# Meeting Manganese Removal Goals: A Pilot Study

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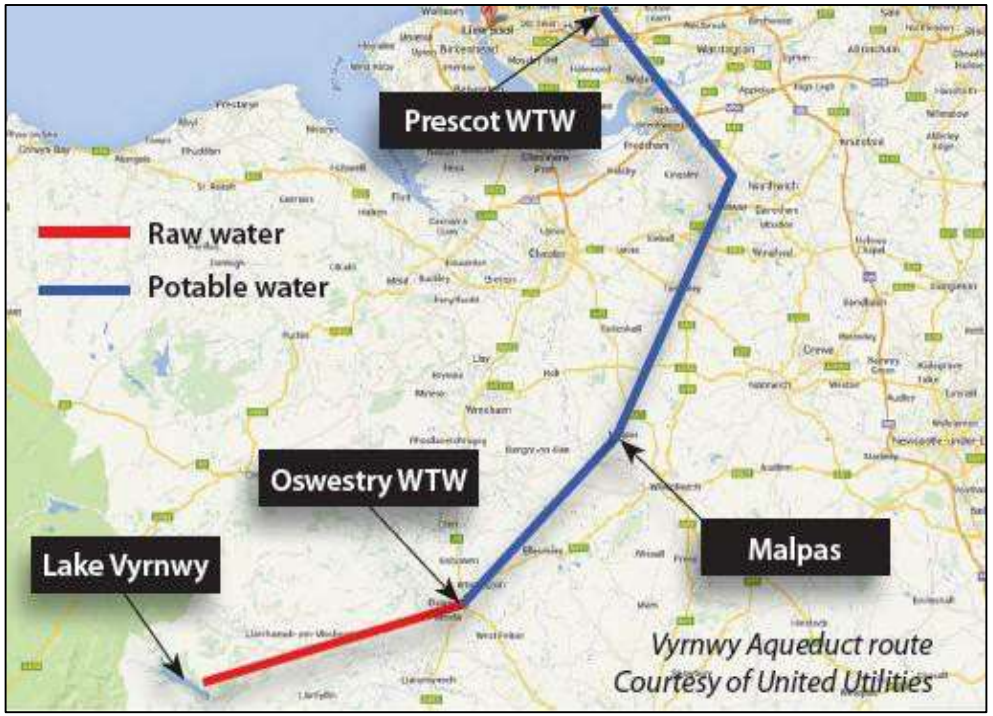
ch2m

# Background – Oswestry WTW

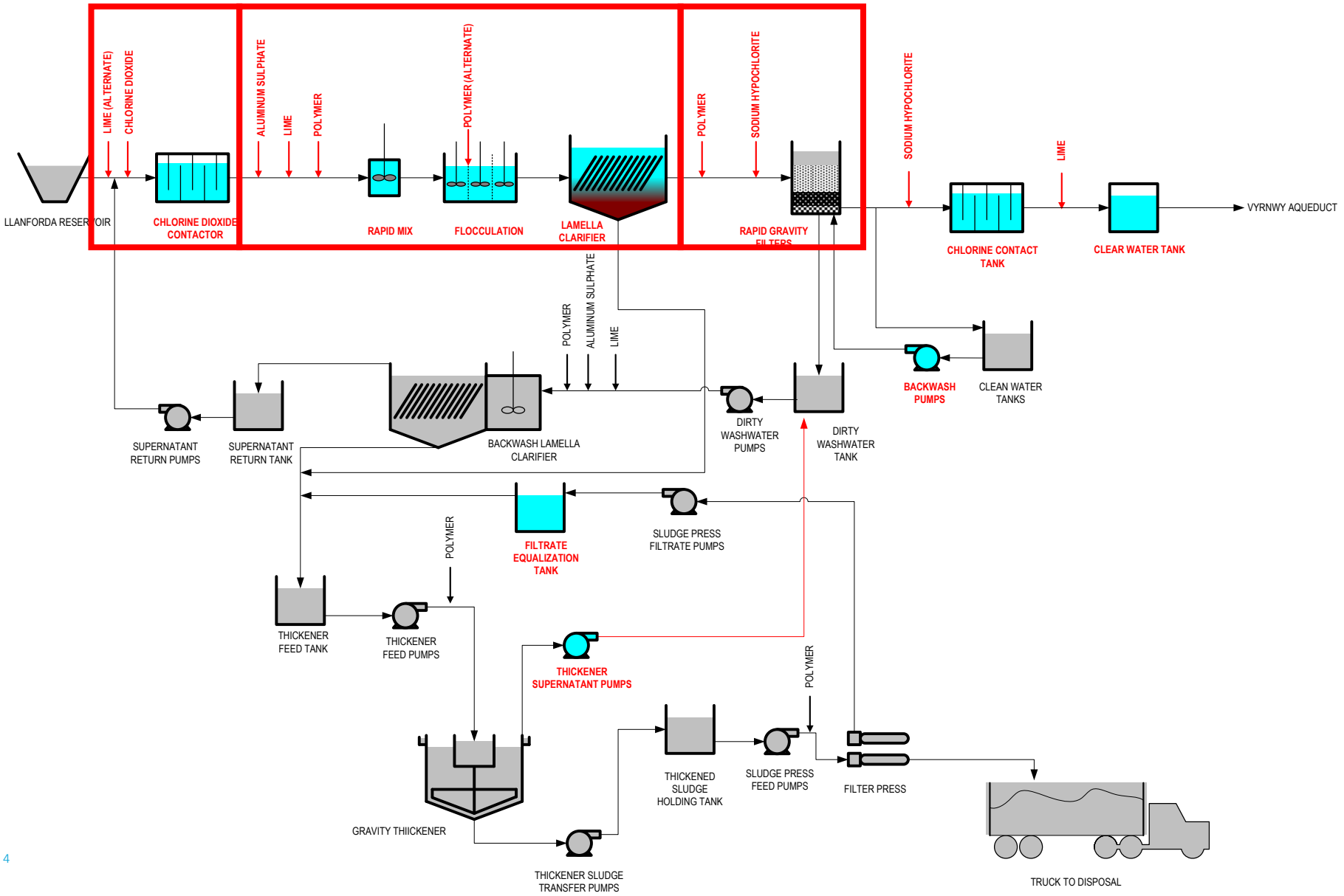
- Owned and Operated by United Utilities
- ~55 MGD
- Source water: Llanforda Reservoir
- High doses of Alum overwhelmed the existing direct filtration plant
- Manganese in finished water is concern
- Robust, multi-barrier process to minimize risks in finished water



# Raw Water Quality

| Parameter | Units | Min | Average | 99th %ile | Max |
|---|---|---|---|---|---|
| Temperature | Degrees Celsius | 1.8 | 10.7 | 17.9 | 18.6 |
| Turbidity | NTU | 0.44 | 1.20 | 3.40 | 6.23 |
| Alkalinity | mg/L as CaCO3 | 1.19 | 5.36 | 15.98 | 32.60 |
| Total Hardness | mg/L as CaCO3 | 7.26 | 10.51 | 21.40 | 22.70 |
| pH | S.U. | 6.12 | 6.84 | 7.65 | 7.88 |
| Conductivity | umohs/cm | 26.0 | 39.2 | 81.0 | 112 |
| True Colour | PtCo | 0.91 | 35.37 | 50.09 | 111.0 |
| TOC | mg/L | 1.66 | 4.20 | 5.99 | 6.06 |
| Iron | ug/L | 184 | 345.8 | 498.9 | 536 |
| Manganese | ug/L | 16.3 | 53.7 | 187.6 | 251 |
| Aluminum | ug/L | 47.5 | 88.7 | 162.6 | 186 |
| Ammonia as N | mg/L | 0.01 | 0.02 | 0.07 | 0.10 |

# Plant Upgrades



# Performance Goals

| Parameter | Average | 70th %ile | 80th %ile | 90th %ile | 95th %ile | 99th %ile | Max |
|---|---|---|---|---|---|---|---|
| TOC (mg/L) | <1.17 | <1.30 | <1.38 | n/a | <1.55 | <1.75 | <2.0 |
| Iron (ug/L) | < 12.6 | - | - | - | - | - | <12.6 |
| Manganese (ug/L) | - | - | <0.4 | <0.91 | < 1.20 | < 2.50 | < 12.5 |

| Sample Point | Parameter | Evaluation Criteria | Goal |
|---|---|---|---|
| Clarified water | Turbidity (steady-state) | <2.0 NTU | <1.0 NTU |
| Clarified Water | Chlorite/Chlorate | <500 ug/L | <500 ug/L |
| Filter Effluent | Turbidity (steady-state) | <0.1 NTU | <0.05 NTU |
| Filter Effluent | Turbidity spike (ripening) | 0.2 NTU | <0.1 NTU |
| Filter Effluent | Ripening time | 30 minutes | < 15 min. to <0.1 NTU |
| Filter Production | Unit Filter Run Volume | > 4900 gal/sf | > 7800 gal/sf |

