RESERVOIR MANAGEMENT USING ADENOSINE TRIPHOSPHATE (ATP)

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Outline

1. Background
2. EPCOR's reservoir history overview
3. A representative reservoir history – referred to as Reservoir E
4. Heterotrophic plate counts versus adenosine triphosphate (ATP)
5. ATP values at different sample locations
6. Using ATP for reservoir management

Water Quality in Reservoirs

US EPA's Finished Water Storage Facilities (2002)

Table 1
Summary of Water Quality Problems Associated with Finished Water Storage Facilities

Chemical Issues	Biological Issues	Physical Issues
Disinfectant Decay	Microbial Regrowth*	Corrosion
Chemical Contaminants*	Nitrification*	Temperature/Stratification
DBP Formation*	Pathogen Contamination*	Sediment*
Taste and Odors	Tastes and Odors	

*Water quality problem with direct potential health impact.

Reservoir Inspection Programs

- Regular monitoring, maintenance & inspection programs ensure reservoir water quality.
- Maintenance and inspection programs are not standardized across the industry.
- An AWWA Research Foundation study (Kirmeyer et al. 1999) concluded:
  - that many storage facilities are not inspected at all.
  - Inspected facilities have typical inspection intervals of 6 to 8 years.
- The US EPA recommends “sanitary surveys” are completed every 3 to 5 years.

EPCOR Reservoir Management Program

- First significant field reservoir; constructed in 1955
- Bulk of field reservoirs built between 1960 and 1985
- Long standing visual inspection program
- Typical 10-year interval on wash-down and inspection
- Formal roof inspections started in 1995 after significant issues identified at Primary Reservoir E
- Photo records starting in 2002
- Formal structural inspection program from 2018 onward

History of “Primary Reservoir E”

- 67ML reservoir
- Constructed in 1979
- Construction:
  - Cast in place slab and walls
  - Pre-cast double tee roof
  - Mud slab topping
  - Bitumous coating
- Long-standing chlorine retention issues
- In the same pressure zone as the water plants

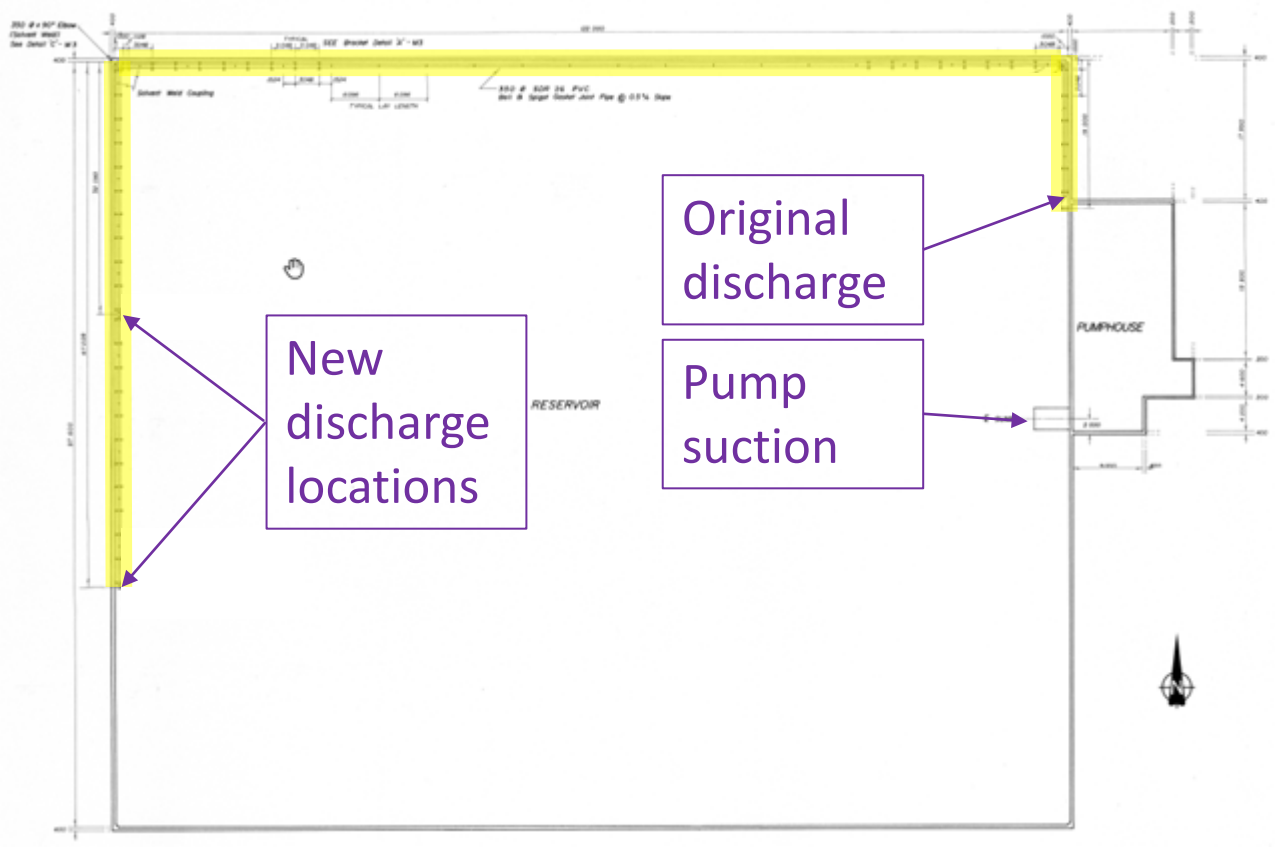
History of “Primary Reservoir E”

The issue of chlorine retention at this reservoir is mentioned in a 1986 article from the Journal of the AWWA:

“Chlorine Dioxide for Taste and Odor Control”

“From 1981 to 1983, reduced water consumption in the northeastern sector of the city slowed turnover in certain storage reservoirs, which in turn led to localized loss of chloramine residual. The target range in Edmonton is 1.5 to 2.0 mg total chloramines/L at the consumer’ s tap. When the residual dropped below 1.0 mg/L in certain areas, the dosage was raised to as high as 2.2 to 2.3 mg/L. Empirical observation of the limited number of complaints of a chlorinous (bleach) taste suggested that total chlorine residuals (chloramines without detectable free Cl) above the critical level of 2.2mg/L elicited complaints. By 1984 appropriate adjustments in system flow patterns had been implemented to prevent having to raise chloramine dosage at the plants.”

