Assessment of the Practicality of Reusing Treated Produced Water from Shallow Gas Wells of the Western Canadian Sedimentary Basin

ConocoPhillips Canada and

GP Resources Limited

April 22, 2010

Agenda

- Introduction
- Background
- Research Objectives
- Research Methodology
    - Data collection and testing
    - Technology Selection and Description (EDR)
    - Field Application of Technology
- Results and Discussion
- Next steps of research

Introduction

- First phase of a multi-year project
- First phase funded by ConocoPhillips
- Applied to PTAC for research funding for years 2+
- First years work part of M.Sc. Thesis by James Douglas

Background

- Produced water generated during the production of oil and gas
- Reported annually to ERCB

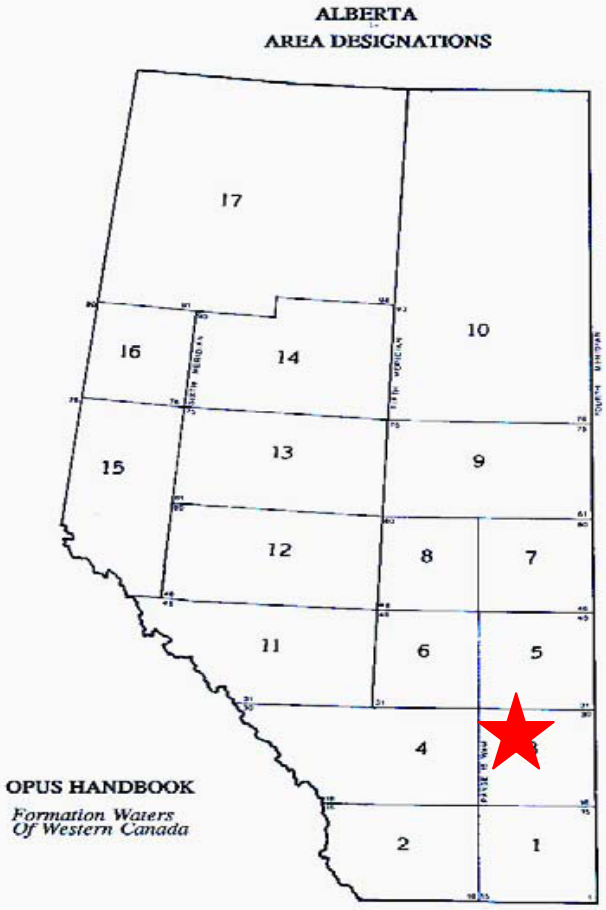
Total Volume of Produced Water Injected and Disposed (Fossil Water,2007)

Year	2002	2003	2004	2005	2006
Total Volume (MMm3)	263.17	267.91	266.53	261.04	261.42
Average Daily volume (m3)	721,005	734,008	730,235	715,109	716,217

Injected volumes not available for reuse and are required for pressure maintenance

Background

- Salinity highly variable across Province



Data from Opus Engineering, 1992

Area	Min Salinity (mg//L)	Max Salinity (mg/L)
1	1,945	5,623
2	2,589	15,593
3	4,639	36,785
4	5,752	66,822
5	6,894	58,698
6	7,802	154,421
7	10,444	62,347
8	63,495	92,039
9	17,696	37,664
10	7,662	7,714
11	7,861	126,522
12	7,170	115,697
13	7,246	245,646
14	13,654	250,010
15	3,462	205,264
16	2,150	197,345
17	31,595	130,745

Background

Summary of High TDS Water chemistry (107 Samples) – Fossil Water, 2007

Parameter	Mean	Max	Min
Na	7,345	45,360	3.4
Cl	16,593	189,905	4
TDS (mg/L)	30,036	328,536	37
K (mg/L)	1,381	20,290	1
Ca (mg/L)	1,632	61,760	1
Mg (mg/L)	634	34,077	1
Ba (mg/L)	43	379	0
Fe (mg/L)	68	1,060	1
HCO3 (mg/L)	1,564	63,344	0

Chemistry is highly variable spatially and temporally containing salinity, metals, organics

Background

Summary

- Significant quantities of produced water generated in Province
- Highly variable chemistry
- Generation and disposal focused in several key locations
- Produced water injected for pressure maintenance not available
- Likely a significantly smaller volume suitable for treatment and reuse

Research Objectives

- Pre-screen proven technologies
- Complete pilot field assessment of pre-selected technology to treat produced water and assess results
- Determine under what circumstances is treatment and reuse practical and economic?
- Define roadblocks for the beneficial reuse of produced water and propose solutions to close gaps?

