Water Storage Tanks in Newfoundland and Labrador: Blessing or Curse?

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Overview of Presentation

- Characteristics of Tanks in NL
- Tank Design and Components
- Tank Condition and Economic Considerations
- Operation of Tanks
- Tanks and Water Quality
- How to Correct Tank Issues?
Typical Water System with a Tank

- Tank is there to provide fire flow, pressure or emergency storage
- Network feeds water to town and water storage tank at same time
- Pump on distribution system

Source Supply
Pump house/chlorination bldg
First customer
Storage Reservoir
Types of Tanks in NL

- Elevated
- Standpipe
- Reservoir
- In Ground
Tank Characteristics in NL

- 123 water storage tanks in province
- 48% are standpipe tanks
- Tanks are fairly evenly distributed across regions:
  - Most in Eastern
  - Fewest in Labrador
- 80% of tanks are on systems with a surface water source
Tank Characteristics in NL

- Tank capacity ranges from 10-20,000 m³
- Most tanks in NL around 325 m³
- Even distribution of:
  - Concrete tanks
  - Welded steel tanks
  - Bolted steel tanks
- 42% of tanks located at beginning of system, 45% in the middle
Design of Tanks

- Design of storage tanks changed over years
  - Since 2000 more glass-lined steel-bolted tanks
- Type of tank must suit design need
- Tank design must meet:
  - Guidelines for the Design, Construction and Operation of Water and Sewerage Systems
  - AWWA Standards
- Operation of tank not necessarily looked at in the design
Daily Water Demand

- Demand peaks in morning and evening
- Tank used to store water to meet these peak demands
- Tank fills when demand drops
Components of Storage

- 25% of maximum day demand
- Established by Insurance Advisory Organisation
- 25% of Operational and Fire Storage
Fire Storage

- Based on building type and density

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Flow Rate (gpm)</th>
<th>Duration (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low Density Residential (0-2 DU/acre)</td>
<td>1,000</td>
<td>2</td>
</tr>
<tr>
<td>Low Density Residential (2-4.5 DU/acre)</td>
<td>1,250</td>
<td>2</td>
</tr>
<tr>
<td>Medium Density Residential (4.5-15 DU/acre)</td>
<td>2,000</td>
<td>2</td>
</tr>
<tr>
<td>High Density Residential (15-30 DU/acre)</td>
<td>3,500</td>
<td>3</td>
</tr>
<tr>
<td>Commercial</td>
<td>3,000</td>
<td>3</td>
</tr>
<tr>
<td>Industrial</td>
<td>4,000</td>
<td>4</td>
</tr>
</tbody>
</table>
Tank Components

Access Hatch

Roof Vents

Overflow

Ladders & Safety Rails

Security Fencing & Locks
Inlet and Outlet Configuration Considerations

- Common or separate inlet/outlet
- Inlet and outlet location
- Vertical and horizontal separation of inlet/outlet
- Orientation of the inlet
- Inlet and outlet diameter
Water Level Controls

- Used to regulate water level so tank doesn’t overflow or drain completely
- Integrated with pumping system—tell pump when to cut in and off
- Common types:
  - Float operated
  - Altitude valves
  - Hydrostatic types
  - Ultrasonic types
Condition of Tanks in NL

- Approximately 25% of tanks in province installed since 2000
## Capital Cost of Tanks

<table>
<thead>
<tr>
<th>Town</th>
<th>Year</th>
<th>Capacity (m³)</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBS</td>
<td>2003</td>
<td>2 x 2835</td>
<td>1,698,898</td>
</tr>
<tr>
<td>Paradise</td>
<td>2003</td>
<td>8000</td>
<td>1,925,923</td>
</tr>
<tr>
<td>St. John’s</td>
<td>2000</td>
<td>16,000</td>
<td>1,239,045</td>
</tr>
<tr>
<td>Rigolet</td>
<td>2009</td>
<td>1220</td>
<td>1,200,000</td>
</tr>
<tr>
<td>Wabana</td>
<td>2009</td>
<td>1134</td>
<td>745,800</td>
</tr>
<tr>
<td>Reidville</td>
<td>2002</td>
<td>345</td>
<td>580,513</td>
</tr>
<tr>
<td>Winterland</td>
<td>2000</td>
<td>286</td>
<td>274,275</td>
</tr>
</tbody>
</table>
Condition of Tanks in NL

- Tanks should have a useful life of 25-100 years depending on the tank material
Tank Inspections