History of “Primary Reservoir E”



In 1987, the fill line was extended to the back side of the reservoir.

History of “Primary Reservoir E”

Test #5

Membrane has large holes (up to 8 x 20 mm), 1 mm thickness unbonded. Deck not primed. Very wet under membrane.

On September 12, 1994, I inspected the interior of the reservoir accompanied by William Ngan of Swan Design Ltd. While lighting was very poor, and the inspection very preliminary, we observed at least six actual water leaks. In addition we observed numerous examples of white streaking - generally indicative of long term leakage.

CONCLUSION

1. The roof assembly is not water tight. Leakage is occurring in many areas of the reservoir.

2. The existing roof membrane is not repairable in a manner suitable for long term performance. All of the insulation ballast, soil and sod must be removed simply to inspect the membrane. Membrane upgrade should be undertaken.

3. We are not qualified to judge whether the quantity and quality of water leakage compromises the drinking water.

In September 1994, a roof inspection revealed ingress and that the roof membrane was in poor condition.

History of “Primary Reservoir E”

ARCA
ALBERTA ROOFING CONTRACTORS ASSOCIATION LTD.
CERTIFICATE OF ASSURANCE

WARRANTY AND GUARANTY

Certificate No. 9550349 Date of Issue February 2, 1995

H & D Roofing Ltd.

This Certificate is issued by ... and Alberta Roofing Contractors Association Ltd. and subject to conditions on the reverse hereof, and delivery of the receipt attached hereto to the roofing contractor and Alberta Roofing Contractors Association Ltd. respectively, are giving assurance to you.

1. THAT the roofing system described below has been constructed in accordance with and meets with the requirements of Alberta Roofing Contractors Association Ltd.
2. THAT the workmanship relative to the construction of the roofing system described below meets with the requirements of Alberta Roofing Contractors Association Ltd.
3. THAT the materials relative to the construction of the roofing system described below have been accepted by Alberta Roofing Contractors Association Ltd.
4. THAT the plans, specifications and approved changes for the roofing system have been followed and the materials and workmanship incorporated in the construction of the roofing system have been inspected by an ARCA Accepted Inspector.
5. THAT this roofing contractor and Alberta Roofing Contractors Association Ltd. jointly or severally shall, at no additional expense to the owner:
   (a) Cause the completed roofing system described below to be reinspected on or about the second anniversary date of the effective date of this Certificate and to provide a copy of the reinspection report to the owner, and
   (b) Cause to be repaired any actual leaks in the roofing system described below occurring within five (5) years of the effective date of this Certificate and which have resulted from workmanship relative to the construction of the said roofing system by this contractor.

PROJECT INFORMATION

Name of Building: Reservoir - Reroof
Location: Edmonton, Alberta
Owner: City of Edmonton
Approximate Area: 1285 Squares
Roofing Specification: Soprema Specification #4, Protected Membrane Two Ply
Architect: City of Edmonton
General Contractor: Lorac Construction Ltd.
Contractor Member: H & D Roofing Ltd.
Effective Date: 8-Dec-1994

ALBERTA ROOFING CONTRACTORS ASSOCIATION LTD. (ARCA) Signed

5 YEAR

ROOFING CONTRACTOR Signed

By December of the same year, the city had replaced the roof membrane with an SBS (Polystyrene-Butadiene-Styrene) roof.

Inspection reports during construction noted that the membrane remained un-bonded in many places due to the cold weather during installation.

Lack of edge adhesion was deemed acceptable.

History of “Primary Reservoir E”

Inspection in 2002 - no notes, only photos:

- Typical sludge deposition
- Some movement on fill line noted
- Some debris from fill line in Reservoir

History of “Primary Reservoir E”

In 2007, correlations between reservoir chlorine out readings and a variety of parameters were examined. Increases in turnover rate were the practical outcome.

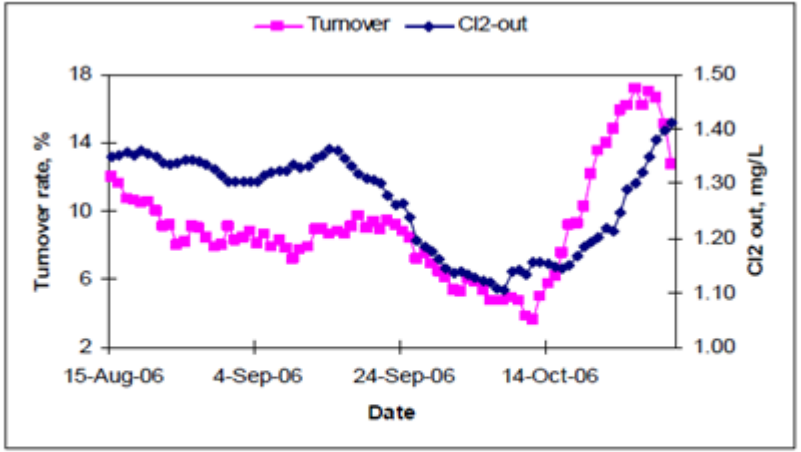
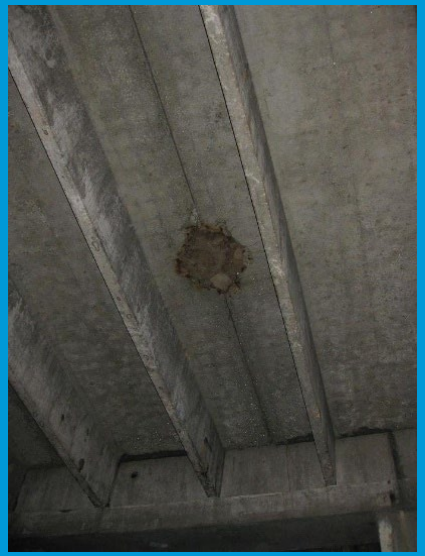


Figure 2 Daily Turn Over Rate and Total Chlorine Residual (out) Variation with Time (14 Days Moving Average)