Research Methodology

- Screening of CPC gas wells to find candidate sites
- Detailed baseline testing of produced water
- Field scale testing of technology
  - ERCB approval for this specific project.
  - 30 m^3 of produced water was treated over 2.5 days.
  - Detailed analytical testing of produced water.
  - Data analysis (treatment efficiency, removal rates and cost).
- Economic model development
  - Focus on natural gas assets in southern Alberta.
  - What economic factors control success (trucking, value of water, etc).

Initial Analytical from Gas Well

Cations

ION	mg/L	mmol/L	meq/L
Na	10400.0	452.4	452.4
K	38.9	1.0	1.0
Ca	214.0	5.3	10.7
Mg	72.0	3.0	5.9
Fe	TRACE	0.0	TRACE
		Total Cations	470.0

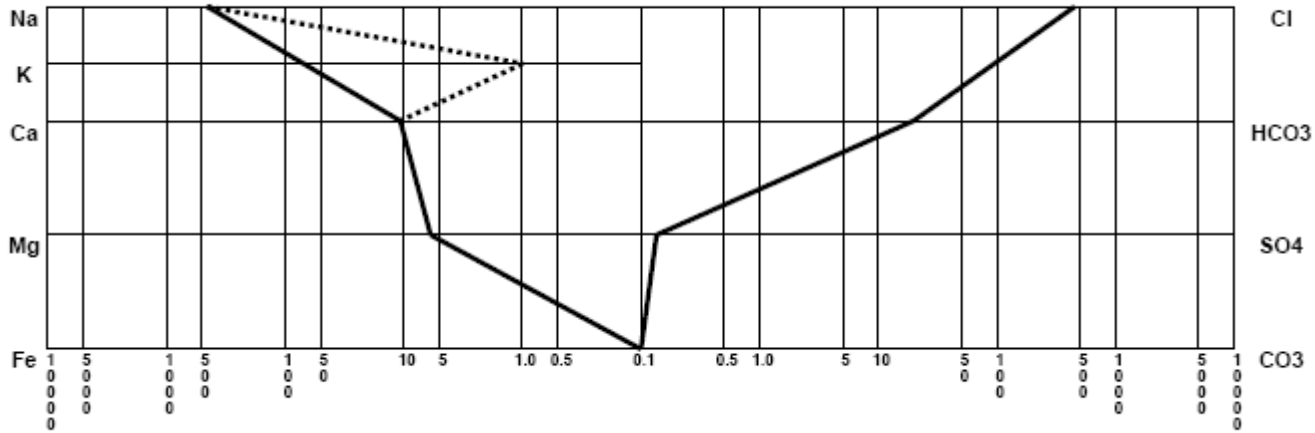
Anions

ION	mg/L	mmol/L	meq/L
Cl	15995.0	451.2	451.2
HCO3	1206.7	19.8	19.8
SO4	6.5	0.1	0.1
CO3	Nil	Nil	Nil
OH	Nil	Nil	Nil
		Total Anions	471.1

Other Measurements

Measurement	Value
Total Dissolved Solids (Calculated) mg/L	27933
Observed pH	7.83
H2S (25°C) mg/L	N/D
Relative Density (25°C)	1.022
Refractive Index (25°C)	1.3376
Resistivity/OHM·m (25°C)	0.623
Salinity %	2.83

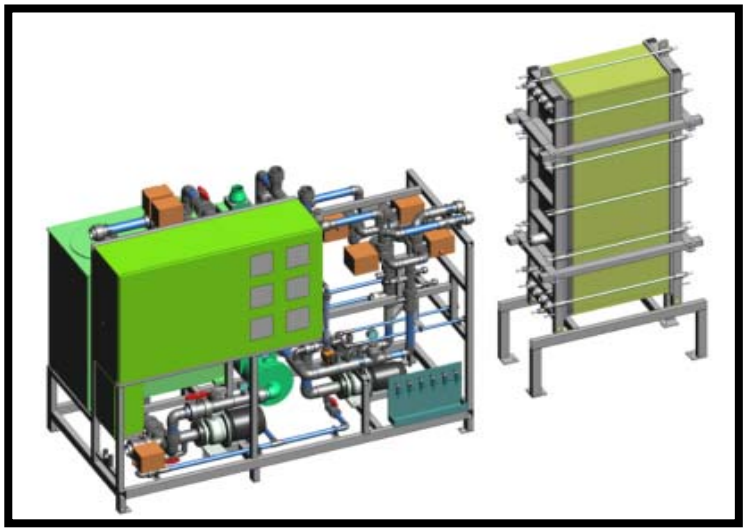
Stiff Diagram (meq/L)