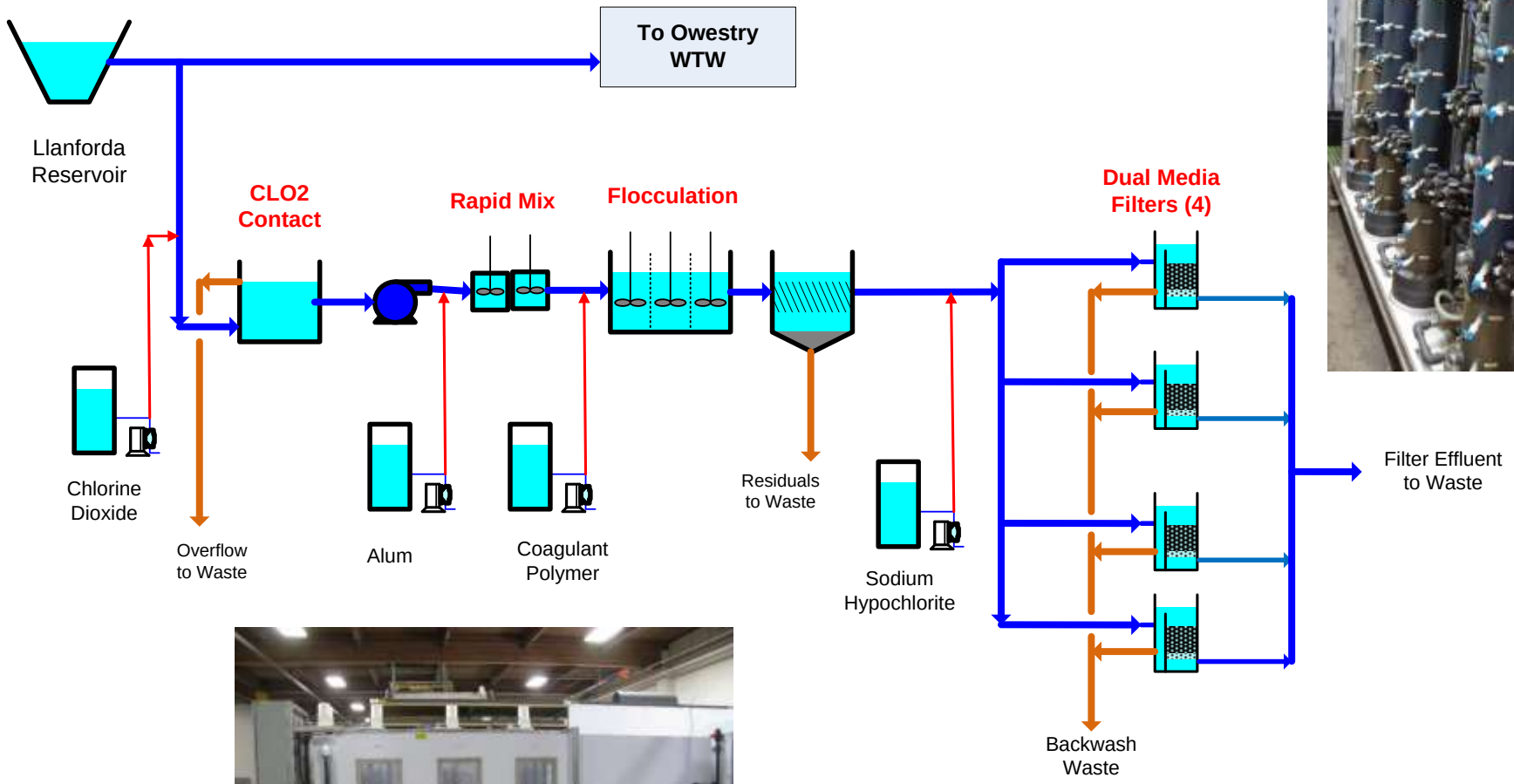
# Objective: Two Phases of Testing

- First Phase (March to May 2015):
  - Verify the ability of treatment train to remove TOC, iron and manganese to meet water quality goals
  - Coagulant optimization
  - Verify performance of alternative filter media configurations at different filter loading rates
- Second Phase (June to July 2015):
  - More optimized data – sustained runs
  - Evaluate performance of proposed train with artificial spikes of raw water manganese
  - Evaluate performance of a modified filter using sand from the UU second stage manganese filter pilot
  - Evaluate trihalomethane formation from proposed train

# Process Setpoints

| | Phase 1 | Phase 2 |
|---|---|---|
| **Chlorine Dioxide** | • 4 minutes detention time<br>• Dose = 0.5 – 0.6 mg/L<br>• Trials run with no $ClO_2$ | • 4 minutes detention time<br>• Dose = 0.55 mg/L |
| **Alum Dose** | 2.5 – 3 mg/L | 3 mg/L |
| **Polymer Dose** | 0.2 – 0.5 mg/L | 0.25 mg/L |
| **Caustic Dose** | 8 – 12 mg/L | 8 – 12 mg/L |
| **Target pH** | • 6.0 – 6.5<br>• 6.5 – 7 (with chiller) | • 6.5 – 7 (with chiller) |
| **Flocculation** | • 30 minutes, 3 stages<br>• G value of 60/30/15 | • 30 minutes, 3 stages<br>• G value of 60/30/15 |
| **Chlorine Dose** | 0.5 - 1.0 mg/L residual | 0.5 - 1.0 mg/L residual |
| **Filter Loading Rate** | 2.5 gpm/sf and 4.0 gpm/sf | 2.5 gpm/sf |

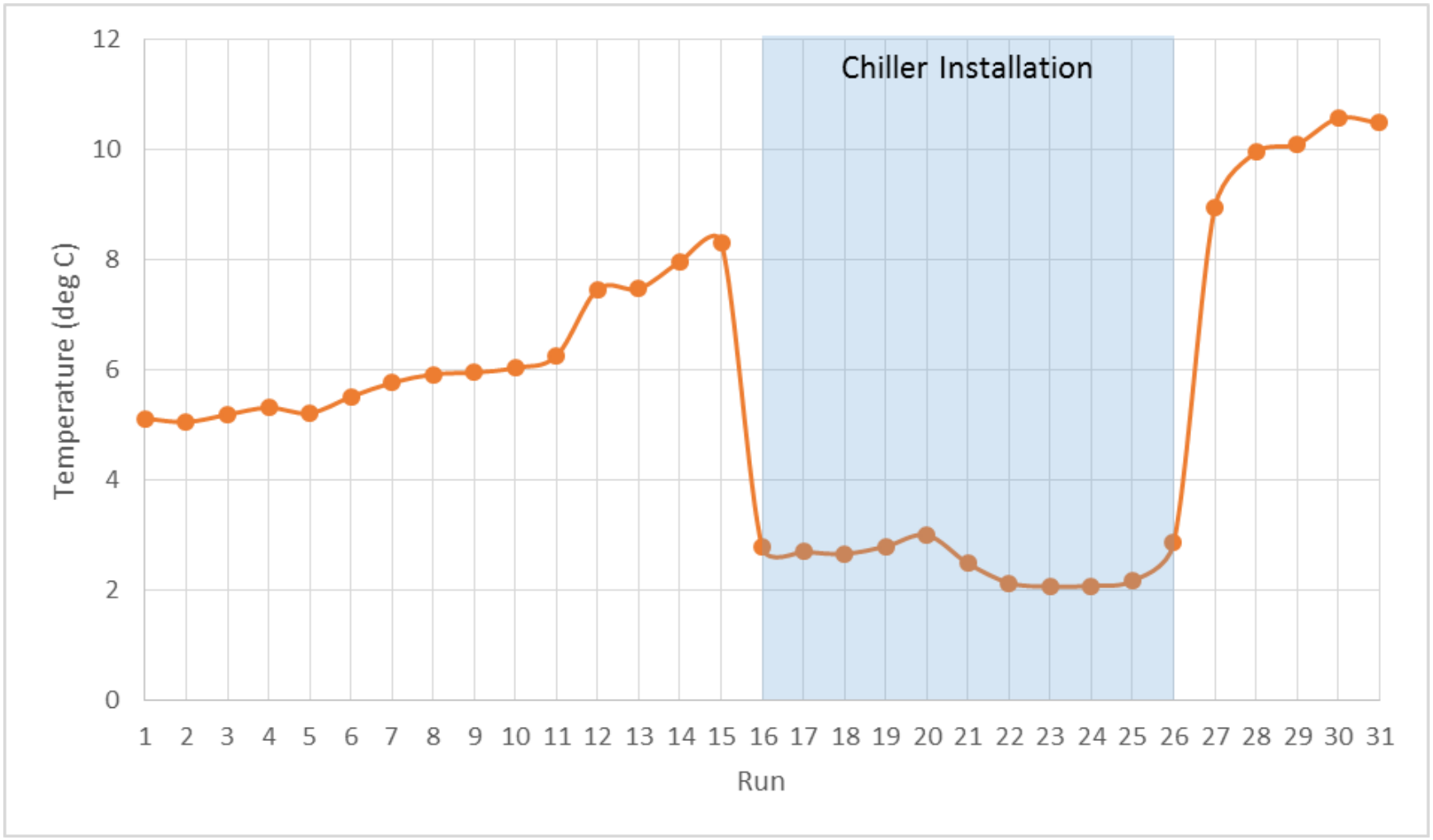
# Phase 1: PFD


To Owestry WTW
Llanforda Reservoir
CLO2 Contact
Rapid Mix
Flocculation
Dual Media Filters (4)
Chlorine Dioxide
Overflow to Waste
Alum
Coagulant Polymer
Residuals to Waste
Sodium Hypochlorite
Filter Effluent to Waste
Backwash Waste

