Changing Trends in Water Use
Planning & Design of Water & Wastewater Infrastructure
February 27, 2019

CWN Webinars
Connecting water professionals to decision-ready knowledge
Insights for the water sector helping decision-makers move forward

Canadian Water Network frames what is known and unknown in a way that usefully informs the choices being made.

cwn-rce.ca
Canadian Trends in Water Use

From 2011 to 2015

- The number of people served by WTPs increased by 6% ↑
- Potable water volume processed by WTPs decreased by 2% ↓
- Average per capital daily residential water use decreased by 6.5% ↓

(Statistics Canada)
Implications of decreasing water use on planning and design of infrastructure
Webinar Speakers

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Changing water use trends
Outline

1. Background
2. Approach for water planning
3. Approach for wastewater planning
4. Moving forward
Background
Historical water use

Total Water Demand - 1994 to 2018

First ten years

Next fifteen years

Water Efficiency MP
Rain barrel distribution
Outdoor water use bylaw
WET challenge for businesses
Restaurant certification

Toilet replacement program

Outdoor water use bylaw

Restaurant certification
Approach for changing trends

Think differently about future water use

Opportunity to focus on optimization

Master planning provides opportunity to account for new trends
Approach for water planning
Typical forecast approach

Timing of Strategic Plan Elements
Integrated Urban System

- 3 to 5 MGD Groundwater
- Displacement Pipeline exact size to be determined
- 5 MGD ASR

Recommended strategy with maximum week demand effective water efficiency program & water restrictions

- 150 ML/d (33.7 mgd)
- Demand With Water Efficiency
- Demand Without Water Efficiency

Region of Waterloo Water Services | www.regionofwaterloo.ca/water
Modified forecast approach

2013 Master Plan
Opportunities for optimization

Optimization opportunities arise with the lower demands.

Well optimization  |  Pumping optimization  |  Distribution System optimization
Value of master planning

Doing the right projects at the right times

- Deferring new water supply infrastructure
- Alignment with related Region initiatives: water efficiency, asset management, etc.
- Impact on user rates
Approach for wastewater planning
Typical engineering approach

If we know water use is declining, how will this impact our wastewater treatment plants?

Flow [m$^3$/d]

Year

Plant hydraulic capacity

Trigger for expansion based on plant hydraulic capacity

Wastewater flow projection

Region of Waterloo Water Services | www.regionofwaterloo.ca/water
New approach

Consideration of higher influent loading rates as a result of lower water use
Uncertainty in wastewater flows

Wastewater flow rates are more influenced by weather as a result of extraneous flows, making it harder to forecast declining trends in flows.

Approach for wastewater planning is more conservative for timing of capital projects based on higher degree of uncertainty.

Adjusted flow accounts for seasonal variations caused by rainfall and snow thawing.
Opportunity for optimization

Opportunities for optimization as a result of lower flows:

**Plant re-rating**
Lower projected flows open up opportunities for re-rating plants to accommodate moderate increases rather than large plant expansions in the near future for greater flows.

**Optimizing plant operations**
Deferring projects provides an opportunity to look at how to make the most of existing infrastructure.

**Diversion of flows**
More gradual rates of flow increase provided opportunities to look at diverting flows in the short-term to nearby facilities.
Value of master planning

Doing the right projects at the right times

Accounting for trends in wastewater flows at a master planning level provided opportunities to:

- Defer large capital projects
- Confirm appropriate project triggers to monitor
- Review levels of uncertainty to make informed decisions on acceptable levels of risk
Moving forward
Approach for future planning

1. Be open to change
   Open-minded review of information to make informed decisions on what approach makes sense for planning.

2. Look for new opportunities
   Change often means new opportunities. Take the time to identify what benefits a new trends or approaches may bring your organization.