Technology Description

- Pilot/ demonstration plant to prove and develop a model for the beneficial re-use of produced water
- GPR's goal is to be the operator of water treatment plants that meet the needs of both produced water generators (largely well owners/operators) and fresh water users
- Specific fields and locations in Western Canada are economic and feasible in current environment
- GPR continues to operate the pilot facility and is investigating a full scale new facility in the near future

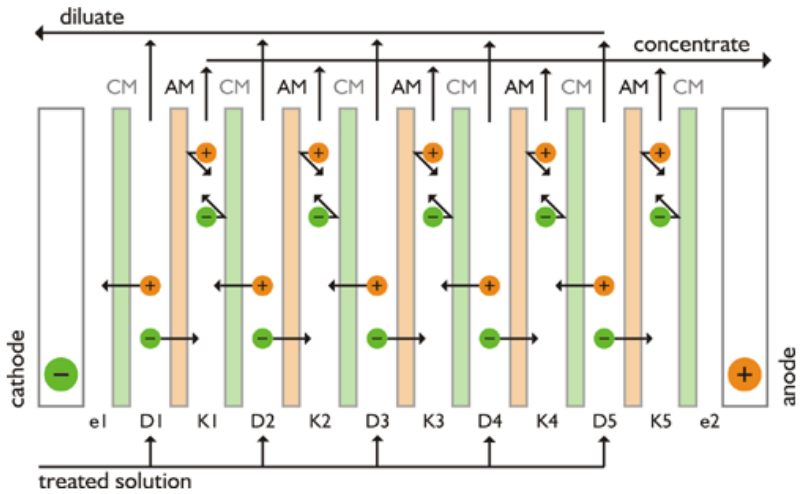
Technology Description



- Electro-dialysis reversal (EDR) plant originally designed for 40 m^3/day of <10,000 mg/L TDS water
- Three tanks: two tanks for batch treatment, third for brine storage
- EDR equipment supplied by MEGA Corp of Czech Republic
- Entire site is powered by a 45 kW natural gas generator running on fuel gas
- Plant located on GPR 100 per cent owned Belly River wellsite

EDR Technology Description

GP Resources – Electrodialysis



- DC Power used to push/pull charged ions across a semi-permeable membrane
- Result is alternating compartments of concentrated salts and desalted water.
- Small amount of concentrated brine flows to 3rd Tank and hauled to deep well disposal.
- Desalted stream is batched through treatment tank until desired water quality is reached