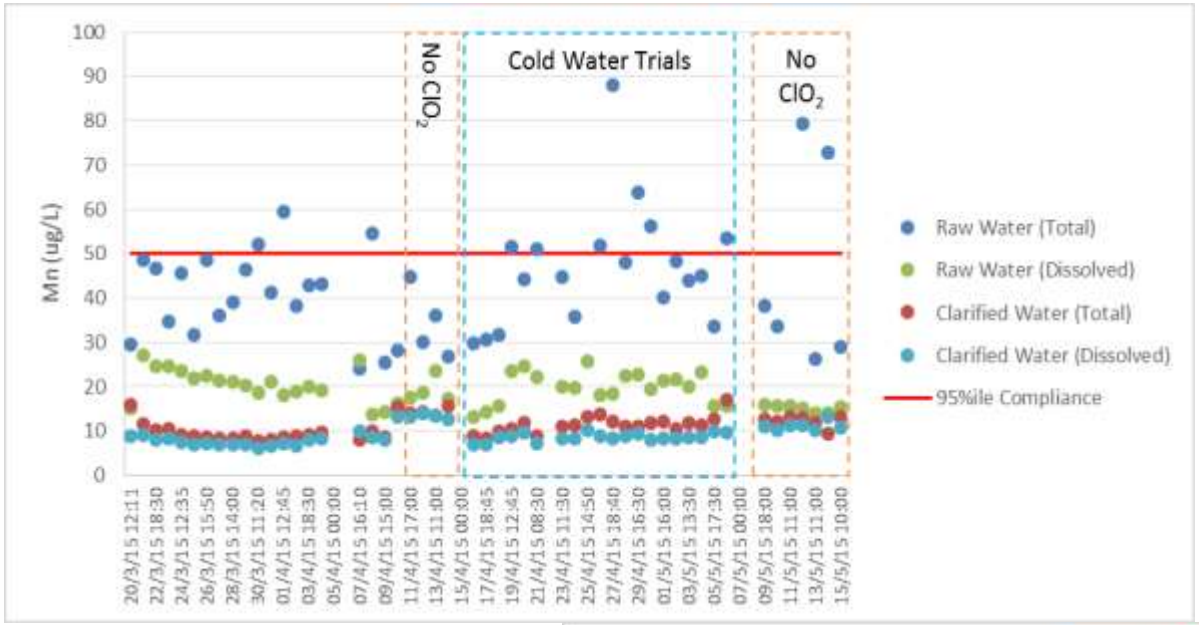
# Phase 1 Filter Setups

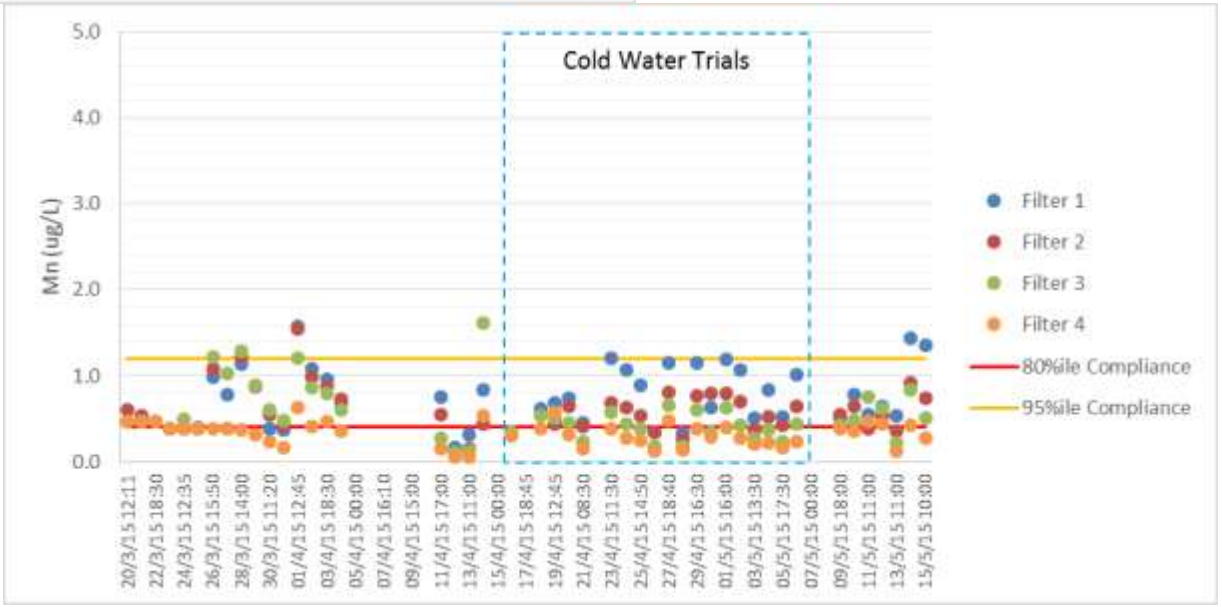
| | Media/Depth | ES/UC | Media/Depth | ES/UC | Notes |
|---|---|---|---|---|---|
| **Column 1-Control** | Anthracite/ 400 mm | 1.3 mm/ 1.5 | Sand/800 mm | 0.625 mm/1.4 | Mimic Existing Filter |
| **Column 2** | Anthracite/ 800 mm | 1.3 mm/1.5 | Sand/400 mm | 0.625 mm/1.4 | Increase anthracite depth |
| **Column 3** | Anthracite/ 800 mm | 1.0 mm/1.5 | Sand/400 mm | 0.5 mm/ 1.4 | Smaller effective size media |
| **Column 4** | Anthracite/ 900 mm | 1.0 mm/1.5 | Sand/300 mm | 0.5 mm/ 1.4 | Additional anthracite and less sand.<br>Sand pre-mixed with 10% Polarite |