History of “Primary Reservoir E”

2009 Inspection

- Edge Leakage Noted
- Concerns with construction quality of the precast roof noted

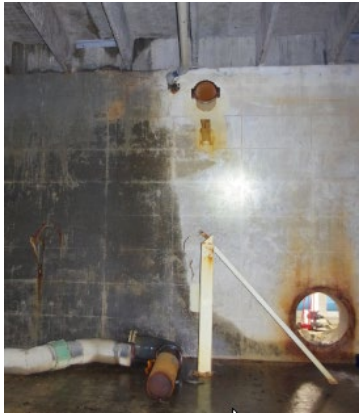


History of “Primary Reservoir E”

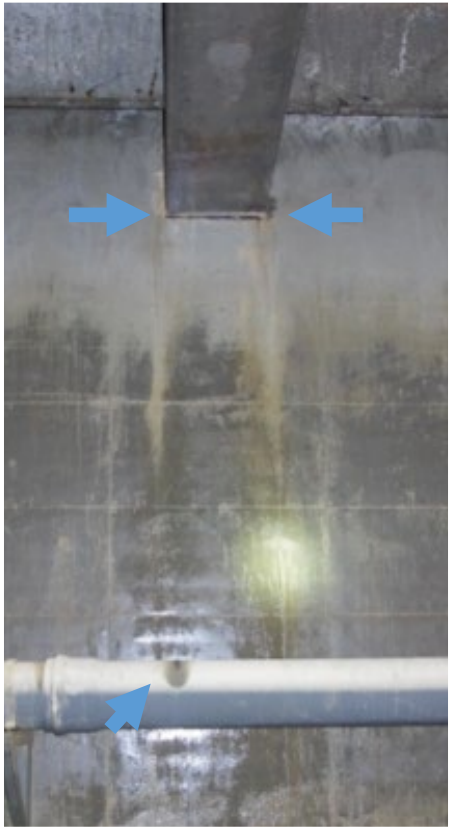
2020 pre-clean inspection

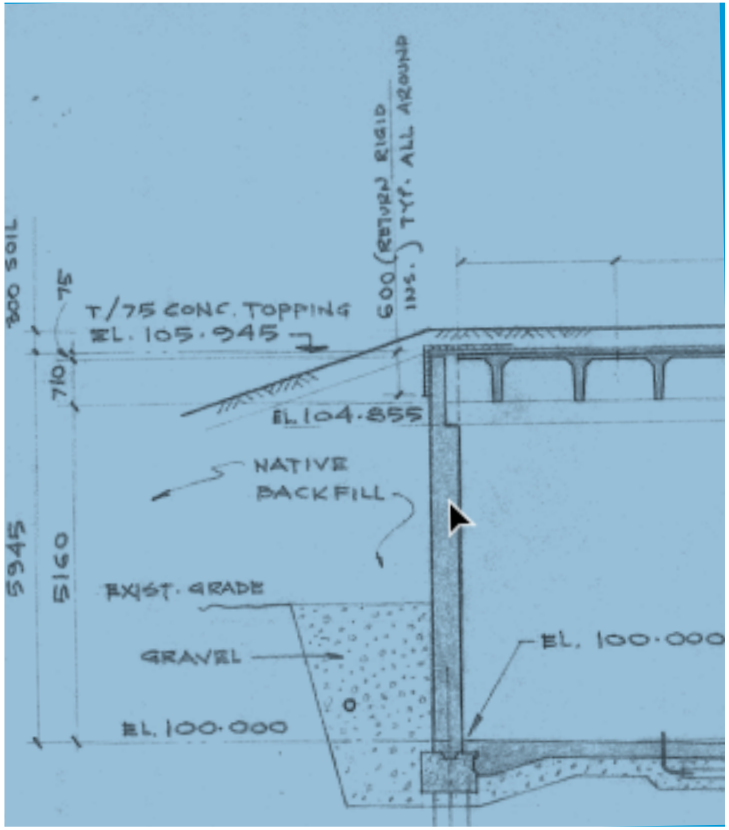
- Active ingress noted
- Water impoundment on top of reservoir noted
- Samples collected of sludge ingress for ATP measurement
- Sediment found at worst ingress point



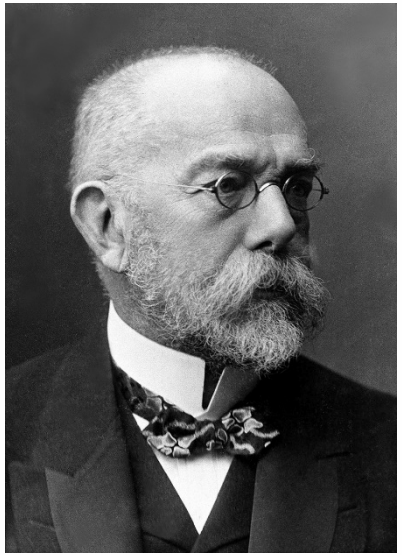



History of “Primary Reservoir E” Reservoir





Heterotrophic Plate Counts (HPCs)



