Case Study: Critical Milestones in Permitting, Construction, and Commissioning of the Stafford County Lake Mooney Water Treatment Facility

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Overview

• Historical perspective
• Infrastructure overview
• Reservoir Permitting
• Challenges
• Pretreatment optimization
• Membrane filtration system
  – Functional testing
  – Performance testing
  – Facility start-up and commissioning
Historical Perspective

• Why the need for a new Reservoir & Greenfield Water Treatment Plant?
  – Growth in Stafford County
  – Planning for the future!
    • Water supply needs/demands → increasing
    • Drinking water regulations
  – Existing Able Lake Plant old and at the end of its useful life

Infrastructure Overview

• Components
  – River pump station
  – Dam and reservoir
  – Raw water pump station
  – Water treatment facility
  – Water Mains to connect to the Distribution System
    • 24 – inch main (low service)
    • 30 – inch main (high service – future)
Reservoir Permitting
(Federal/State)

- Dam, Intake PS & Withdrawal Permits
  - Project Approval by BOS – 1992
    - Location Studies
    - Operational Studies (demand, volume, type)
    - Financial Studies
  - Joint Permit Application – 1997
    - Ever-changing Policy (USACOE, VaDEQ)
    - Withdrawal Calculations (Based on need, other withdrawals)
    - Mitigation Requirements
    - Flow-by Requirements/Reporting
  - Joint Permit Approval - 2003, 2004
    - Mitigation Implementation
    - Monitoring
    - Mitigation Construction vs. In lieu Fee

Reservoir Permitting
(Local)

- Dam/Reservoir
  - Zoning Requirements (County Department)
    - Board of Zoning Appeals
      - FEMA CLOMR
    - Board/Council Approval
  - State Highway/Transportation Approval (local office)
    - State Route Abandonment
  - State Health Department (local office)
    - Source Water Assessment
      - Verify Quality (drainage basin)
      - Verify Quality (source water – Rappahannock)
    - Special Conditions
      - Exposure to pcb’s, other pollutants (rare but potential)
Complex Construction Coordination

- Permits
- Land Acquisition
- Construction
  - Dam
    - Foundation Preparation 1
    - Foundation Preparation 2
    - Embankment Structure
  - River Intake Pump Station
    - River Intake Structure
    - 3 Phase Power
    - Electro/Mechanical
  - Ancillary Projects
    - Public Access
  - Reservoir Clearing
    - Seasonal Timing
  - Water Treatment Facility
    - Occupancy, Fire (chemicals)
  - Environmental Mitigation
    - Prior to Construction/Measured Progress
  - Distribution Pipelines (multiple pressure zones)
    - Flushing/Source Water (greenfield)
  - Operational Permits (Dam, WTP, Distribution)
    - State Dam Regulatory
    - State Health Dept. (plant, distribution)

Large Scale Overview

- Rappahannock River
- Plant Pump Station & Intake
- Dam & Reservoir
- Water Treatment Facility
WATER TREATMENT FACILITY

Treatment Facility Site Aerial

Pretreatment Building
- Flash Mixers
- Super Pulsators
- Wet wells & MF feed pumps

Membrane Filtration
- Strainers
- Membrane Racks
- RF Pumps

Chemical Systems & Solids Handling
Raw Water Quality Challenges

- New Water Source = no water quality design parameters
- Abel Lake was used as a baseline
- Actual Raw Water Quality
  - Most parameters consistent with baseline
  - Dissolved manganese concentrations (>1.5 mg/L)
  - Dissolved iron concentrations (>1.0 mg/L)
- Issue
  - Possible long-term fouling membrane
- Key
  - Need optimized feed water quality parameters to the membrane system

General Schedule of Testing

<table>
<thead>
<tr>
<th>Pretreatment Optimization</th>
<th>Clarifiers Performance test</th>
<th>Functional Testing of Membrane System</th>
<th>Performance Test of Membrane System</th>
<th>Complete Plant Testing</th>
</tr>
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<tbody>
<tr>
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Weeks

1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18  19  20
Pretreatment Optimization

• 2 Phased Approach
  – Phase 1 - Optimization of chemical feed systems
    • Adjusted KMnO₄ and NaOH
    • Soluble iron easily oxidized and removed
    • Improved manganese removal but not consistent results
  – Phase 2 - Raw Water Source Options
    • Continuous filling of the 5.5 billion gallon reservoir
    • 4 gates on the intake structure
    • Reservoir water Level
      – High enough to pull from upper gate
      – Dissolved manganese (>0.40 mg/L)
      – Dissolved iron lower
      – Overall better water quality

Pretreatment General Process Flow Diagram

1. Addition of Ferric Sulfate (coagulant)
2. Low alkalinity water – drives pH down to enhance TOC removal
1. Increase pH to improve reaction kinetics
2. Addition of KMnO₄ – Oxidation of soluble Fe and Mn
Manganese Concentrations

<table>
<thead>
<tr>
<th>Date</th>
<th>Total Manganese</th>
<th>Dissolved Manganese</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-Aug-14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Sep-14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-Sep-14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15-Sep-14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22-Sep-14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-Sep-14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Oct-14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-Oct-14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-Oct-14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Oct-14</td>
<td></td>
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</tr>
</tbody>
</table>