# Raw Water Temperature – Phase 1

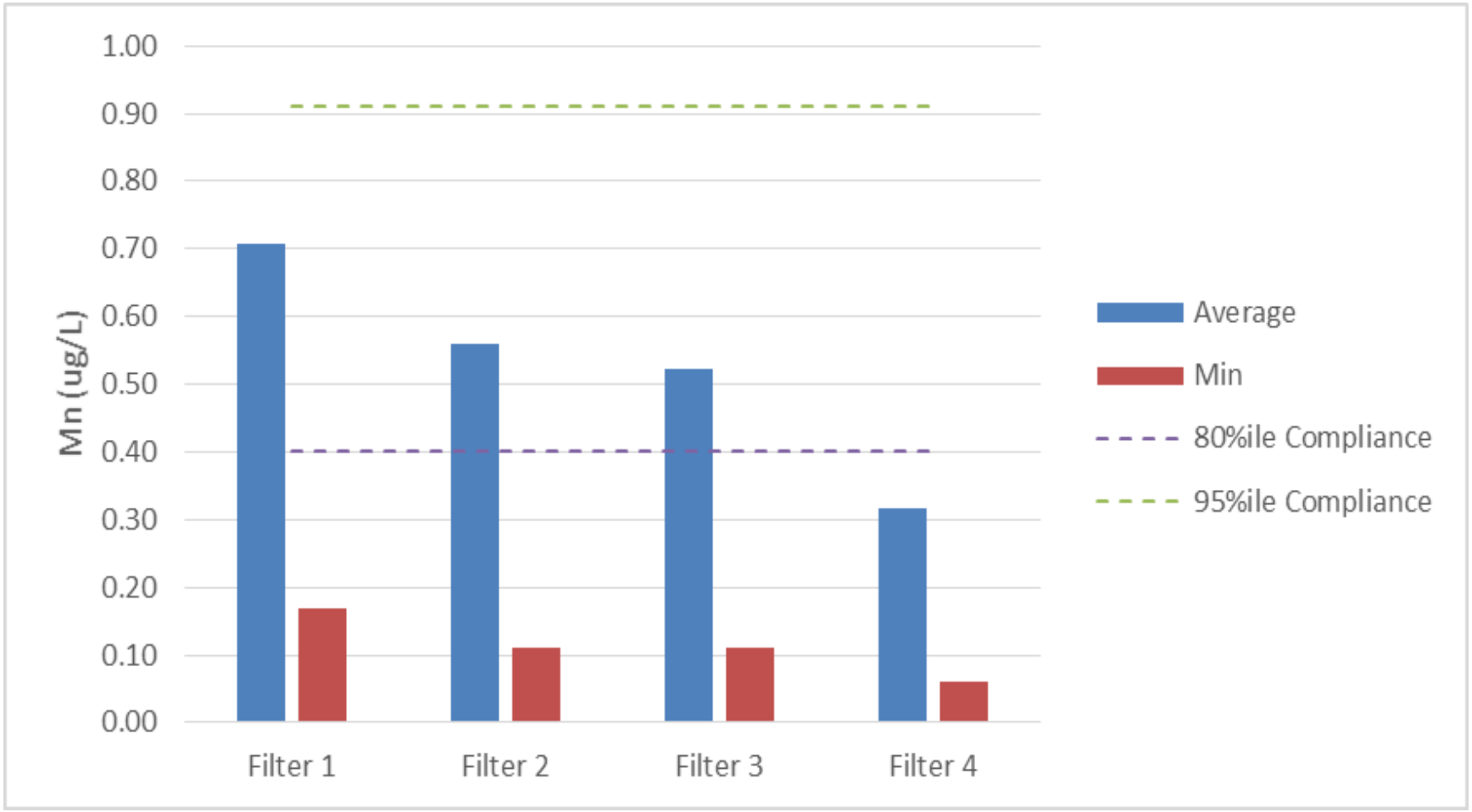


# Phase 1: Mn

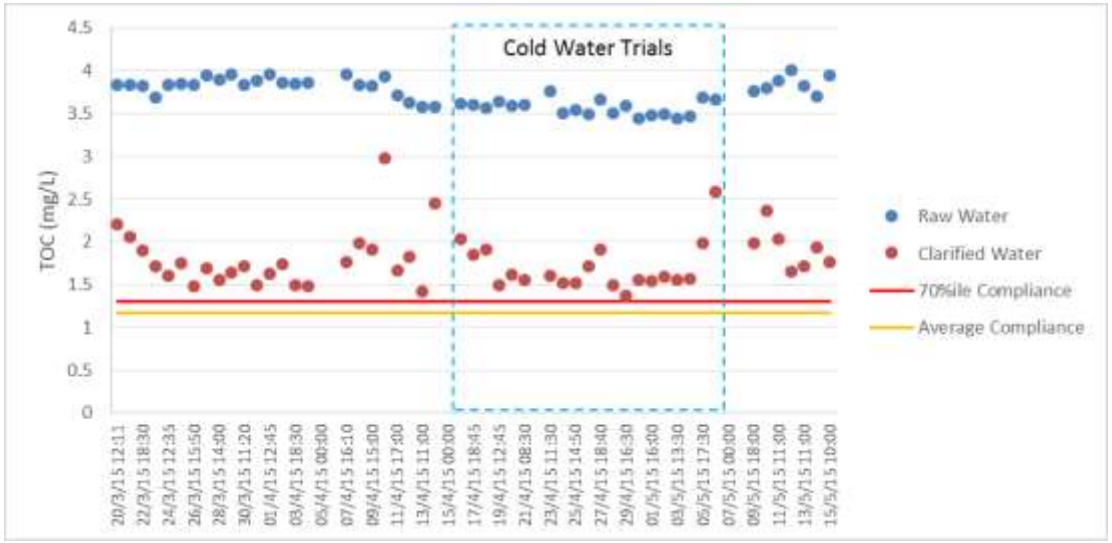

Mn (ug/L)
No ClO2
Cold Water Trials
No ClO2
Raw Water (Total)
Raw Water (Dissolved)
Clarified Water (Total)
Clarified Water (Dissolved)
95%ile Compliance

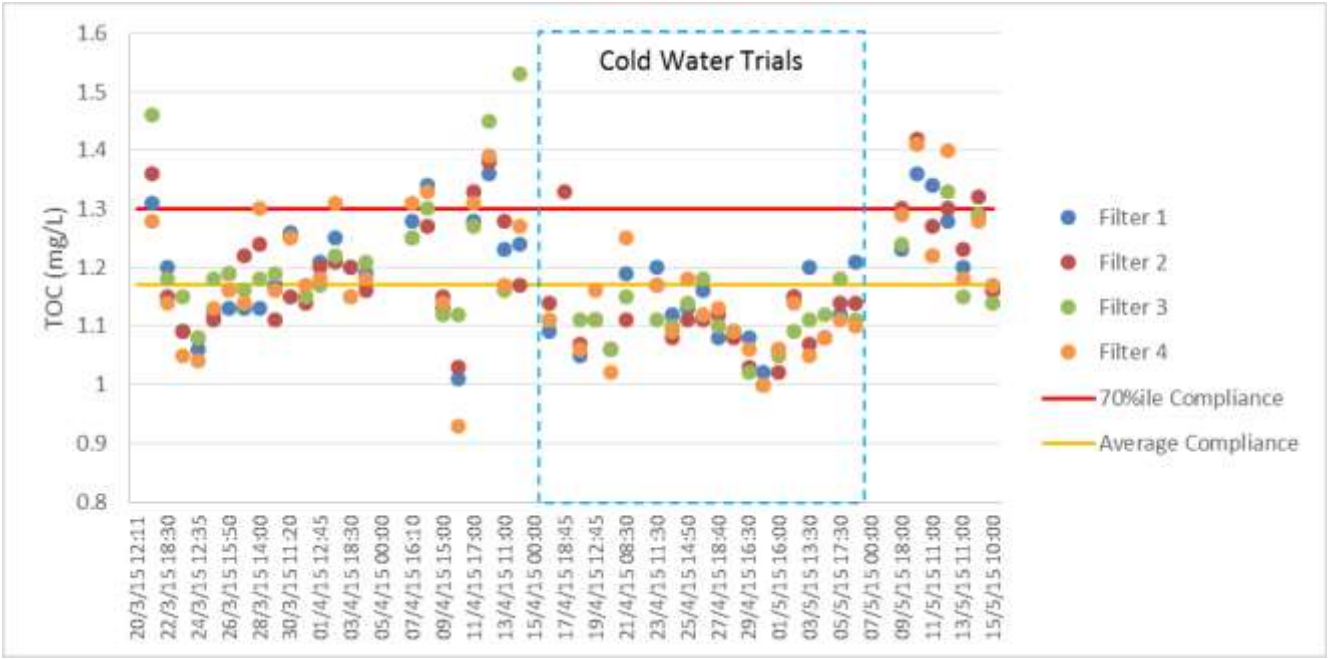

Mn (ug/L)
Cold Water Trials
Filter 1
Filter 2
Filter 3
Filter 4
80%ile Compliance
95%ile Compliance

# Phase 1: Filter Performance



# Phase 1: TOC

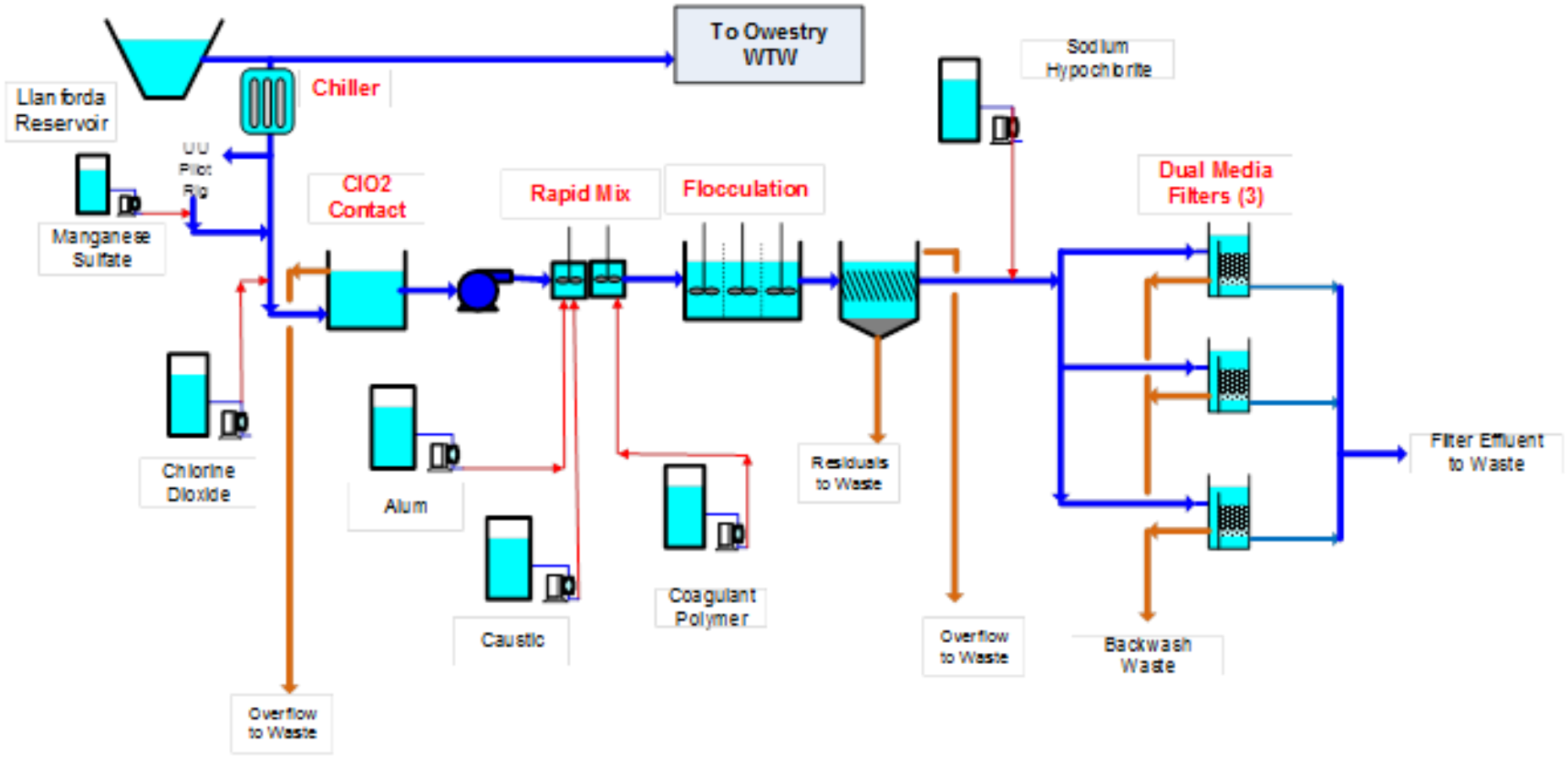

Cold Water Trials
TOC (mg/L)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Raw Water
Clarified Water
70%ile Compliance
Average Compliance


Cold Water Trials
TOC (mg/L)
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
Filter 1
Filter 2
Filter 3
Filter 4
70%ile Compliance
Average Compliance

# Phase 1 Pilot Testing Conclusions

- Overall proof of concept
  - Overall treatment process demonstrated good manganese and TOC removal
  - Pilot unit operated at 2 C to 8 C with good performance
- Evaluate manganese control
  - Minimum concentrations of 0.11 ug/L of manganese were observed.
- Evaluate TOC removal
  - Filtered water TOC goals were achieved
  - Anticipated that full-scale settling will be optimized
- Evaluate filter media configurations
  - Proposed media (800mm anthracite/400mm sand) provides more productive filter performance

