BQE Water

Demonstrating Performance of Innovative Treatment Systems

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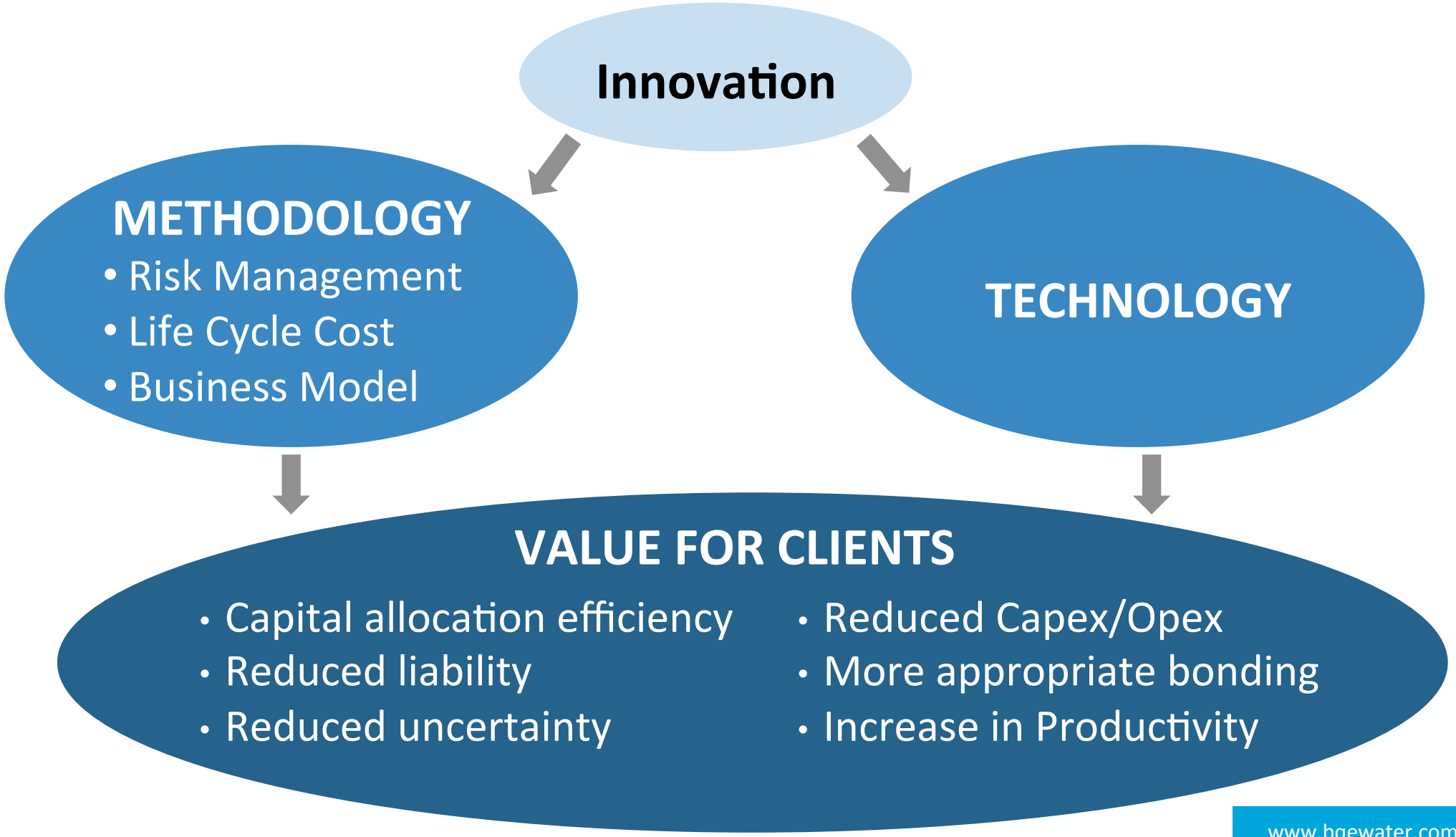
Why Innovative Treatment?