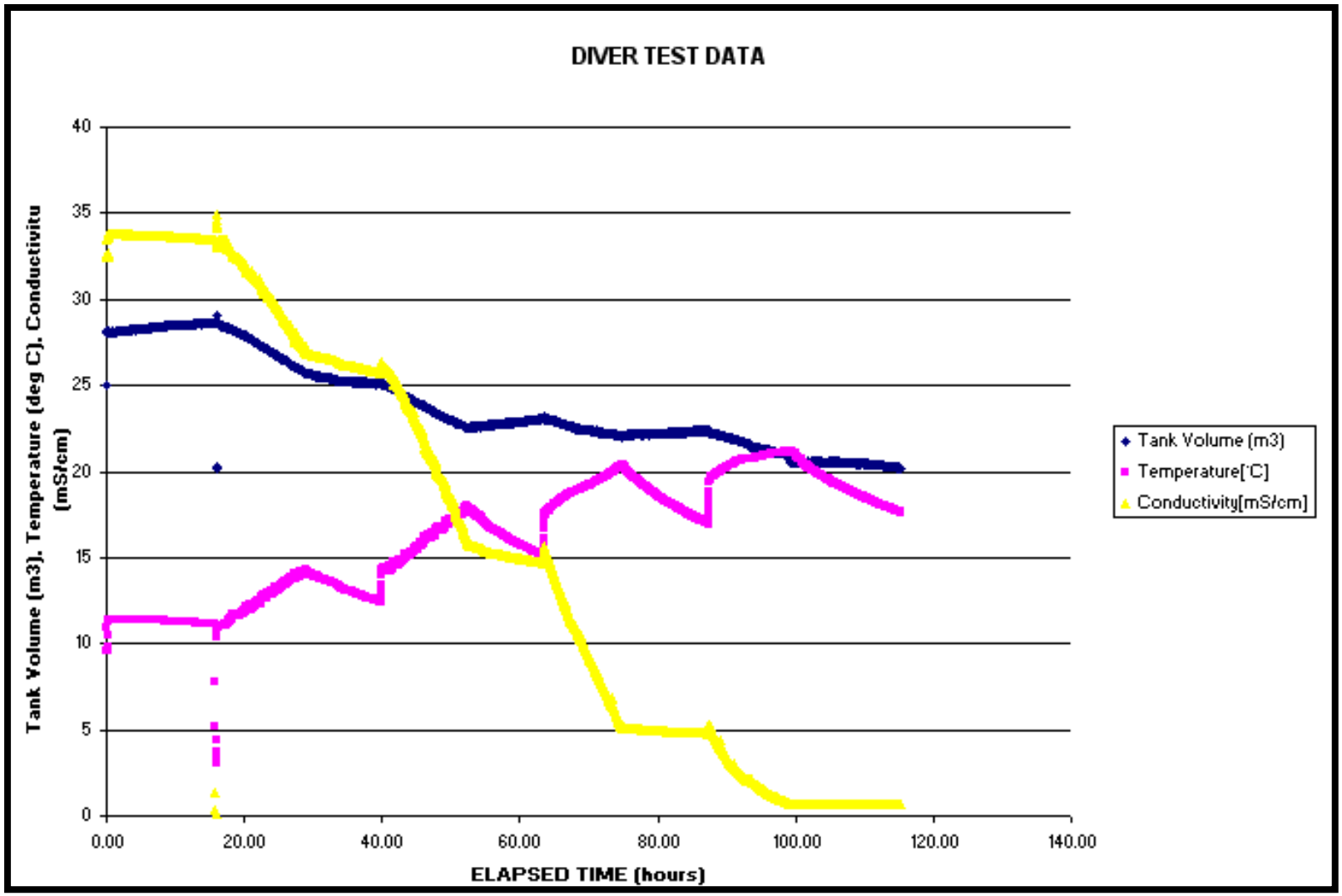
EDR Technology Description

- Overall recovery is limited by scale formation on the brine side.
- Scale formation is related to Calcium, Magnesium, Carbonates and Sulphates in the produced water
- Scaling can be suspended to higher salt concentrations through:
  - Acid addition
  - Antiscalant addition
  - Polarity Reversal of stack and water flows
- Advantages – high water recoveries possible, low pressure, energy requirements correspond to salt removed
- Future plants will likely require additional pre and post treatment depending on specific application

Results and Discussion

Results	
Total M^3 Treated	28 M^3
Total Treatment Time	48 hours
Total Salt Removed	760 KG
Total Power	312 KWH
Power/M^3	11.1 KWH/M^3
Energy Efficiency	0.41 KWH/KG of salt
Fresh Water Recovery	75% - 21 M^3