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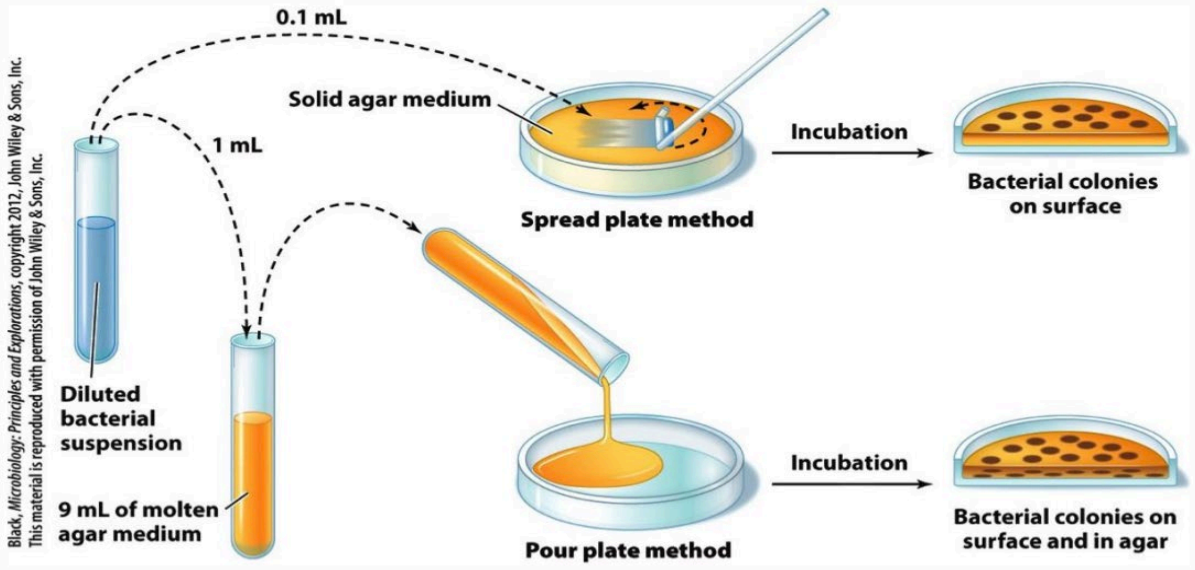
- In 1883, Robert Koch published the article: “About Detection Methods for Microorganisms in Water.”
- The article was about the first application of microbial indicators for surveillance of water hygiene.

HPCs ≠ Pathogens ≠ Public health risk

How to run HPCs?

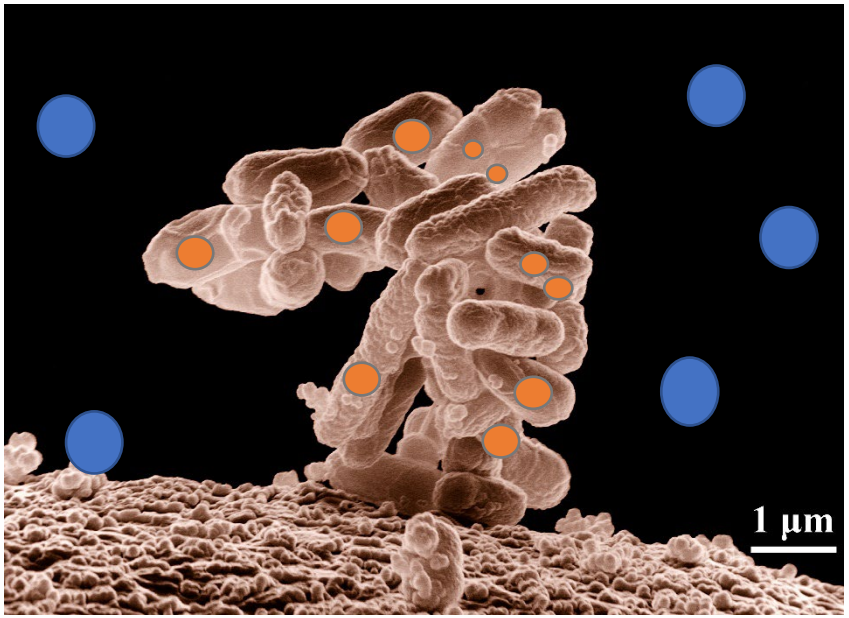


Limitations

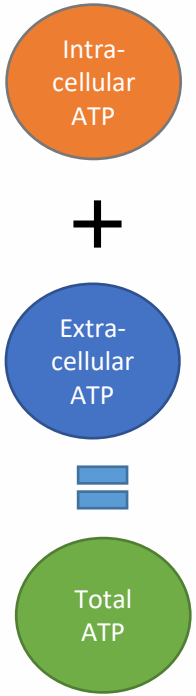
- Incubation time
- Sample volume
- Type of organisms due to growth conditions (medium, oxygen)

Changes in microbial water quality take 2-5 days to detect

What is Adenosine Triphosphate (ATP)?



Public domain - Photo by Eric Erbe, (USDA, ARS, EMU)



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How easy is it to run the ATP test?

50 mL sample filtered → Cell on filter lysed → ATP collected → Enzyme added → Light emission measured

Results in 10 minutes

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History of "Primary Reservoir E"

Summary of ATP results for pre-clean inspection of reservoir:

Date	Sample ID	Sample Type	cATP (pg/mL)	*Pseudomonas*	TC/EC	HPC
06/02/2020	1	Drip-Liquid	7.59	<1	<1	40
	2	Liquid	18.29	<1	<1	310
	3	Solid	0.05	<1	<1	<10
	4	Solid	-	<1	<1	<10
	5	Solid	-	<1	<1	<10
	6	Solid	0.08	<1	<1	<10
	7	Solid	0.13	<1	<1	<10
	8	Solid	0.10	<1	<1	<10
	9	Solid	0.27	<1	<1	<10
	10	Solid	0.84	<1	<1	<10
	11	Solid	-	<1	<1	<10
	12	Solid	-	<1	<1	<10
	13	Solid	0.52	<1	<1	<10

History of “Primary Reservoir E”