- Industry recognizes that “business as usual” approach does not always secure future business
- Public demands and expects that “we do better”
- Regulations continue to evolve and create need for innovation

Innovation as Value Creation



Barriers to Innovation – Understanding Risks vs Rewards

- **Lack of full understanding and/or recognition of value**
  - Life cycle context and risks
  - Limits $$ spent – may lead to selecting options with lowest burden of proof to save on immediate cost
  - Doing nothing may represent failure in itself

- **Poor understanding, assessment and management of risks**
  - Fear of rejection leads to:

    a) Defaulting to status quo even if it is not the right solution

    b) Miscommunication and/or mismanagement of risks which leads to increased costs

- **Lack of clarity about criteria for success**
  - Road map to acceptance by regulators

Treatment Demonstration Stages & Objectives

Treatment Demonstration Stages and Objectives

Demonstration Stage	Mining Project Stage	Objectives of Demonstration
Fatal Flaw / Proof of Concept	EA Scoping/Pre-feasibility	• Ability to meet effluent limits • Order of magnitude costs
Pilot	Permitting Pre-feasibility /Feasibility	• Continuous steady state operation • Residue generation and characterization • Ability to respond to variability in feed
Industrial demonstration	Construction/O&M budget	• De-risking engineering scale-up • Understanding O&M labour requirements

Treatment Demonstration Stages and Objectives contd

Demonstration Stage	Capex/Opex Accuracy	Use of Outcomes
Fatal Flaw / Proof of Concept	+/-50% at best	• Elimination of options
Pilot	+/-30%	• Cost/benefit analysis • Constructability • Bonding • Residue mgmt. plan • Risk assessment and mitigation plans
Industrial demonstration	+/-15%	• Scale-up risks • Design issued for construction • O&M requirements confirmation

Body of Evidence Requirements

Demonstration Staged - Level of Effort Indicators

Demonstration Stage	Volume of feed water treated	Residue produced	# of solution samples analyzed by accredited labs
Fatal Flaw / Proof of Concept	< 50 L	~ 100 g	< 100
Pilot	~ 100 to 1,000 m3	~ 100 kg	2,000 to 5,000
Industrial demonstration	> 10,000 m3	~ 10 tons	> 1,000

When is Pilot Demonstration Requested for BC Projects?

Threshold #1

- Has to be proven on an industrial scale at a mine site in BC to skip piloting
  - If not in BC then in Canada, and global mining industry (but not guaranteed)

Threshold #2

- Similarity and Completeness of Reference Sites
  - Feed water quality, climate, or receiving environment are similar to project in question
  - If treatment involves multiple stages then all must meet threshold #1

Challenges with Pilot Demonstrations

- **Uncertainty with water quality**
  - Streams may not exist or do not reflect anticipated future changes in WQ – time horizon 10 to 50 yrs
  - 98 percentile predicted WQ cannot physically exist
  - Sensitivity of treatment to changes in WQ – service providers to help focus and pilot scope

- **Scale-down of unit operations**
  - Some equipment cannot easily scale-down (MMF)
  - Operability issues specific to small scale (slurry lines)

- **On-site pilot demonstrations costs are excessive and conditions not always reflect those during full scale deployment**
  - Remote sites not conducive to “proving up” new processes
  - Turn-around on assays extend project schedules and increase costs

- **Steady state not always possible**
  - Biological systems constantly evolving – residues changing (methylation of Hg/As/Se)

Examples and Experiences

Silvertip Mine Water Treatment

- **Original design in permit application was based on HDS Lime**
  - Lime reactor with aeration, long HRT
  - Large clarifier
  - Need for effluent acidification via CO_2 addition to meet discharge pH limit
  - Sludge production of up to 1.35 kg/m^3 of water treated

- **Metals of concern** – Zinc and Cadmium, feed water pH 7 to 8

- **BQE Water recommended design change from HDS Lime to ChemSulphide**
  - Sulphide instead of hydroxide allowing use of in-line reactors
  - No need to change pH (eliminated re-acidification stage)
  - Solid-liquid separation in a sea container
  - Sludge production < 0.1 kg/m^3 (mostly TSS coming from U/G)