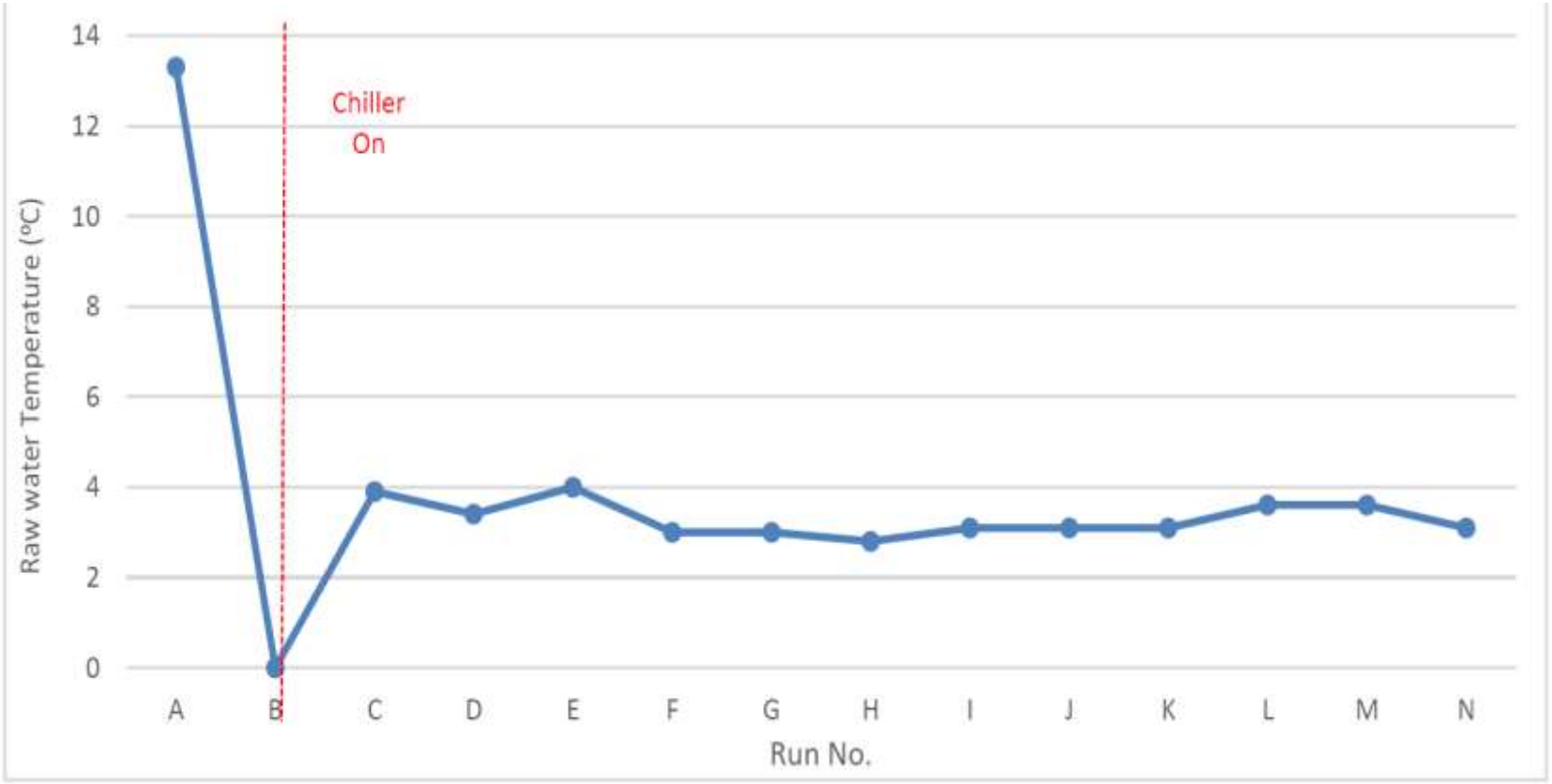
# Phase 2: PFD


To Owestry WTW
Llanforda Reservoir
Chiller
UU Pilot Rig
Manganese Sulfate
ClO2 Contact
Rapid Mix
Flocculation
Sodium Hypochlorite
Dual Media Filters (3)
Chlorine Dioxide
Alum
Caustic
Coagulant Polymer
Residuals to Waste
Overflow to Waste
Overflow to Waste
Backwash Waste
Filter Effluent to Waste

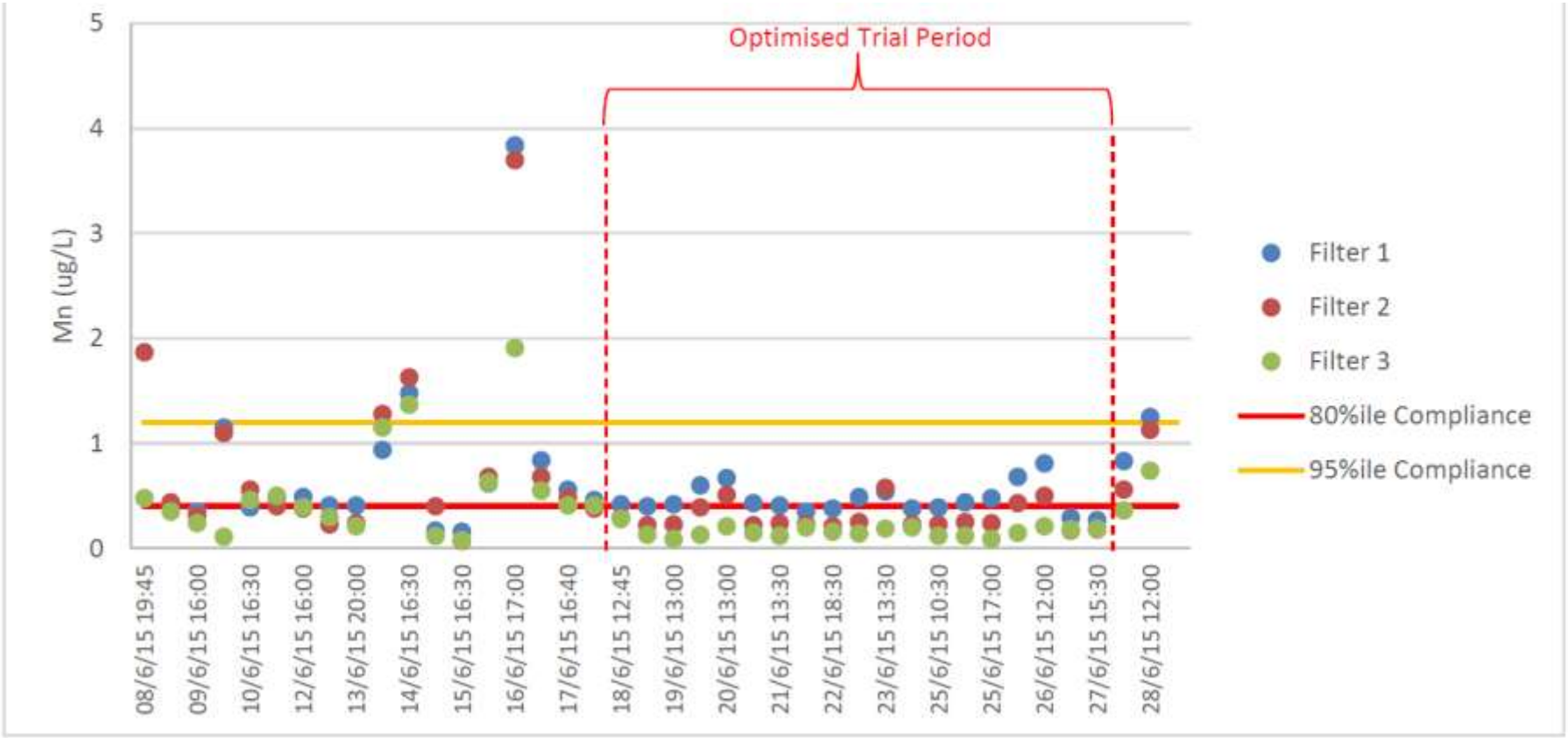
# Phase 2 Filter Setups

| | Media/Depth | ES/UC | Media/Depth | ES/UC | Notes |
|---|---|---|---|---|---|
| **Column 1-Control** | Anthracite/ 400 mm | 1.3 mm/ 1.5 | Sand/800 mm | 0.625 mm/1.4 | Mimic Existing Filter |
| **Column 2** | Anthracite/800 mm | 1.3 mm/1.5 | Sand/400 mm | 0.625 mm/1.4 | No change |
| **Column 3** | Anthracite/800 mm | 1.3mm/1.5 | Sand/400 mm | 0.625 mm/ 1.4 | Sand from UU manganese pilot trial filters |