Results and Discussion



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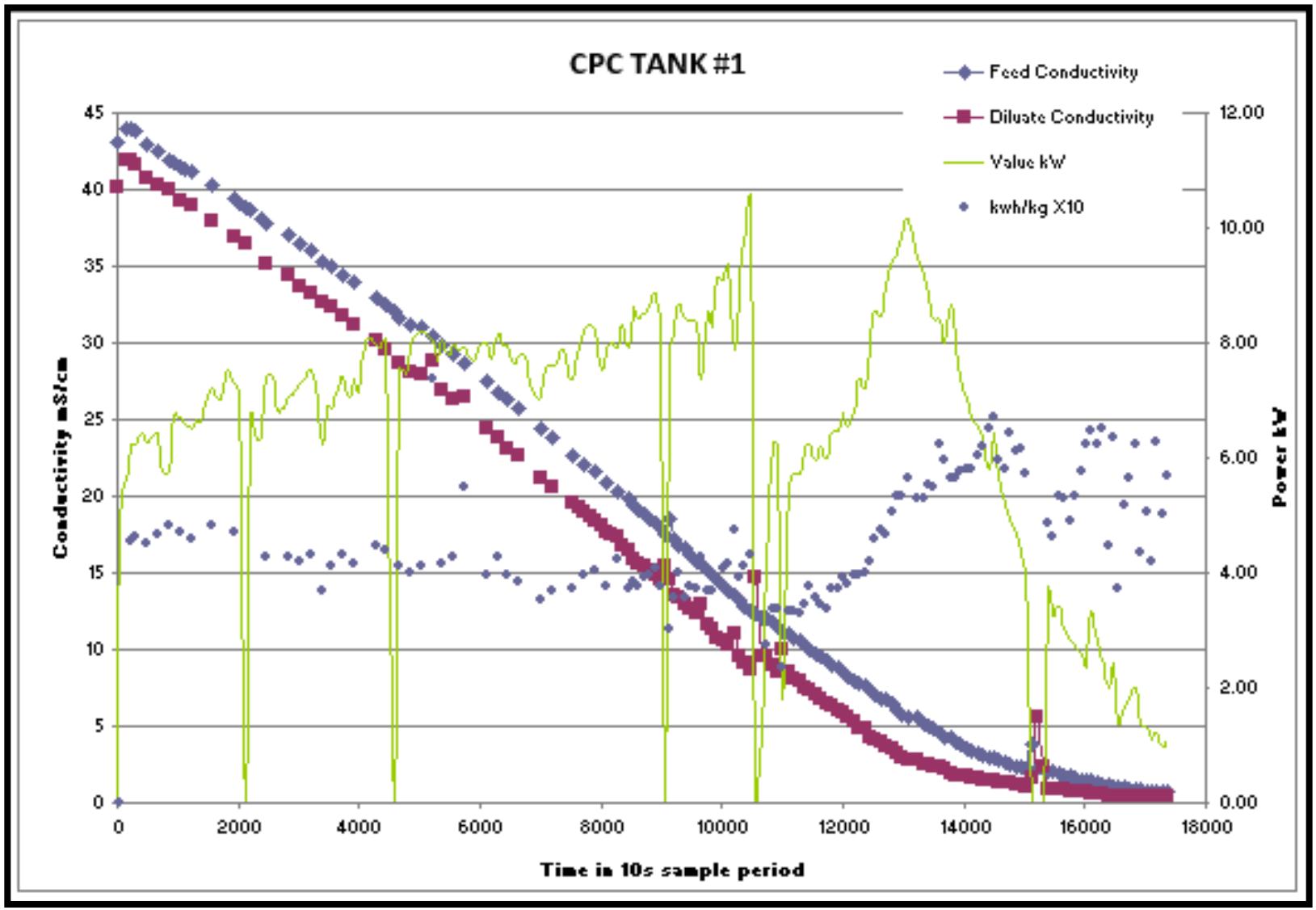
Results and Discussion