3. Adapt to new trends
   Continue to use master planning to identify and adapt to new trends
Thank you

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Overview

- Edmonton’s declining water consumption trends
- Operational & maintenance challenges
- Planning & design opportunities
Water Use in Edmonton

Edmonton Water Usage

- Total Per Capita Demand
- Population (000's)
- Edmonton Average Day Demand

Year:
- 1971
- 1975
- 1979
- 1983
- 1987
- 1991
- 1995
- 1999
- 2003
- 2007
- 2011
- 2015

Edmonton Total Per Capita Demand [L/c/d]
- 250
- 350
- 450
- 550
- 650
- 750
- 850
- 950

Edmonton Population (000’s)
- 175
- 200
- 225
- 250
- 275
- 300
- 325

In-City Average Day Demand (ML/d)
Residential Water Usage

40% reduction per account since 1971
Residential Water Usage

2008 Average Monthly Consumption

2016 Average Monthly Consumption
Commercial Water Usage

Commercial Consumption

46% reduction per account since 1991
Declining Demand Effects on an Interconnected Water System

Benefits:
- Reduced, deferred or avoided capital expenditure of water and wastewater infrastructure
- Extension of water supplies and maintain aquatic ecosystems
- Reducing environmental impacts (i.e. GHG emissions)

Risks:
- Water distribution:
  - quality/age issues due to increased detention times
- Wastewater conveyance:
  - increased odour production
  - increased rate of corrosion
  - settling and blockages

Declining Demand Effects on an Interconnected Water System

“An ounce of prevention is worth a pound of cure.”
- Benjamin Franklin

- Mitigation (reactive)
  - Capital projects
  - Operational changes
  - Maintenance

- Prevention (proactive)
  - Planning and design changes
    - Master Plan forecasting
    - Per capita design standard changes
Water Use Assessment

- Water consumption patterns have changed and design standards are outdated
  - Water consumption: 250 l/c/d
  - Wastewater generation: 300 l/c/d

- Conduct a consumption assessment to propose updated water consumption & sewer generation standards
Results: Residential Consumption

Neighbourhood Classifications by Era

Core: Oldest Neighbourhoods
Mature: Prior to 1970
Established: 1970-1990
Developing: 1990+

Average Consumption by Neighbourhood

- Developing
- Established
- Mature Area
- Central Core
## Results: Residential Consumption

<table>
<thead>
<tr>
<th>Neighbourhood Type</th>
<th>Count</th>
<th>Average (lcd)</th>
<th>Percentile (%) at:</th>
<th></th>
<th></th>
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<td></td>
<td></td>
<td></td>
<td>Average</td>
<td>250</td>
<td>235</td>
<td>225</td>
<td>200</td>
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<tr>
<td>Developing</td>
<td>66</td>
<td>178</td>
<td>56</td>
<td>98</td>
<td>97</td>
<td>97</td>
<td>93</td>
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<td>Established</td>
<td>91</td>
<td>200</td>
<td>64</td>
<td>97</td>
<td>93</td>
<td>91</td>
<td>65</td>
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<tr>
<td>Mature Area</td>
<td>97</td>
<td>194</td>
<td>57</td>
<td>98</td>
<td>95</td>
<td>91</td>
<td>69</td>
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<tr>
<td>Mature Area - Central</td>
<td>11</td>
<td>217</td>
<td>53</td>
<td>81</td>
<td>68</td>
<td>62</td>
<td>34</td>
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<tr>
<td>All</td>
<td>265</td>
<td>193</td>
<td>56</td>
<td>96</td>
<td>93</td>
<td>91</td>
<td>72</td>
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</tbody>
</table>

### Distribution of Residential Neighbourhood Consumption

![Distribution Graph](image_url)
### Results: Commercial, Industrial, Institutional (CII) Consumption

Analysis shows that all zonings over-estimate sewer generation
- Commercial is less problematic than industrial