# Phase 2: Raw Water Temperature

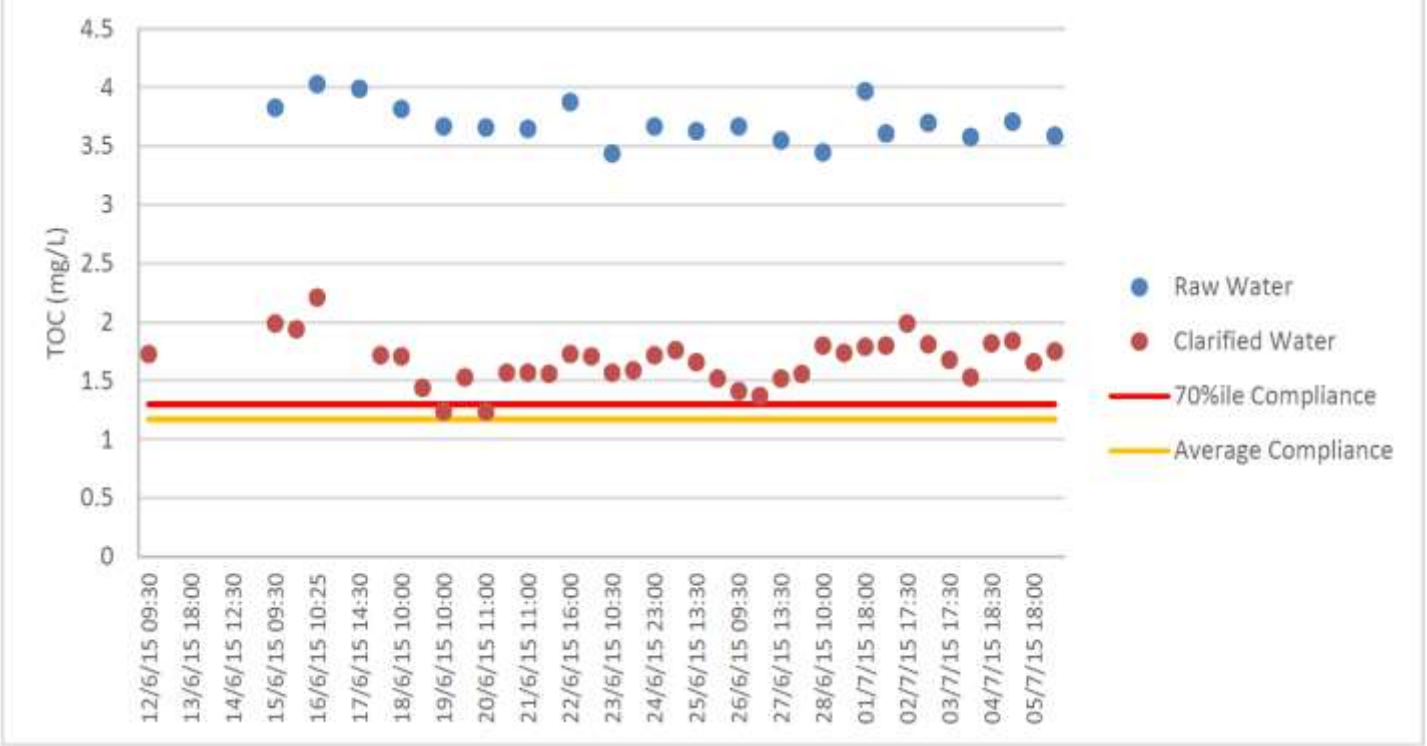


# Phase 2: Mn



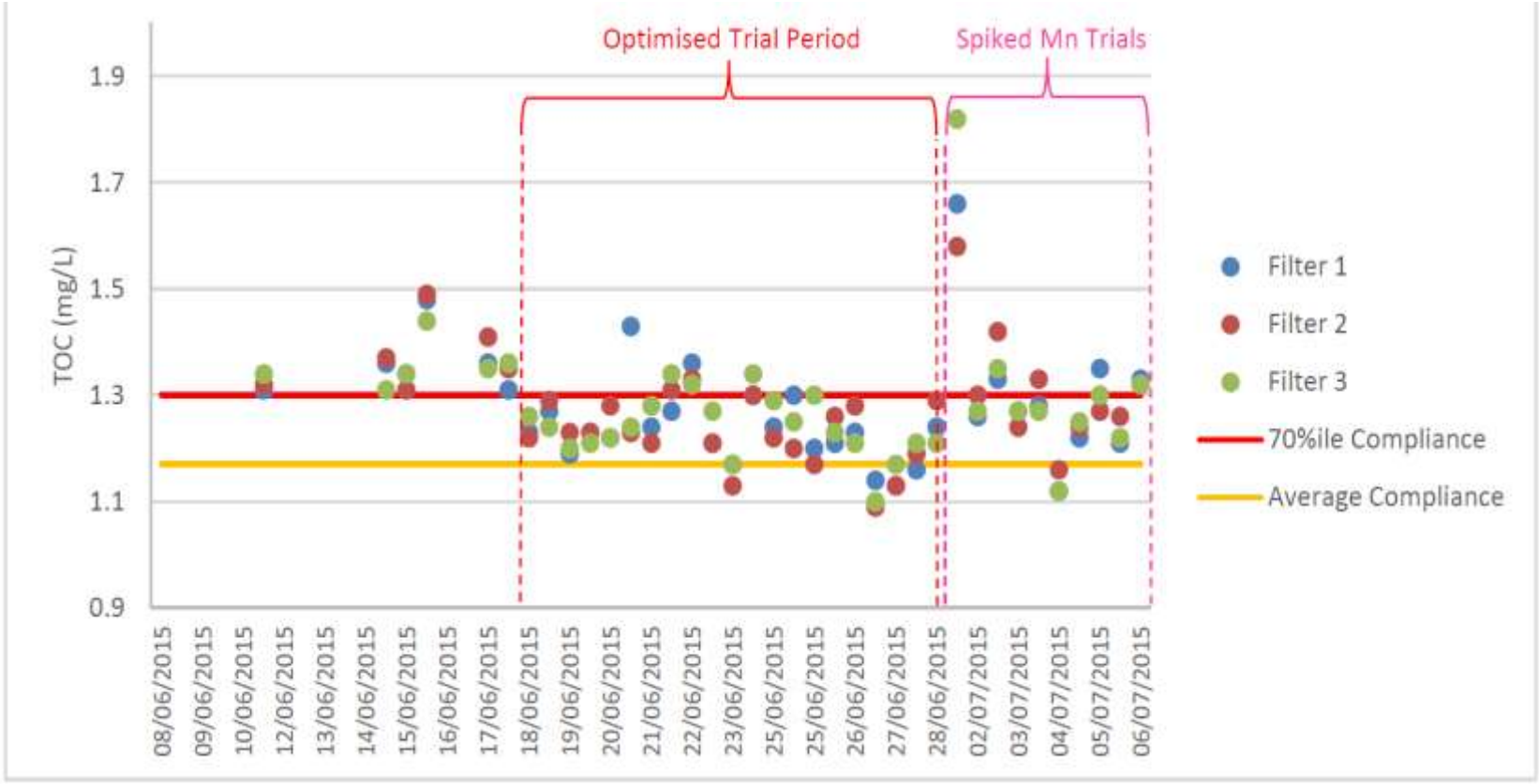

| Manganese Compliance (Trials C – K) - Optimised Period | | | | |
|---|---|---|---|---|
| | Filter 1 | Filter 2 | Filter 3 | Compliance |
| Average | 0.47 | 0.30 | 0.17 | N/A |
| 80%ile | 0.55 | 0.40 | 0.20 | <0.4 µg/L |
| 90%ile | 0.67 | 0.50 | 0.22 | <0.91 µg/L |
| 95%ile | 0.69 | 0.51 | 0.29 | <1.20 µg/L |
| 99%ile | 0.79 | 0.57 | 0.39 | <2.50 µg/L |
| Max | 0.81 | 0.58 | 0.41 | <12.5 µg/L |
| Min | 0.17 | 0.17 | 0.09 | N/A |

# Phase 2: Clarified TOC



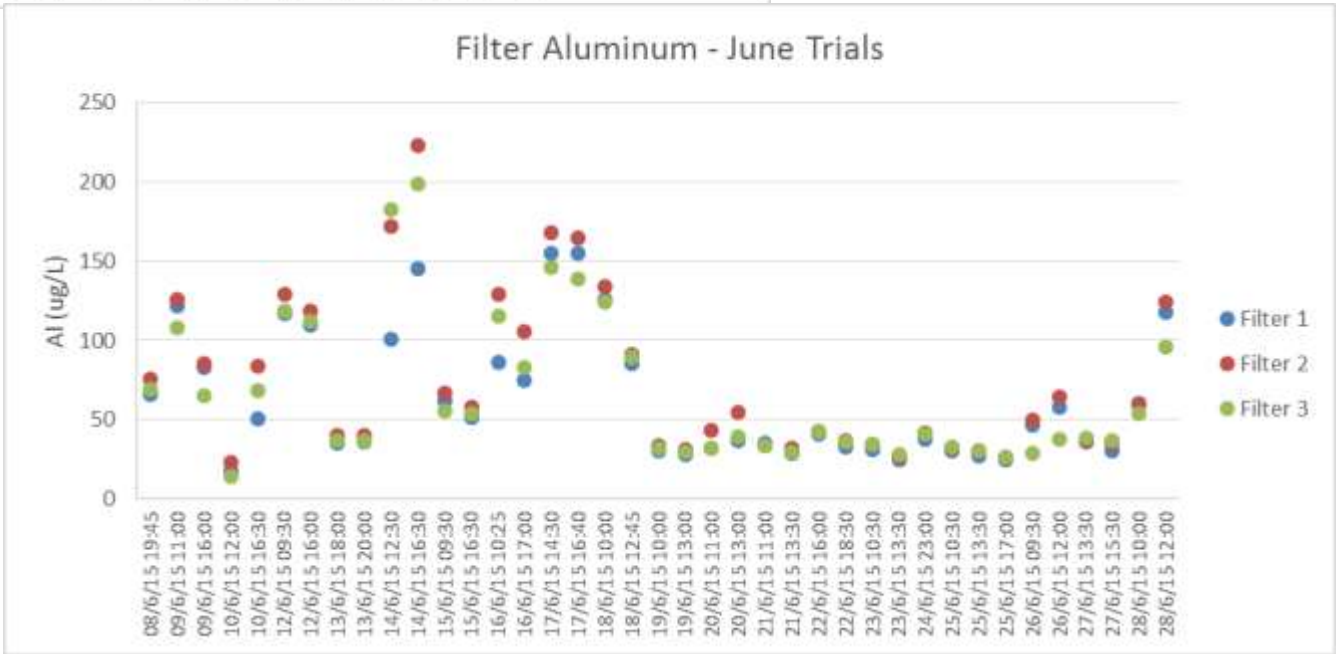

| TOC Compliance (Trials C – N) | | |
|---|---|---|
| | **Clarifier** | **Compliance** |
| Average | 1.67 | <1.17 mg/L |
| 95%ile | 1.99 | <1.55 mg/L |
| Max | 2.21 | <2 mg/L |
| Min | 1.24 | N/A |