Upflow Clarifier Optimized

- Clarifier performance test results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Goal</th>
<th>Actual Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Eff. Turbidity (NTU)</td>
<td>&lt; 3.0</td>
<td>0.29</td>
</tr>
<tr>
<td>Maximum Turbidity (NTU)</td>
<td>&lt; 10.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Eff. Total Manganese Conc. (mg/L)</td>
<td>&lt;0.05</td>
<td>0.04</td>
</tr>
<tr>
<td>Eff. Total Iron Conc. (mg/L)</td>
<td>n/a</td>
<td>0.07</td>
</tr>
<tr>
<td>Total Organic Carbon (% removal)</td>
<td>n/a</td>
<td>49.5</td>
</tr>
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</table>
Membrane Filtration Process Equipment Overview

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Pumps</td>
<td>4 – horizontal split case</td>
</tr>
<tr>
<td>Strainers</td>
<td>3 – 10 micron</td>
</tr>
<tr>
<td>Membrane module type</td>
<td>UNA-620A</td>
</tr>
<tr>
<td>Rack configuration</td>
<td>5 racks, 94 modules per rack</td>
</tr>
<tr>
<td></td>
<td>(Future - 138 total modules)</td>
</tr>
<tr>
<td>Outside area</td>
<td>538 sq. ft.</td>
</tr>
<tr>
<td>Method of filtration</td>
<td>Dead end</td>
</tr>
<tr>
<td>Pore size</td>
<td>0.1 micron</td>
</tr>
<tr>
<td>Flow direction</td>
<td>Outside-in</td>
</tr>
<tr>
<td>Membrane material</td>
<td>PVDF</td>
</tr>
<tr>
<td>CIP</td>
<td>2 bulk tanks and neutralization tank</td>
</tr>
</tbody>
</table>
Membrane Functional Test

• Purpose
  – Demonstration of key systems functions & features

• Duration ~ 13 weeks

• Dry Test
  – PI&D walk through
  – Verification of process equipment
    • Pumps, compressors, CIP system, etc..
  – PLC/HMI Network functionality with Plant SCADA
    – I/O Checks
    – Alarm testing

Membrane Functional Test

• Wet Testing
  – Flush system completely using “dummy” modules
    • Process Water (Super Pulsator Settled Water)
    • Thoroughly flushes headers and piping
  – Installation of UNA Series Modules
    • Removal of “dummy” modules
    • Flush Modules (5 rack volumes)
      – Removes calcium chloride solution
    • Pressure test modules
Module Installation

RPR WTF 9/9/14 - First Delivery Pall Module Membranes. Day 1 Install.

Fully Functional System

MEMBRANE FEED PUMPS

MEMBRANE RACKS
Membrane Performance Test

• Purpose
  – Validate membrane system meets design criteria (recovery, flux rate, MIT system, etc.)

• Duration
  – 2 weeks of continuous operation
  – 1 baseline rack @ design flux, 4 racks @ low flow
  – If system fails – contractor may need to start over

Membrane Performance Test

• Written Protocol (Key Elements)
  – Test duration (In this case 2 weeks)
  – Develop a summary of design criteria for membrane system
  – Membrane feed water quality requirements
  – Data collection (Who is doing it?)
  – Water quality testing (what, who and when)
  – Roles and responsibilities

• Endorsement by key stake holders
  – Owner, Engineer, VDH, CG, and MF Mfg.
Membrane Performance Criteria

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design Goal</th>
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</thead>
<tbody>
<tr>
<td>System production capacity (mgd)</td>
<td>7.66</td>
</tr>
<tr>
<td>Recovery (%)</td>
<td>96</td>
</tr>
<tr>
<td>Maximum TMP (psi)</td>
<td>40</td>
</tr>
<tr>
<td>Instantaneous and average flux rate (GFD)</td>
<td>45</td>
</tr>
<tr>
<td>Membrane Filtered Water Turbidity</td>
<td></td>
</tr>
<tr>
<td>95% of time (NTU)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Maximum (NTU)</td>
<td>0.10</td>
</tr>
<tr>
<td>CIP/EFM cleaning intervals (days)</td>
<td>&gt;30 / &gt; 3</td>
</tr>
</tbody>
</table>

Performance Test Results

• Testing October 3\textsuperscript{rd} through October 9\textsuperscript{th}
• Power outage
  – Plant was down 24 hours
  – Allowed test to resume
• Performance flux was 45 GFD @ 4.4 C
• Recovery – consistently > 96.0%
• Max TMP was 14 psi
• Combined turbidity was < 0.05 NTU
• Integrity test = 0.13 psi/min (LRV > 5.0)
**Process Performance Data**

- **Clean In Place (CIP)**
- **EFM Marker**
- **Integrity Tests (IT’s)**
- **Clariified Turbidity (NTU)**
- **Ave. TMP (< 14.0 psi)**
- **Filtrate Turbidity (NTU)**
- **System off Line**

**Design Recovery** 96.0%

**Net Filtrate Production** 1.92 mgd
Conclusions

• Plan for unpredictable raw water in a new source application
• Pretreatment optimization is critical
• Membrane system met performance requirements (flux, recovery, TMP, etc..)
• Performance test data and optimization is a valuable tool for operations staff
• Plant is now supplying water to Stafford County Customers