<table>
<thead>
<tr>
<th>Zoning</th>
<th>Count of Parcels</th>
<th>Average Flow Generation Values[^1] (m³/ha/d)</th>
<th>Median</th>
<th>90%ile</th>
<th>95%ile</th>
<th>99%ile</th>
</tr>
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<tbody>
<tr>
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<td>Standard (Table A3)</td>
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<tr>
<td></td>
<td></td>
<td>Calculated Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNC</td>
<td>312</td>
<td>85</td>
<td>20</td>
<td>13</td>
<td>47</td>
<td>68</td>
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<tr>
<td>CHY</td>
<td>72</td>
<td>85</td>
<td>28</td>
<td>22</td>
<td>52</td>
<td>68</td>
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<tr>
<td>CSC</td>
<td>287</td>
<td>80</td>
<td>18</td>
<td>11</td>
<td>37</td>
<td>53</td>
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<tr>
<td>CB-1</td>
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<td>108</td>
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<tr>
<td>CB-2</td>
<td>580</td>
<td>108</td>
<td>31</td>
<td>11</td>
<td>73</td>
<td>118</td>
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<tr>
<td>CO</td>
<td>21</td>
<td>108</td>
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<td>26</td>
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<tr>
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<td>71</td>
<td>7</td>
<td>3</td>
<td>12</td>
<td>25</td>
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<td>IM</td>
<td>1698</td>
<td>60</td>
<td>6</td>
<td>2</td>
<td>8</td>
<td>14</td>
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<tr>
<td>IH</td>
<td>250</td>
<td>54</td>
<td>6</td>
<td>2</td>
<td>9</td>
<td>16</td>
</tr>
</tbody>
</table>

[^1]: All values reported in terms of Net Area.
Distribution of Industrially Zoned Parcels in Table A3
Conclusions & Next Steps

- Declining demand is positive with respect to water management, however operational, maintenance and design considerations can’t be overlooked.
- Residential per capita water consumption & sanitary generation usage metrics are not reflective of current consumption/generation trends.
- Created a working group with Water, Drainage and consulting industry to determine updated per capita metrics.
- A standard review should occur every 5-10 years to keep metrics current for design of water & sewer infrastructure.
Knowledge Building and Adaptive Management Practices for Water Demand Forecasting

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Main Messages

Demand forecasting is highly nuanced

Forecasts will be inaccurate because of myriad uncertainties

Knowledge building and adaptive management processes offer advantages for coping with uncertainty
Approaches to Forecasting Vary Widely

- Planning objectives
- Geographical and sector segmentation
- Modeling methods
- Influential factors considered
- Knowledge, skill, and resources

“Different horses for different courses”

The Facts about Forecasts

• Forecast “numbers” will inherently be inaccurate (except by chance)

• Decisions still have to be made

• Addressing forecast uncertainties helps us define
  • Potential risks
  • Ways and costs to reduce or mitigate them

• “Risk-informed” decisions convey the appetite or tolerance for different risks
Technical methods for addressing forecast uncertainty

Rules of thumb

\[ Q_{\text{Predicted}} \pm z \% \]

Qualitative scenarios

\[ X_{\text{Expected}} \pm z\% \rightarrow Q_{\text{Predicted}} \pm z'\% \]

Statistical scenarios

\[ \left( \hat{Q} - t_{(1-\alpha)/2} \sqrt{s_f^2} \right) \leq Q_{\text{Actual}} \leq \left( \hat{Q} + t_{(1-\alpha)/2} \sqrt{s_f^2} \right) \]

Probabilistic scenarios
Exploit

Known Knowns

Known Unknowns

Unknown Knowns

Unknown Unknowns

Relationships of Uncertainty to Knowledge
Meta-Knowledge

Knowns

Unknowns

Known Knowns

Known Unknowns

Unknown Knowns

Unknown Unknowns

exploit

explore

find

imagine

Relationships of Uncertainty to Knowledge

Hazen
Case Example – Tampa Bay Water

Regional water supply authority

2.4 million customers

6 member governments, across three counties
Foundation of Demand Analysis: Unique water using locations

Geographic attributes linked to each location

- Unique Locations
- Blocks
- Block Groups
- Traffic Analysis Zones
- Tracts
- Water Demand Planning Areas
- Water
- Tampa Bay