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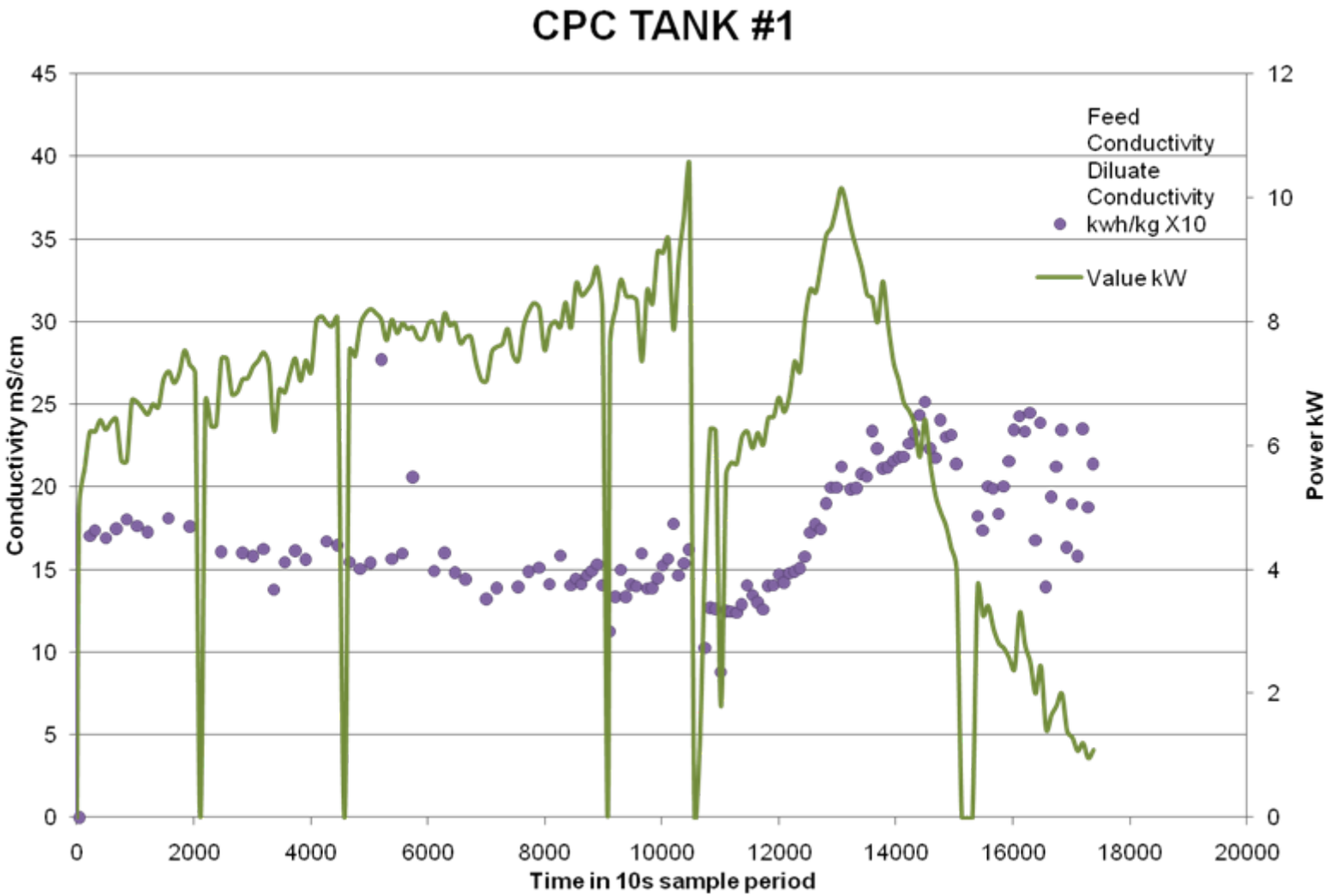

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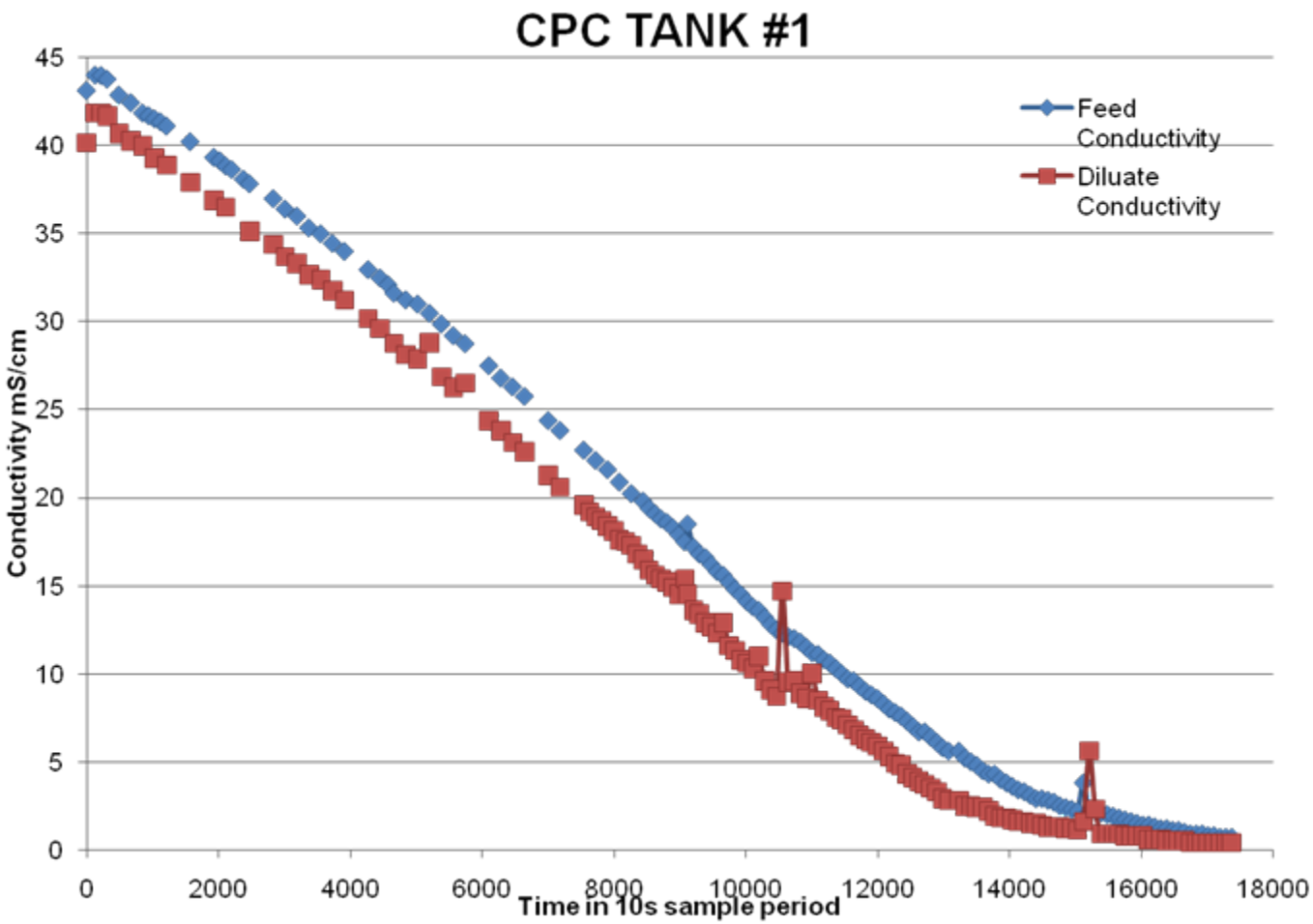