# Phase 2: Filter TOC

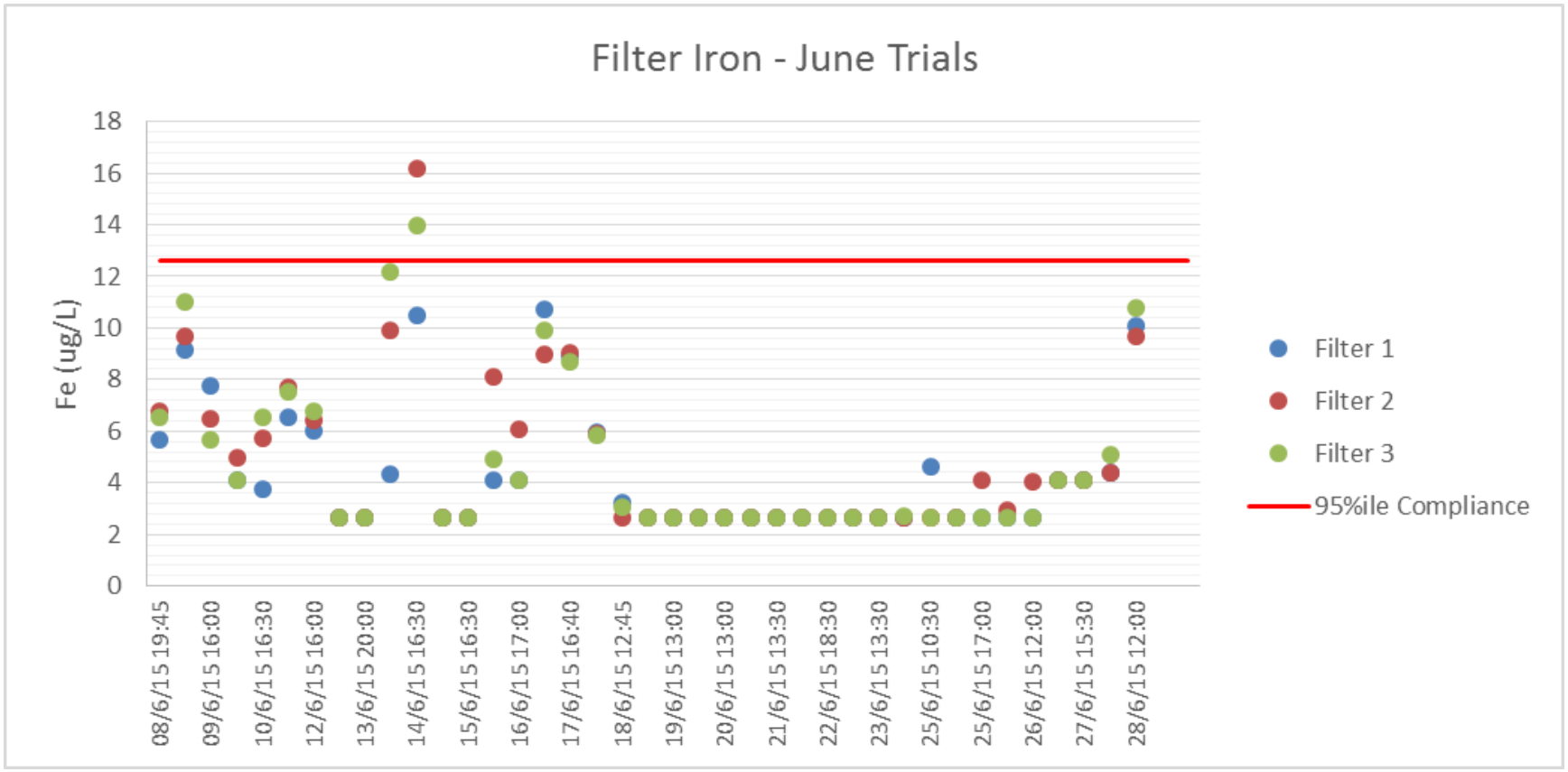



| TOC Compliance (Trials C – N) – Optimised Period | | | | |
|---|---|---|---|---|
| | Filter 1 | Filter 2 | Filter 3 | Compliance |
| Average | 1.24 | 1.23 | 1.25 | <1.17 mg/L |
| 70%ile | 1.27 | 1.28 | 1.29 | <1.3 mg/L |
| 80%ile | 1.30 | 1.29 | 1.30 | <1.38 mg/L |
| 95%ile | 1.36 | 1.33 | 1.34 | <1.55 mg/L |
| 99%ile | 1.42 | 1.35 | 1.36 | <1.75 mg/L |
| Max | 1.43 | 1.35 | 1.36 | <2 mg/L |
| Min | 1.13 | 1.09 | 1.10 | N/A |