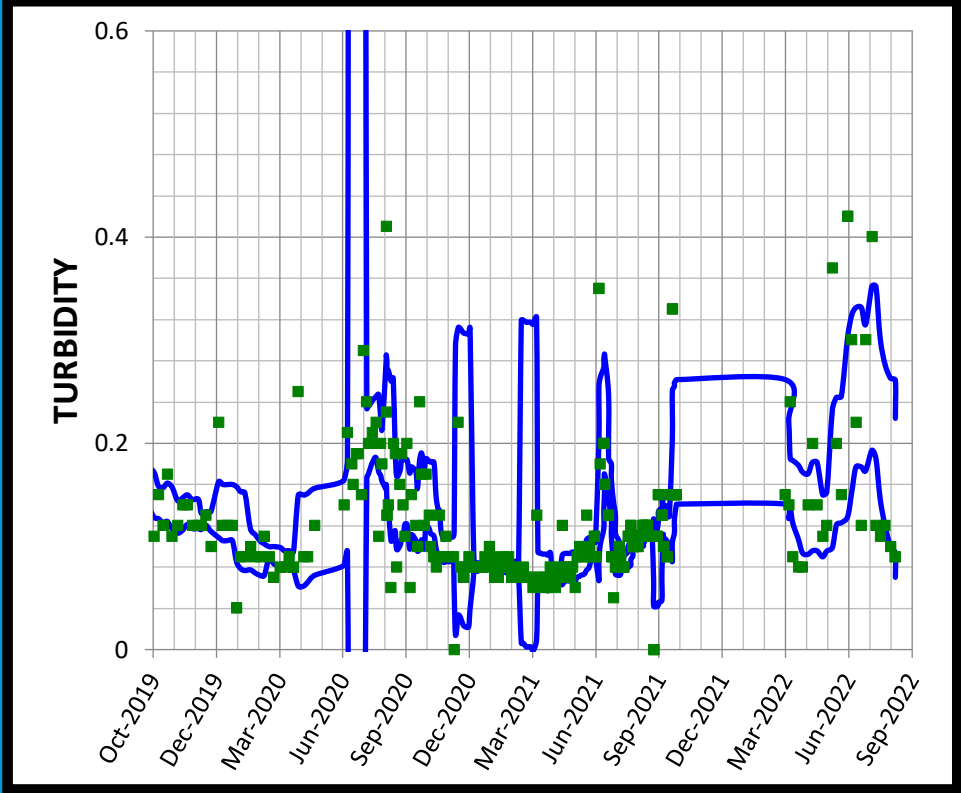
September 2021

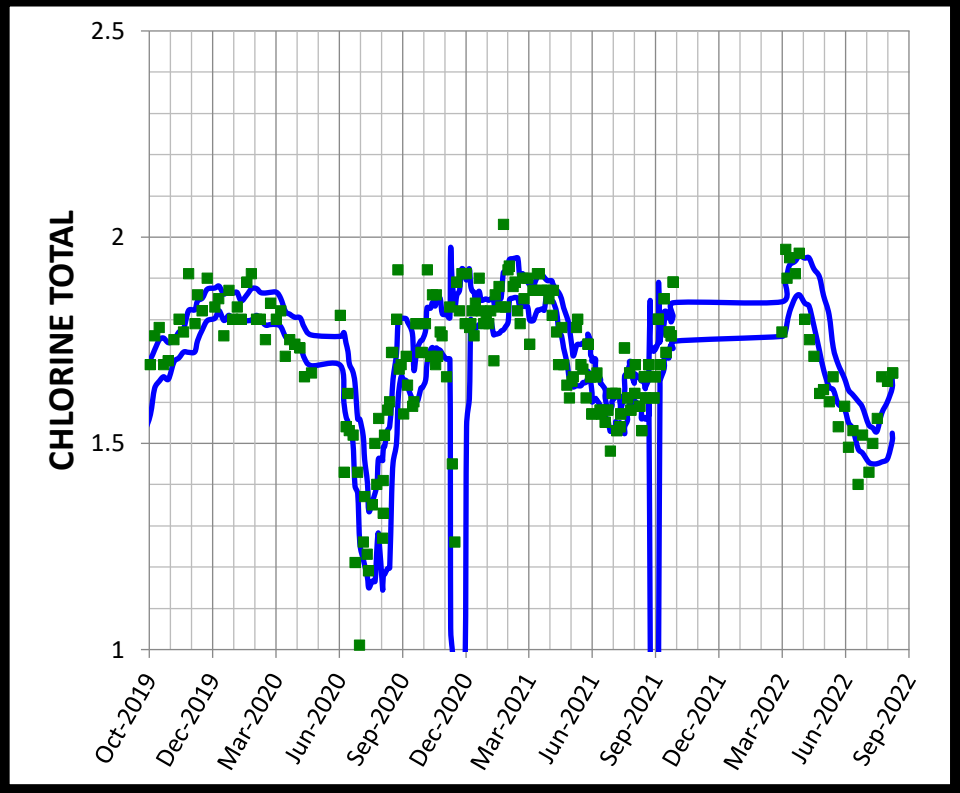
- Edge repair of roof membrane
- Membrane extended beyond beam pockets
- Pull testing of membrane to confirm bond strength