Drill Down
Aggregate Up
Collaborative Database Design and Development

Collaborative Exploratory Data Analysis (EDA)
Key Model Features Support Scenarios and Forecast Simulations
Key Model Features Support Scenarios and Forecast Simulations

- Residential users split into single-family and multifamily sectors

<table>
<thead>
<tr>
<th>Multifamily vs Single-family</th>
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</thead>
<tbody>
<tr>
<td>✔ More dense (units per acre)</td>
</tr>
<tr>
<td>✔ Smaller households</td>
</tr>
<tr>
<td>✔ Lower incomes</td>
</tr>
<tr>
<td>✔ Less seasonal use</td>
</tr>
<tr>
<td>✔ More “shared” uses</td>
</tr>
</tbody>
</table>

Key Model Features Support Scenarios and Forecast Simulations

- Residential users split into single-family and multifamily sectors

- Nonresidential model accounts for mix of 10 industry groups

Multifamily vs Single-family
- More dense (units per acre)
- Smaller households
- Lower incomes
- Less seasonal use
- More “shared” uses

Index of Estimated Impact on Total Gallons per 1000 Square Foot
(relative to sample mean of square footage distribution)

<table>
<thead>
<tr>
<th>Industry</th>
<th>Index Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restaurants</td>
<td>6.7</td>
</tr>
<tr>
<td>Hotel</td>
<td>6.1</td>
</tr>
<tr>
<td>Retirement</td>
<td>4.2</td>
</tr>
<tr>
<td>Health Services</td>
<td>3.6</td>
</tr>
<tr>
<td>Other</td>
<td>2.9</td>
</tr>
<tr>
<td>Retail</td>
<td>2.7</td>
</tr>
<tr>
<td>Light MFG</td>
<td>2.2</td>
</tr>
<tr>
<td>Office</td>
<td>1.9</td>
</tr>
<tr>
<td>Heavy MFG</td>
<td>1.6</td>
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<tr>
<td>Education</td>
<td>1.0</td>
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<tr>
<td>Government</td>
<td>0.7</td>
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</table>

Composite model provides forecast simulation options
Key Model Features Support Scenarios and Forecast Simulations

- Water use models parameterized with:
  - ✔️ Climate and weather

<table>
<thead>
<tr>
<th>Summer Season 2090 Hot/Dry Scenario</th>
<th>Δ Mean Temperature</th>
<th>Δ Mean Precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>°F</td>
<td>%</td>
</tr>
<tr>
<td>Colorado Springs Utilities</td>
<td>18</td>
<td>22%</td>
</tr>
<tr>
<td>Durham Region</td>
<td>13</td>
<td>17%</td>
</tr>
<tr>
<td>Massachusetts Water Resources Authority</td>
<td>11</td>
<td>14%</td>
</tr>
<tr>
<td>Southern Nevada Water Authority</td>
<td>12</td>
<td>12%</td>
</tr>
<tr>
<td>San Diego County Water Authority</td>
<td>12</td>
<td>14%</td>
</tr>
<tr>
<td>Tampa Bay Water</td>
<td>10</td>
<td>11%</td>
</tr>
</tbody>
</table>

11% warmer than historical normal with half the rain!

Key Model Features Support Scenarios and Forecast Simulations

- Water use models parameterized with:
  - Climate and weather
  - Socioeconomics
  - Land development density
Key Model Features Support Scenarios and Forecast Simulations

- Water use models parameterized with:
  - Climate and weather
  - Socioeconomics
  - Land development density
  - Price

Water and sewer prices are outpacing the general rate of inflation.
Key Model Features Support Scenarios and Forecast Simulations

- Water use models parameterized with:
  - Climate and weather
  - Socioeconomics
  - Land development density
  - Price
  - Water efficiency indices

![chart showing average residential indoor use per capita](chart.png)

Baseline point forecast – No uncertainty here!
~7% lower point forecast for 2045 under passive efficiency scenario
Regional Water Demand Forecast - Probabilistic Scenario

- Historical
- Median Forecast - Baseline Efficiency
- 5th/95th %ile
- 25th/75th %ile