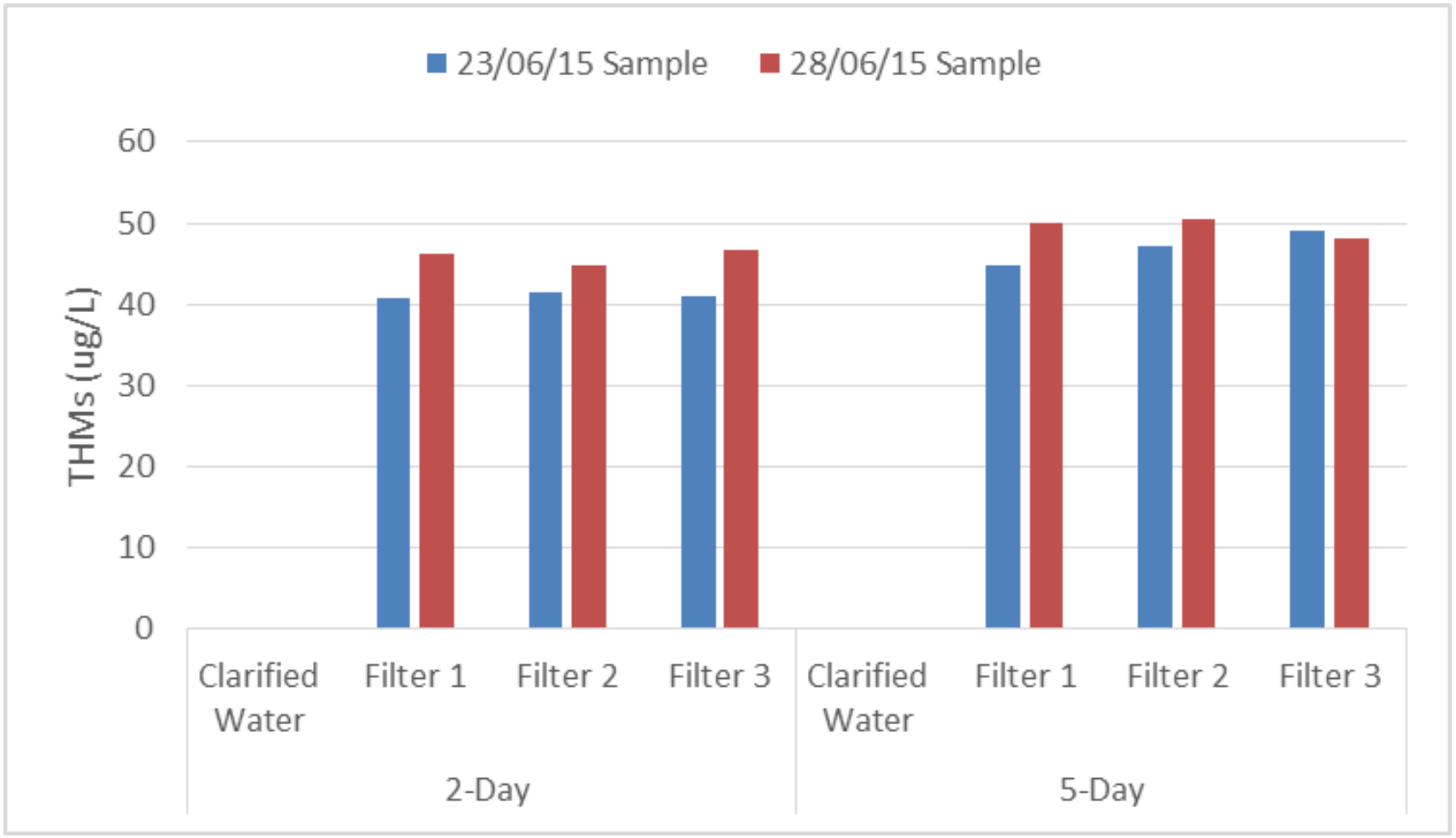
# Phase 2: Aluminum

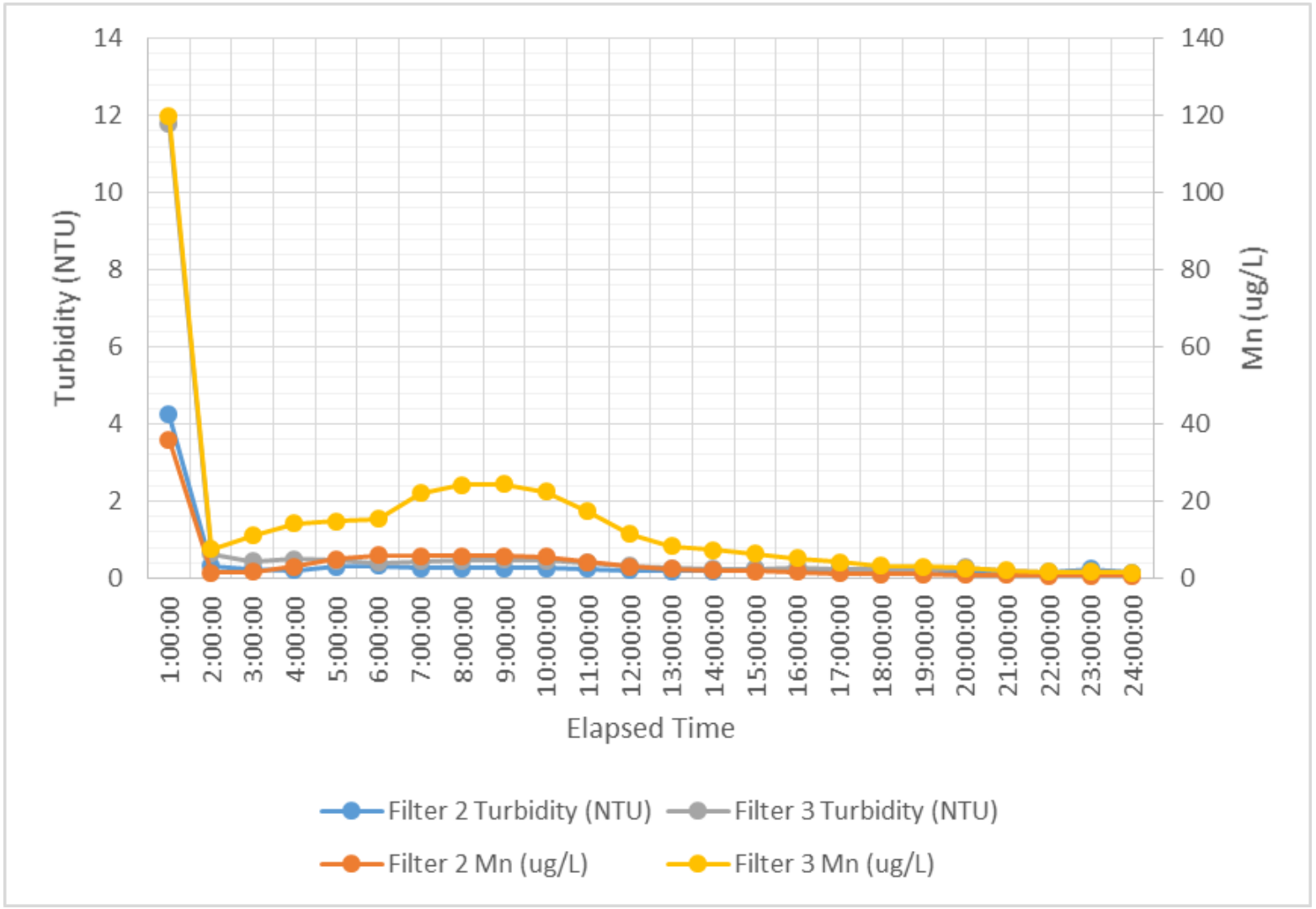
# Phase 2: Iron


Filter Iron - June Trials
Fe (ug/L)
18
16
14
12
10
8
6
4
2
0
08/6/15 19:45
09/6/15 16:00
10/6/15 16:30
12/6/15 16:00
13/6/15 20:00
14/6/15 16:30
15/6/15 16:30
16/6/15 17:00
17/6/15 16:40
18/6/15 12:45
19/6/15 13:00
20/6/15 13:00
21/6/15 13:30
22/6/15 18:30
23/6/15 13:30
25/6/15 10:30
25/6/15 17:00
26/6/15 12:00
27/6/15 15:30
28/6/15 12:00
Filter 1
Filter 2
Filter 3
95%ile Compliance

# Phase 2: THM Evaluation

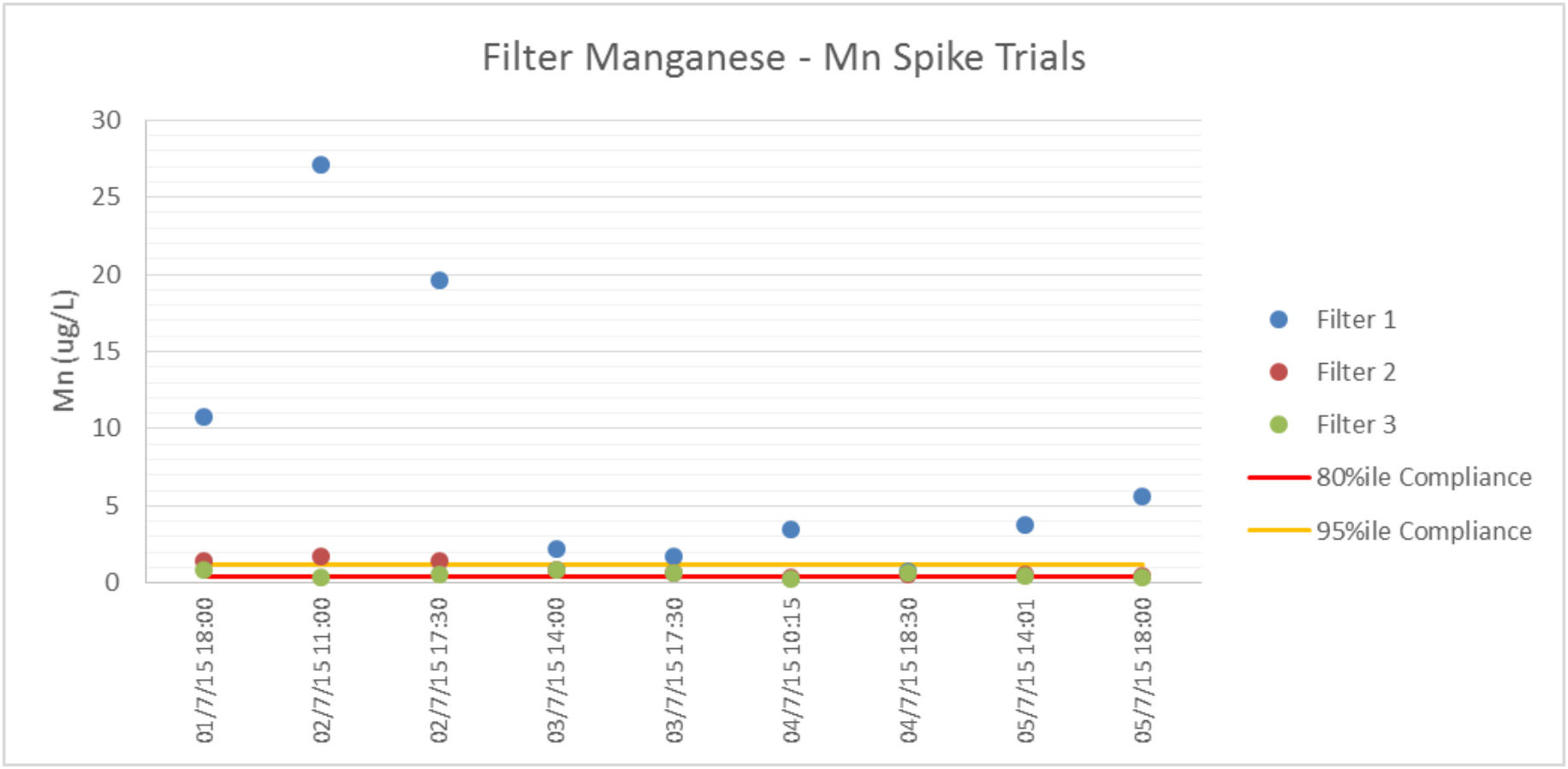


# Backwash Results



# Manganese – Spike Trials

- Average raw water Mn is 236 ug/L



# Phase 2 Pilot Testing Conclusions

- Manganese Spike
  - Treatment train handled a raw water manganese spike of 236 ug/L and delivered filtered water quality that met treatment goals
- Filter Performance – Filter 2 and Filter 3 achieved acceptable performance during sustained operation
  - Manganese and iron goals were achieved
  - Aluminum goals were erratic, which was mainly due to searching for optimal coagulation.
- TOC Removal
  - Clarified TOC goals were not achieved on the pilot plant due to lack of optimal coagulation and physical performance of pilot scale clarifier
  - It is still anticipated that optimal settling can be achieved on full-scale clarifier
  - Filtered water TOC goals were achieved once coagulation was optimized
- THM Formation
  - 2 and 5 day simulated distribution samples show THM formation of 40 to 50 ug/L

# Thank You