- Routine inspection- daily or weekly
- Periodic inspection- quarterly or annual
- Comprehensive inspection- every 3 to 5 years

- Sanitary conditions
  - Inspect openings that can allow fauna (birds, squirrels, insects, etc.) into the tank– roof openings, access hatches, low spots on roof plates, vents, overflows

- Structural conditions
  - Inspect anchor bolts, foundations and grouting, wind rods, metal loss in steel plates, roof trusses

- Safety conditions
  - Inspect ladders (inside and outside), fall prevention devices, handrails, access hatches

- Coatings conditions
  - Evaluate general condition, approximated percentage and type of failure, thickness, adhesion, extent of pitting damage, heavy metal presence, bubbling, alligatoring, ice scraping

- Security conditions
  - Inspect fences, locks, barricades, lighting, ladder guards, alarm systems, water monitors (residual chlorine analyzer), control systems
## Cost of Tank Maintenance and Repair

<table>
<thead>
<tr>
<th>Town</th>
<th>Cost ($)</th>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>St. Bernard-Jacques Fontaine</td>
<td>18,630</td>
<td>2000</td>
<td>Tank cleaning and painting</td>
</tr>
<tr>
<td>New-Wes-Valley</td>
<td>67,160</td>
<td>1999</td>
<td>Reservoir painting</td>
</tr>
<tr>
<td>Lumsden</td>
<td>57,132</td>
<td>2000</td>
<td>Reservoir painting</td>
</tr>
<tr>
<td>Burin</td>
<td>111,145</td>
<td>2007</td>
<td>Exterior painting</td>
</tr>
<tr>
<td>Rose Blanche</td>
<td>393,300</td>
<td>2009</td>
<td>Tank reconstruction</td>
</tr>
<tr>
<td>Wabush</td>
<td>167,900</td>
<td>2004</td>
<td>Tank painting and cleaning</td>
</tr>
<tr>
<td>Whitbourne</td>
<td>268,187</td>
<td>2010</td>
<td>Tank repainting</td>
</tr>
</tbody>
</table>
Tank Operation

- Tank is a like a black box on the distribution system
- How is tank actually operating?
- Need to consider:
  - Turnover rates in water tanks
  - Tank mixing
  - Maintaining optimal water quality in tanks
  - Tank security and access
Tank Operation

- Operator should have some awareness of:
  - Tank dimensions
  - Tank volume
  - Inlet diameter
  - Flow rate into tank
  - Water level in tank
  - Free chlorine residuals in tank
  - Water temperature in tank
  - Rate of sediment accumulation in tank

- Max and min water levels set for tank
- Residence time of water in tank
- % turnover per day
- Tank filling and emptying time
Tank Volume Breakdown

- Dead volume of air at top of tank (5-30%)
- Inactive volume of tank for fire and emergency storage (0-60%)
- Active volume of tank (15-85%)
- Dead volume of water at bottom of tank below outlet riser (15-40%)
CFD Model- St. Paul’s Tank
St. Paul’s Water Storage Tank:
Dimensions: 12 x 5 m
Inlets: 2
Outlets: 1

- Using EasyCFD modeling software
CDF Model - Tank with Inlet & Outlet on Opposite Sides
Brighton Distribution System Model

- End of System
- Pumphouse
- Reservoir
- Tank
Using EPANET water distribution system model
Younger water also means higher chlorine residuals and lower DBPs
Measuring Water Level in Tanks

- Water level in tanks should be monitored daily
Water Level Monitoring

Normal operation

Leak in distribution system
Water Quality Issues with Tanks

- **Physical issues**
  - Water temperature, turbidity from sediment build-up

- **Microbiological issues**
  - Pathogenic contamination, bio-films

- **Chemical issues**
  - Leaching of chemicals from tank linings or coatings, loss of chlorine residual, DBP growth, precipitates
Water Temperature Stratification

Actual Data from tank showed strong temperature stratification

Inlet

Outlet

Thermocline

120 ft
100 ft
80 ft
60 ft
40 ft
20 ft
Ice Formation in Tank
Sediment Build up in Tanks

- A tank should be drained and cleaned every 3-5 years depending on the rate of sediment deposition in the tank.
Biofilm on Tank Wall
Contamination of Tanks
How Tanks Affect Free Chlorine in Distribution Systems in NL

Mean Free Chlorine on Chlorinating Surface Water Systems

<table>
<thead>
<tr>
<th>Chlorine (mg/L)</th>
<th>Tank</th>
<th>No Tank</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>