- **Modular portable plant**

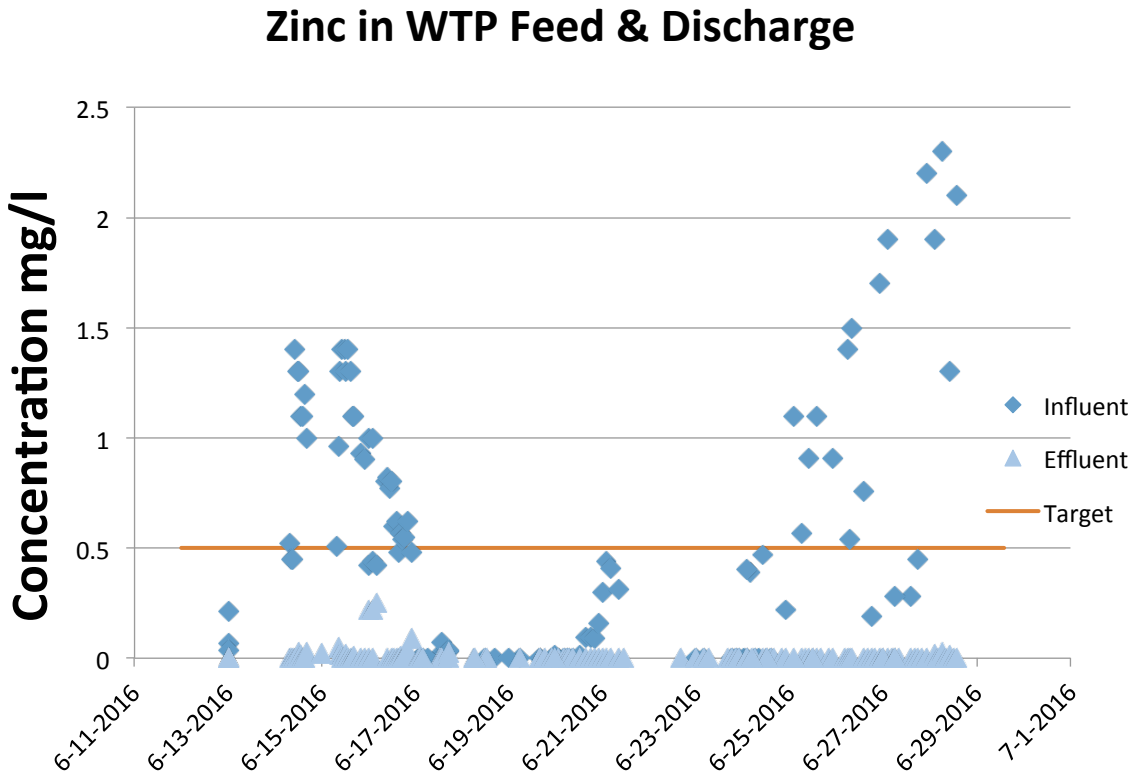
VALUE

Silvertip Mine Water Treatment

- **12 ChemSulphide WTP built** for mine water treatment but none in BC
- Submitted **report referencing existing ChemSulphide installations** and highlights of operating data
- The new **WTP ran the first two weeks as a "pilot"** before permit was issues

Silvertip – Containerized Mine WTP

Parameter	Feed Chemistry	Discharge Limit	Actual Average Effluent Quality
pH	7.0 to 9.0	6.5 to 9.0	7.0 to 8.5
Zinc	0.2 to 2.3 mg/L	0.5 mg/L	< 0.02 mg/L
Cadmium	0 to 5 ppb	2.3 ppb	< 0.5 ppb



Kemess Project Selenium Control

Objective

- Discharge to meet **BC WQG of 2 ppb total selenium at end** of pipe

Value Proposition

- Capable of achieving < 1 ppb at end of pipe
- Purely phys-chem treatment (quick start-up/seasonal ops possible)
- Stable inorganic residue blended with tailings
- Does not generate organo-selenium or selenocyanate
- Significant Life Cycle Cost savings compared to Biosystems used for NO3-Se removal