Results and Discussion

ROUTINE WATER ANALYSES

ANALYTE	UNTREATED	TREATED	UNITS
Chloride (Cl)	**15000**	**130**	mg/L
Calcium (Ca)-Dissolved	210	5	mg/L
Iron (Fe)-Dissolved	2.3	0.45	mg/L
Magnesium (Mg)-Dissolved	39	0.4	mg/L
Manganese (Mn)-Dissolved	0.17	0.018	mg/L
Potassium (K)-Dissolved	46	<0.3	mg/L
Sodium (Na)-Dissolved	**9500**	**170**	mg/L
Ion Balance	96	120	%
TDS (Calculated)	**26000**	**380**	mg/L
Hardness (as CaCO3)	680	14	mg/L
Nitrate and Nitrite as N	<0.06	<0.003	mg/L
Nitrate-N	<0.06	<0.003	mg/L
Nitrite-N	<0.06	<0.003	mg/L
Sulphate (SO4)	7	<1	mg/L
pH	7.83	7.52	pH
Conductivity (EC)	**43000**	**680**	uS/cm
Bicarbonate (HCO3)	1300	160	mg/L
Carbonate (CO3)	<0.5	<0.5	mg/L
Hydroxide (OH)	<0.5	<0.5	mg/L
Alkalinity, Total (as CaCO3)	1100	130	mg/L

Results and Discussion

Metals Analyses Above Drinking Water Guidelines

	Units	UNTREATED	TREATED	CDWQG
Total Barium (Ba)	mg/L	1.9	0.04	1
Total Boron (B)	mg/L	10	9.6	5

Identified Roadblocks

- Economics
  - Disposal costs significantly lower especially if wells tied into pipeline
  - Cost to treat to potable likely 3 to 4 times the cost of municipally supplied water (U. of C. , 2006)
  - Availability of suitable market to recover costs – some users pay little if anything for water
- Regulatory
  - Crown owns the water
  - Current regs require produced water to be disposed
  - ERCB open to alternatives but no formal process with both Provincial regulators
  - No water quality reuse guidelines in place for produced water
  - Process has not been completed in Province
  - Multiple regulatory bodies involved in approvals

Identified Roadblocks

- Legal
  - No legal precedent in Canada (Shyba, 2008)
  - Selling of water
  - 3rd party liability related to reuse of treated water
- Logistics
  - Oil and gas operators are not water treatment plant operators
  - Transport of water (both treated and untreated)

Next Steps in Research

- Look to possibly partner with other companies and/or academic institutions
- Economic model development
  - Build model to assess opportunities
  - What factors control success (trucking distance, value of water, location of end user, etc)
  - Current and alternative disposal costs
- Based on model results and project risks and uncertainties select field to complete longer duration pilot.
- Further define and understand regulatory and liability roadblocks
    - Can these be resolved or are they a project killer

Questions