April 2022

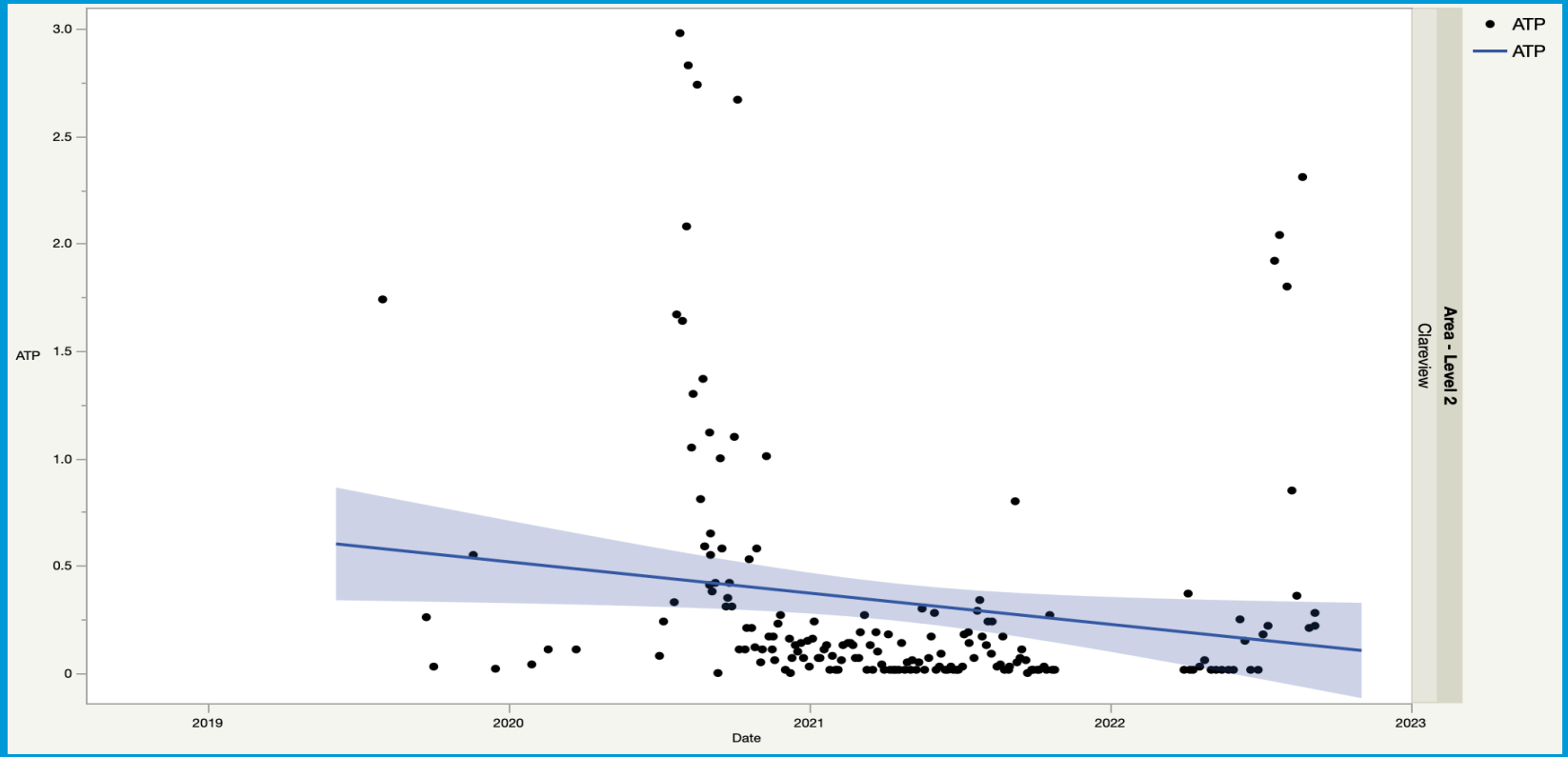
- Reservoir returned to service

“Primary Reservoir E” Long Term Data

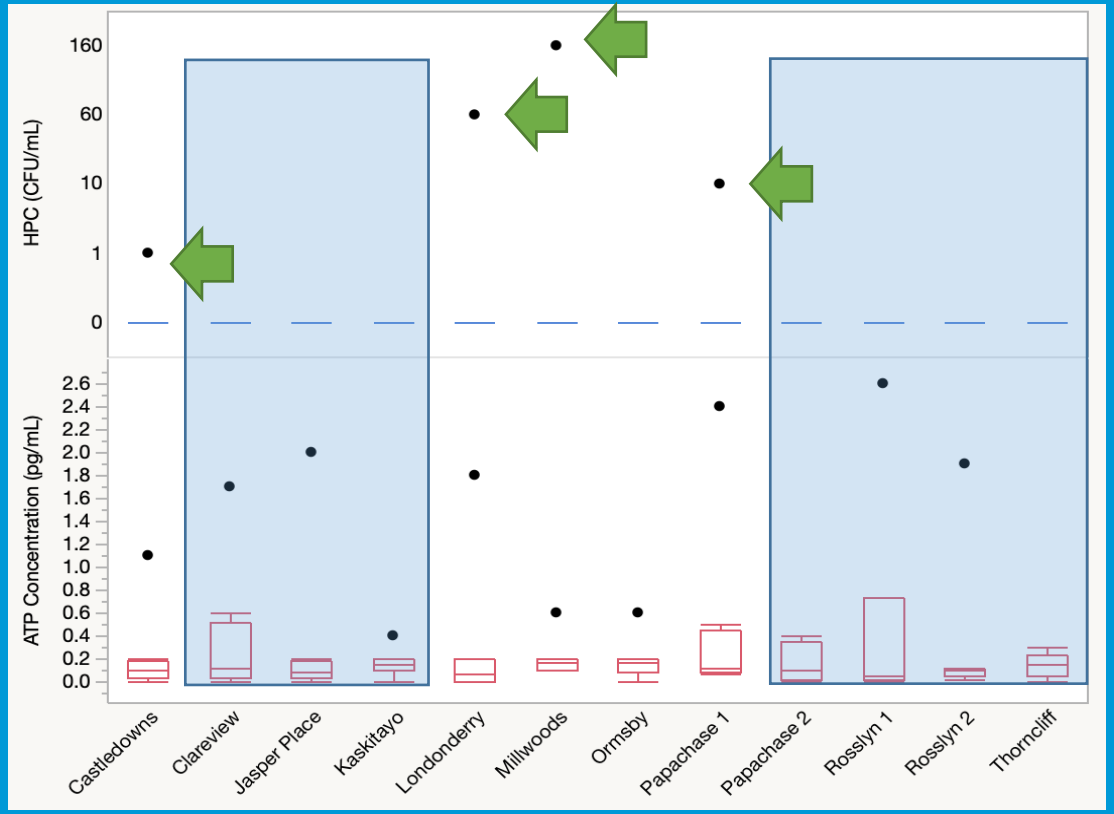




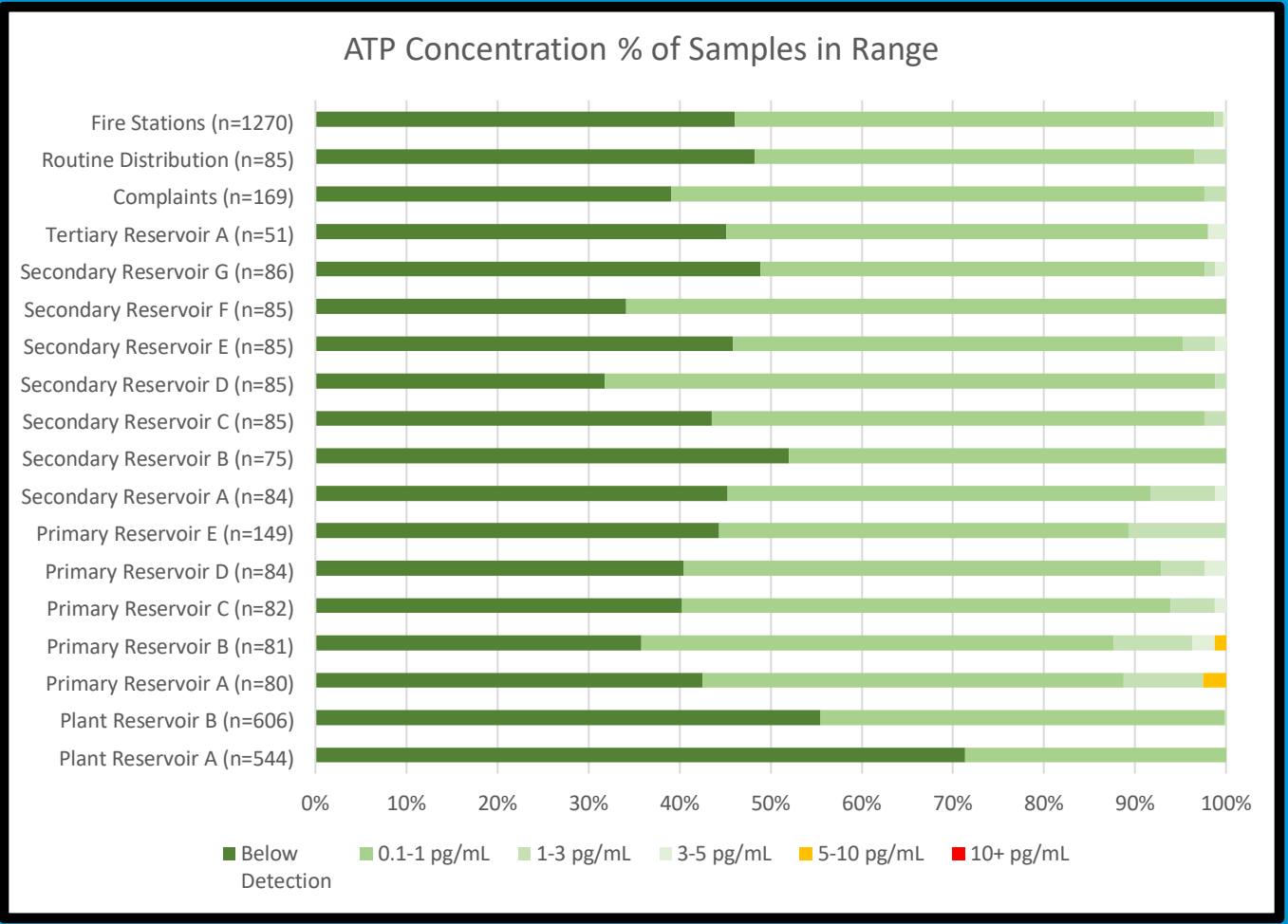
“Primary Reservoir E” ATP Data By Year