Kemess Selen-IX™ Demonstration Chronology

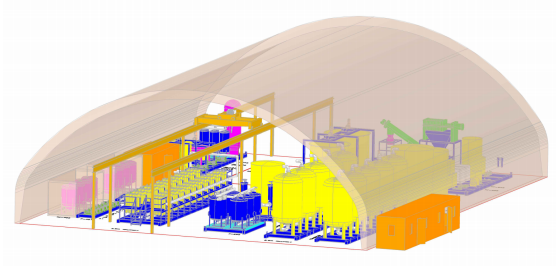
2015
Pilot plant

2017
Industrial Scale Demo of Electro-reduction

2019
Operation

2015
Initial lab treatability assessment

2016
Engineering design for permitting



2018
IFC Design and Plant Construction

Selen-IX™ Mobile Pilot Unit

Continuous operation

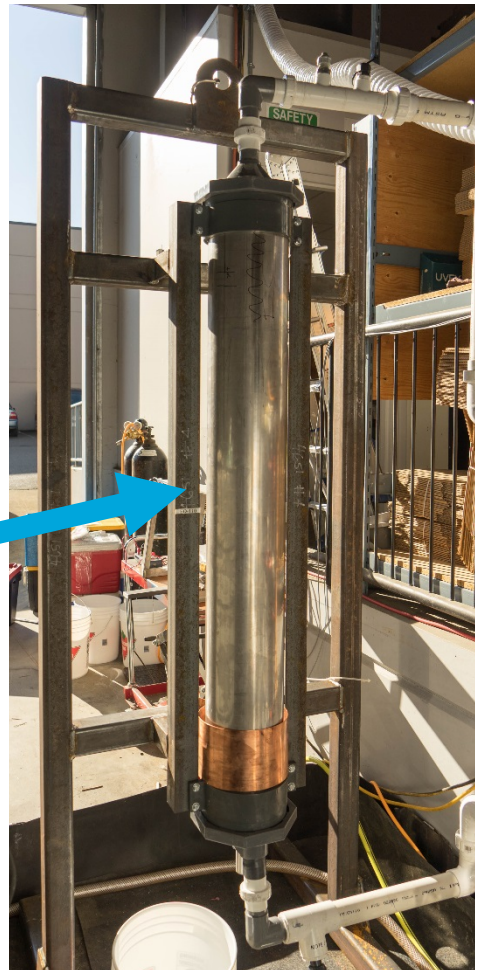
- Hydraulic Capacity: ~ 4 to 8 L/min

Scale-up – Industrial Scale Demonstration

- Demonstration to reduce risks of engineering scale-up
- Size of cell is the same size as that used in full-scale plant
- Further scale-up achieved by multiple units of same size

Pilot
Electrocells

Industrial Scale
Electrocell



Residue Disposal and Stability Demonstration

- TCLP
- Alkali and acid leach with/without strong oxidants
- Elemental Analysis
- XRD
- Particle sizing

- Saturated column tests using blends of tailings with Selen-IX™ residue ~ 9 months
- Commercial evaluation by US steel producer for potential off-take