90% confidence interval representing uncertainty in model inputs
Long-Term Demand Forecasting System (LTDFS) Embodies an Adaptive Management Process

Planning Goals
Support water supply reliability efforts ("just-in-time" supply development)
Inform regional and member-specific demand management efforts

Monitoring
✓ Collection and analysis of water consumption, socioeconomic, and policy conditions (devoted staff resources)
✓ Annual forecast assessments and updates
   • How are models performing?
   • Are we within prediction intervals?
   • Do we need to correct for systematic bias?
   • Are there changes in expectations of growth, development, and other trends?

Refinement
Periodic re-estimation of models with extended data series
New modeling methods and variables
Adaptive Management of Demand Uncertainty

Coping with knowledge uncertainty

- Learning more about past and current water use patterns
- Evaluating why demand varies
- Demand monitoring
- Trends monitoring
- Periodic forecast updates
- “When the facts change, I change my mind.” (John Maynard Keynes via Nate Silver)
Areas of uncertainty and reasonable expectations

Factors to learn about and build into water demand forecasts

- **Technology** will continue to improve water efficiency (-)
- **Prices** will continue to rise (or catch up) (-)
- **Economic cycles** will continue (++)
- **Climate change** will affect seasonal consumption patterns (++)
- **Urban areas** will develop and re-develop to reflect prevailing preferences, tastes, land prices and policies (++)
Planning and Design for Uncertain Wastewater Flows

Wednesday, February 27, 2019
Background on impacts in California

Adapting to Change: Utility Systems and Declining Flows

- 2017 white paper developed by California Urban Water Agencies
- The white paper and policy principles is available for download at the CUWA website (www.cuwa.org).
Lower than expected WWTP influent flow has led to impacts on wastewater treatment processes

Of the impacted wastewater treatment respondents, 68% indicated changes in wastewater influent quality.

*Some items included in other: higher recirculation flows, staffing adjustments, plant upsets.
Lessons Learned #1:
Do not rely on flow to trigger expansion
Flows decreased at many plants

![Graph showing the decrease in summer inflow flow at an example plant compared to rated capacity over time. The graph highlights periods of drought (2007-2009 and 2012-2016) and indicates mandatory water rationing during 2012-2016. The summer inflow is defined as the average of July through September.]
Average Flow is Typically Used to Rate Capacity
What Really Limits Plant Capacity?

- Peak Flow
- Organics Loading and Peak Flow
- Organics Loading

Diagram showing the process of water treatment:
- Primary Clarifiers
- Activated Sludge
- Secondary Clarifiers
- Filtration
- Chlorine Contact
- Discharge
- Advanced Treatment
- Reuse
- Hauling
- Dewatering
- Digestion
- Thickening
Loadings have not decreased

Summer Influent Flow, m³/d

TSS Loading, kg/d

Summer is average of July through September


2007-2009 Drought

2012-2016 Drought
Plants relied on flow to trigger upgrades

Aeration capacity
Secondary clarifier capacity

Digester capacity

Less flow does NOT mean spare capacity
Lessons Learned #2:
Plan for decreasing per capita flows
Be prepared for decreasing flows

- 340 L/capita-d
- 76,000 m3/d
- 250 L/capita-d
- 55,000 m3/d
- 190 L/capita-d
- 42,000 m3/d
Be prepared for decreasing flows

- Reduce per capita flow with time
- Sensitivity analysis
Lessons Learned #3:

As per capita flows decrease, expect increasing concentrations
Increasing Influent Ammonia Concentrations Lead to Operational Adjustments

At the El Estero WWTP in Santa Barbara, increased ammonia reveals alkalinity limitations.
Effluent concentrations may also increase
Planning for increasing concentrations

• Sensitivity analysis in design
• Understand implications for your facility
• Provisions for:
  • Process improvements or expansion
  • Chemical addition
Lessons Learned

Less flow does NOT mean spare capacity, so track loading

Plan for decreasing per capita flows

Expect increasing concentrations
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