Mean Free Chlorine on Surface Water Systems with Tanks

<table>
<thead>
<tr>
<th>Chlorine (mg/L)</th>
<th>Beginning</th>
<th>Middle</th>
<th>End</th>
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<tbody>
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</table>

Tank Location

Water Resources Management Division
Department of Environment & Conservation
How Tanks Affect DPBs in Distribution Systems in NL

Mean THMs and HAAs on Chlorinating Surface Water Systems

Mean THMs and HAAs on Surface Water Systems with Tanks
# Issues With Tanks in NL

<table>
<thead>
<tr>
<th>Town</th>
<th>Issue</th>
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<tbody>
<tr>
<td>Bird Cove</td>
<td>Town put on BWA due to loss of free chlorine and long residence time in tank</td>
</tr>
<tr>
<td>Lawn</td>
<td>Water level controls malfunctioning</td>
</tr>
<tr>
<td>Cook’s Harbour</td>
<td>Ice formed in tank caused walls to collapse</td>
</tr>
<tr>
<td>Glenwood</td>
<td>Trouble maintaining chlorine residuals</td>
</tr>
<tr>
<td>Lourdes</td>
<td>Tank at end of system, have to super-chlorinate, high DBPs</td>
</tr>
<tr>
<td>Port Blandford</td>
<td>Wide variation in free chlorine in system, DBPs, BWAs</td>
</tr>
<tr>
<td>Port aux Choix</td>
<td>Tank in very poor condition</td>
</tr>
<tr>
<td>Ramea</td>
<td>Leaks in tank</td>
</tr>
<tr>
<td>Reidville</td>
<td>Tank taken off-line due to concerns maintaining free chlorine, DBPs</td>
</tr>
<tr>
<td>St. Alban’s</td>
<td>Leaks on system, hard to keep tank filled</td>
</tr>
<tr>
<td>St. Paul’s</td>
<td>Large volume of tank inactive, DBPs</td>
</tr>
</tbody>
</table>
Corrective Measure - Using Models in Design of Tanks

- **Water Distribution System Models**
  - All elements of the water distribution system are modeled
  - Outputs include hydraulic and water quality behavior
  - Used to evaluate tank performance and operation with respect to the rest of the distribution network

- **Computational Fluid Dynamics Models**
  - Only the tank is modeled
  - Outputs include behavior of fluid in the tank
  - Used to evaluate tank mixing
Corrective Measure - Promoting Mixing in Tanks

- Passive mixing:
  - Baffles, walls, obstructions
  - Inlet/outlet methods
    - Reducing diameter of inlet
    - Duckbill valve
    - Separating
  - Force turnover of water in tank

- Active mixing:
  - Adjusting pump operation
  - Install paddle or impellor device
  - Tank aeration or re-circulation
Tank 1 (PAX mixer)

Evenly mixed/homogeneous water all the way up to top of tank (PAX Mixer)

Tank 2 (no mixer)

Pocket of warm water at tank bottom (no mixer)
Corrective Measure - Regulatory Control of Design & Operation of Tanks

- Consideration of water quality in tank design
- Performance specifications for tanks
  - Inlet location relative to tank geometry
  - Inlet momentum
  - Volume turnover
  - Fill time
  - Residence time
- Operator education and training on tank inspection and maintenance of altitude valves
- Promotion of Retention Time Management (RTM):
  - Optimize tank location and type
  - Optimize pump schedule
  - Reduce storage capacity
- Tank maintenance requirements are stipulated in Permits to Operate for water distribution systems
- Monitoring of tank operation:
  - Water level
  - Chlorine residual
  - Water temperature
Blessing or Curse

- Equalize supply and demand of water
- To supply water during emergencies such as fire flow, power outages, and loss of pumping capacity
- To minimize pressure variation during periods of high consumption
- To reduce pump size and energy costs
- To increase pressure in the distribution system
- Surge protection
- Blending of water sources
- Providing contact time for disinfectants to inactivate pathogens
- To provide water for industrial demands

- Water quality deterioration
- Poor mixing, inadequate water turnover, dead zones
- DBP formation
- Loss of free chlorine residual
- Wide variation in chlorine residuals
- Mismatch between tank size and water demand
- Water stratification and stagnation
- Failure to meet GCDWQ
- Excessive use of disinfection chemicals
- Something other than water gets in tank
Summary

- Water storage tank is the most visible asset in your water distribution system
- Make sure your water storage tank remains an asset and not a liability