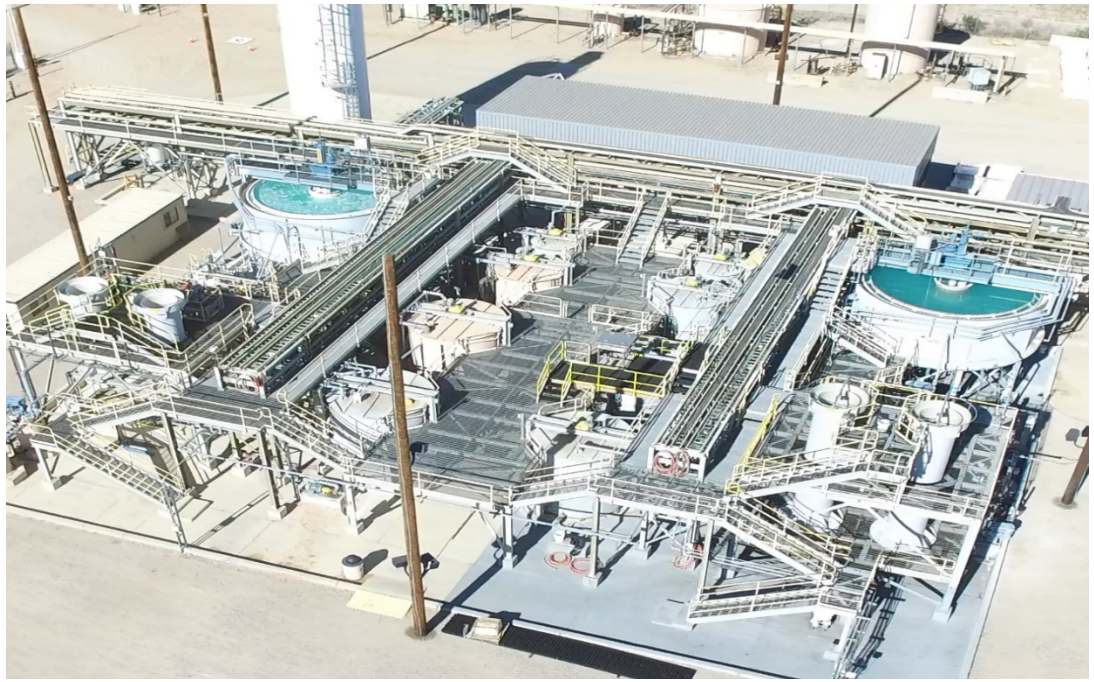
Positive Stakeholder Engagement during Pilot Projects

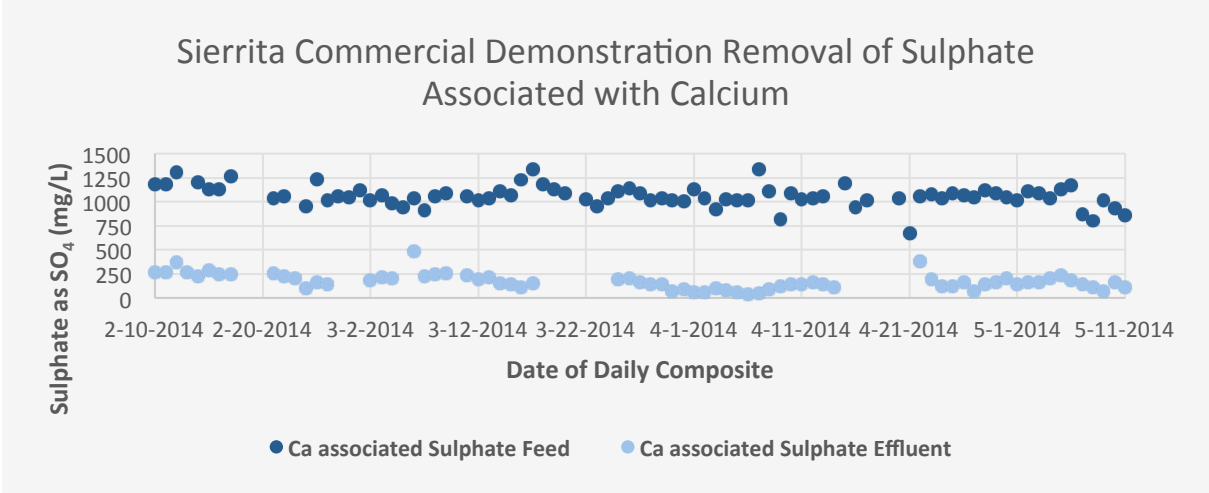
BC Minister of Environment Mary Polak visits the Selen-IX™ pilot during AuRico Kemess piloting

- Environment Canada
- BC Ministry of Energy and Mines (BC MEM)
- Tahltan First Nations
- COM delegates
- BC Ministry of Environment (MOE)
- Golder, Tetratech

Sulphate Control at BC Mine

- **Reliance on passive treatment not acceptable**
- **Sulf-IX™ process met project requirements and thresholds**
  - 2 years of operating data from an industrial scale demo plant in the US





The lightbulb was not invented by continuously improving the candle

Nothing is impossible, the word itself says “I’m possible”

Thank you from

BQE Water

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