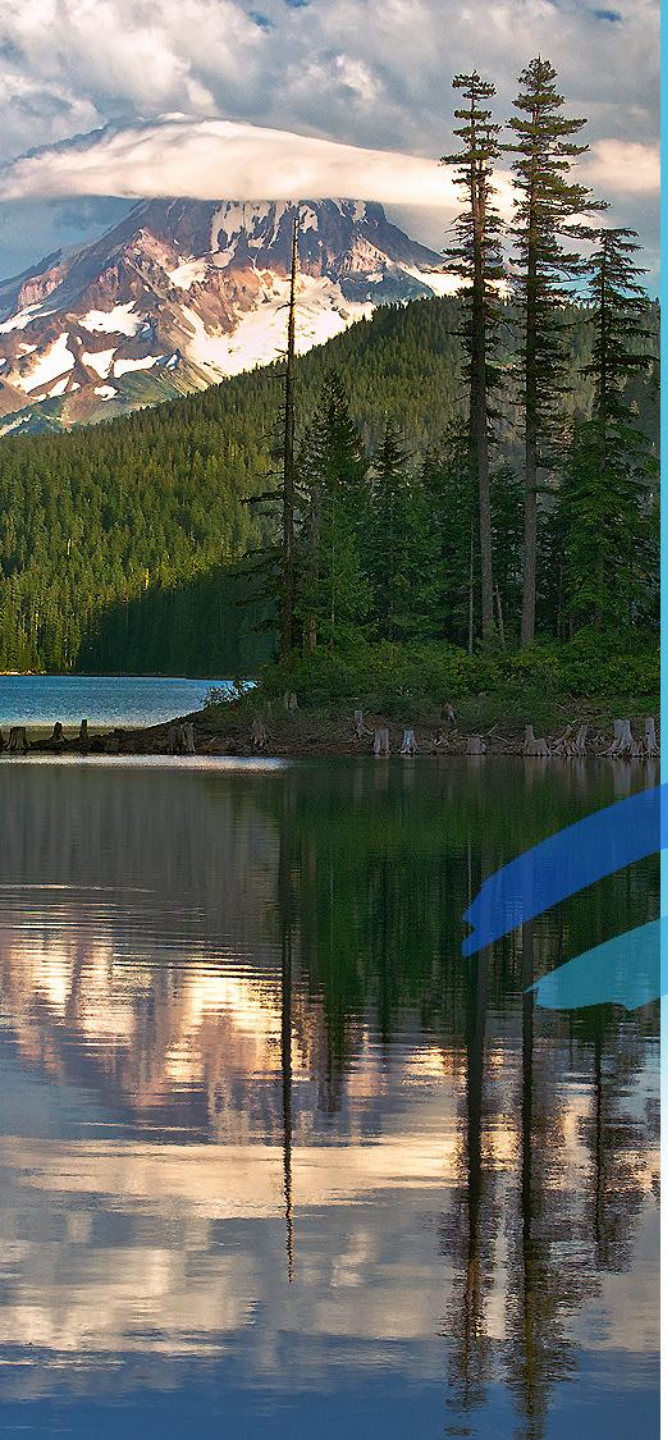
If medium pressure UV reactors are selected, automatic wipers will be needed during the fall months when the metals levels, particularly iron, are elevated.

If low pressure high-output UV reactors are selected, it does not appear that significant fouling of the quartz sleeves will occur, and sleeve cleaning could likely be every 6 to 12 months.

The chemical make-up of the UV sleeve foulant was mainly iron, manganese, copper, and silica.

The addition of bulk hypochlorite to the water just upstream of UV treatment increases fouling dramatically.

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET



Special Thanks:

PWB Sandy River Station Staff

PWB Water Treatment Operators

Mark Heath, Carollo Engineers

Harold Wright, Carollo Engineers

Questions?

PORTLAND WATER BUREAU

FROM FOREST TO FAUCET

CITY OF PORTLAND, OREGON 1851