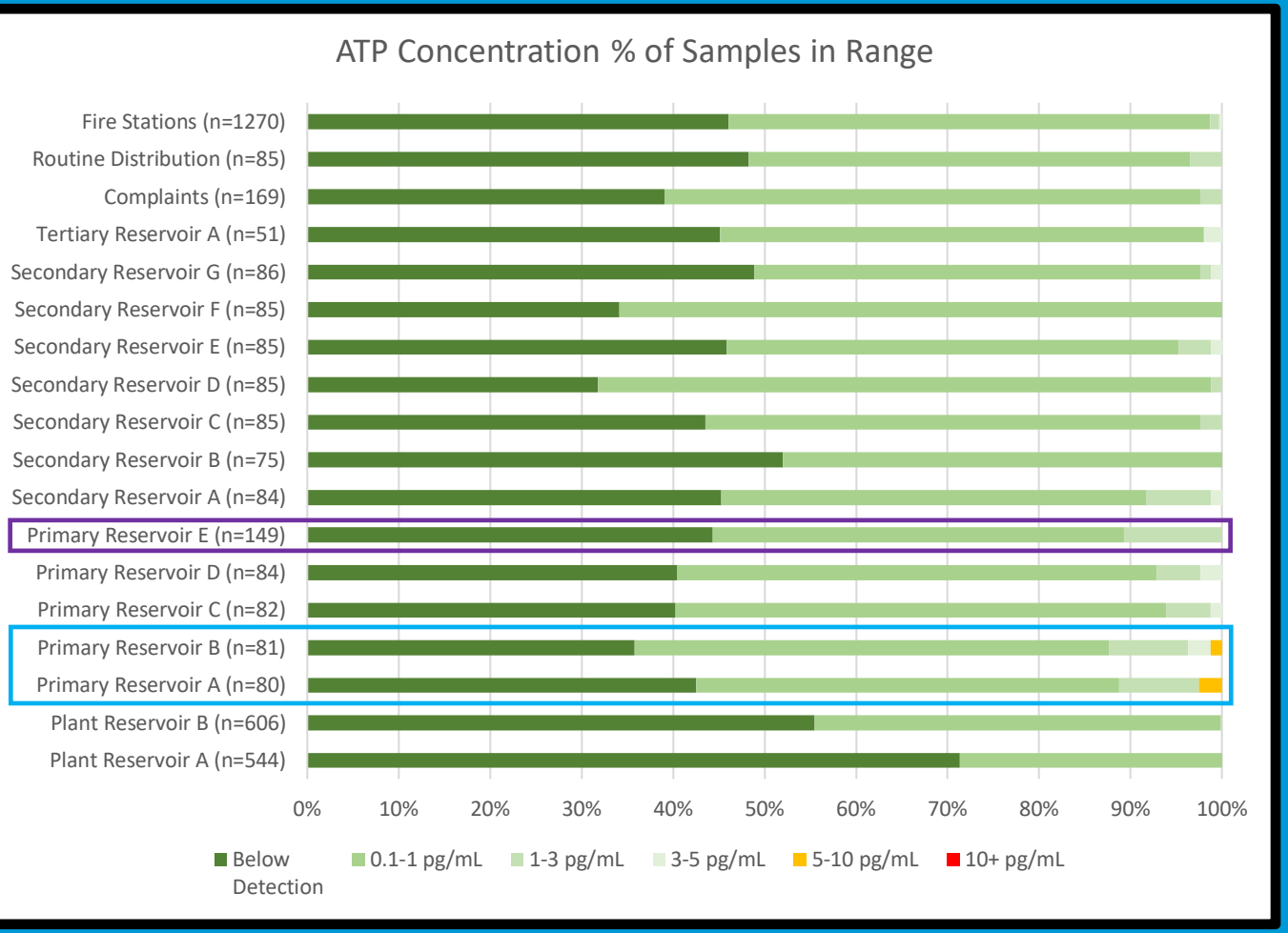
Comparing HPC and ATP in 2019



HPCs did not detect changes in water quality



ATP value range in reservoirs & fire halls 2019-2022



ATP value range in reservoirs & fire halls 2019-2022

What Influences ATP Concentrations?

Reservoir	Predictor	Weight
Plant Reservoir B	pH	40%
	Ambient temperature	24%
	Colour	11%
	Total chlorine	11%
Plant Reservoir A	Ambient temperature	30%
	pH	26%
	Colour	15%
	Total chlorine	14%

Reservoir	Predictor	Weight
Outlying Reservoirs	Total chlorine	58%
	Turbidity	18%
	Conductivity	16%
Primary Reservoir E	Turbidity	55%
	Colour	36%
	Ambient temperature	6%

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Summary

- EPCOR has replaced HPC testing with ATP for routine monitoring.
- ATP testing has generated a large data set vs. limited data from HPC.
- ATP results are providing evidence which is directly influencing our capital renewal program.
- Chlorine has strongest correlation with ATP for outlying reservoirs.
- Outlying reservoirs have significantly higher ATP levels than plant reservoirs.
- Action threshold of 10 pg/mL ATP as proposed is reasonable.
- ATP levels at “Primary Reservoir E” are trending down since repair.
- Modelling this data in conjunction with other parameters will allow us to find exceptions and negative trends.

Thanks!

Operations:

Nicole Dymtruk, Alden Reichert, Kristy Zacharko

Laboratory:

Sharon Lu, Preety Busawon

Maintenance:

Bill Wolsegger, Dallas Trufyn, Brian Gurnett

Projects:

Greg Wilson, Jennifer Moningka

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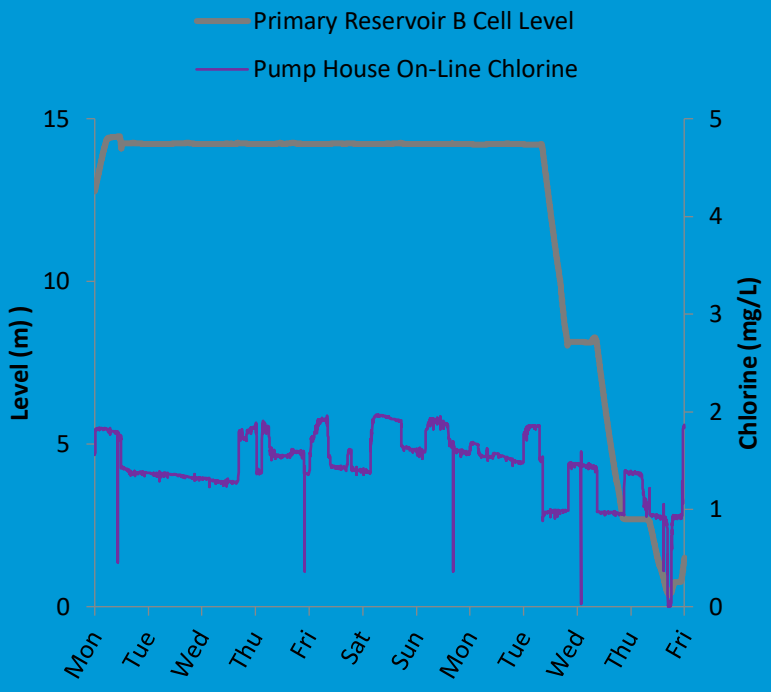
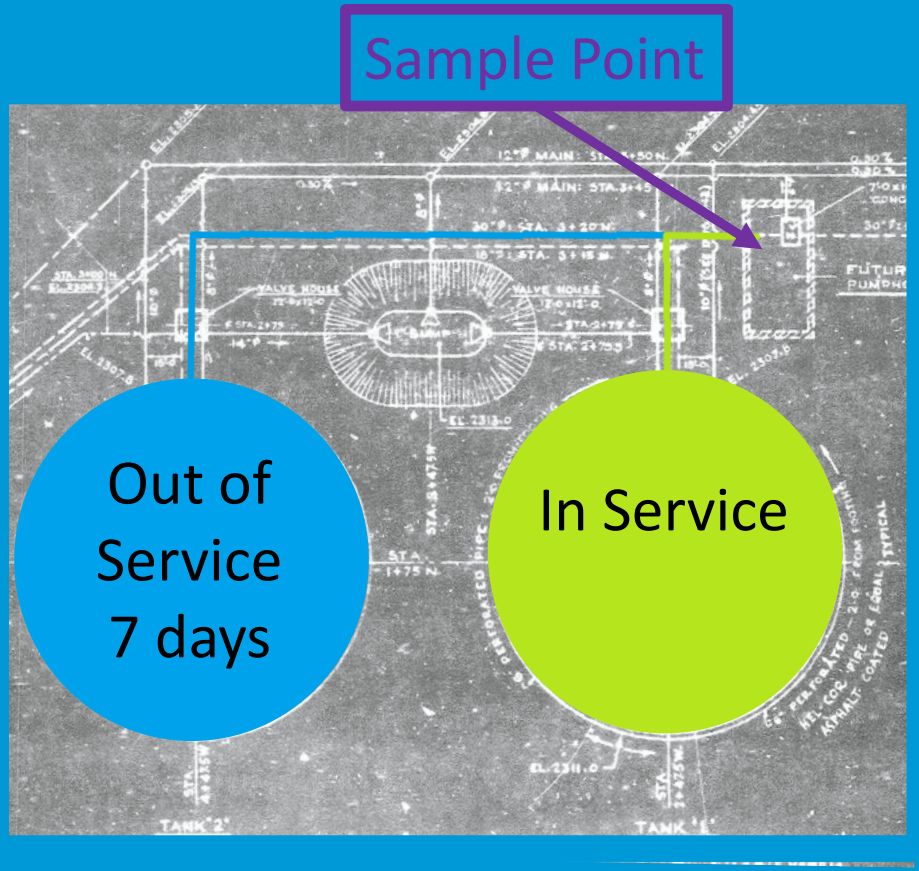
End of Presentation

“Primary Reservoir B” – Stagnation Testing





“Primary Reservoir B” Stagnation and Drain