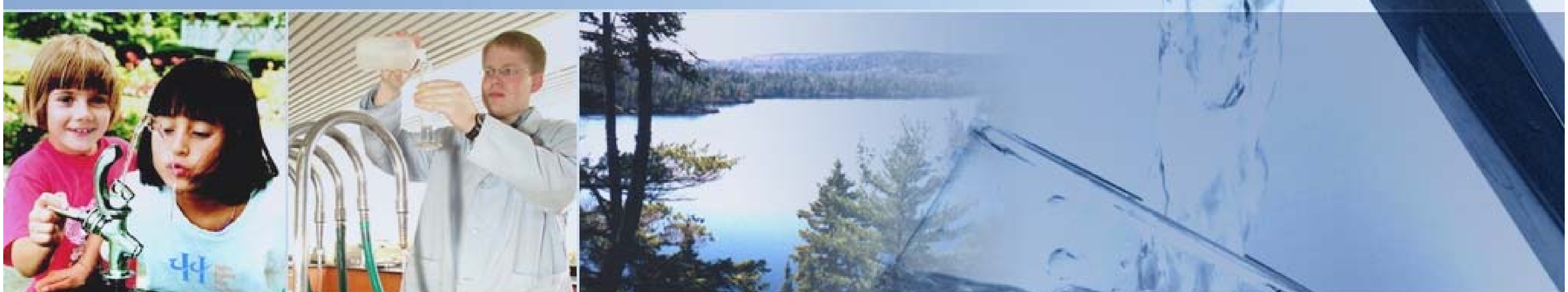
Energy Recovery from PRVs Using In-Line Turbines

Newfoundland Department of Environment & Conservation
Annual Drinking Water Workshop - Gander, NF
March 24th, 2015



Striving for World Class

Energy Recovery from PRV Chambers

Outline

- About Halifax Water
- Energy Management Program
- Energy Recovery from PRV Chambers

Halifax Water

About Halifax Water

A Brief History

- City of Halifax Established **1749**
- Halifax Water Company Formed **1844**
- Public Service Commission Formed **1945**
- Pockwock RWS Commissioned **1977**
- Name Change – Halifax Water Commission **1987**
- HRM Amalgamation **1996**
- Lake Major WSP Commissioned **1997**
- HRM Wastewater/ Stormwater Transfer **2007**

1700's | 1800's | 1900's | 2000's

About Halifax Water

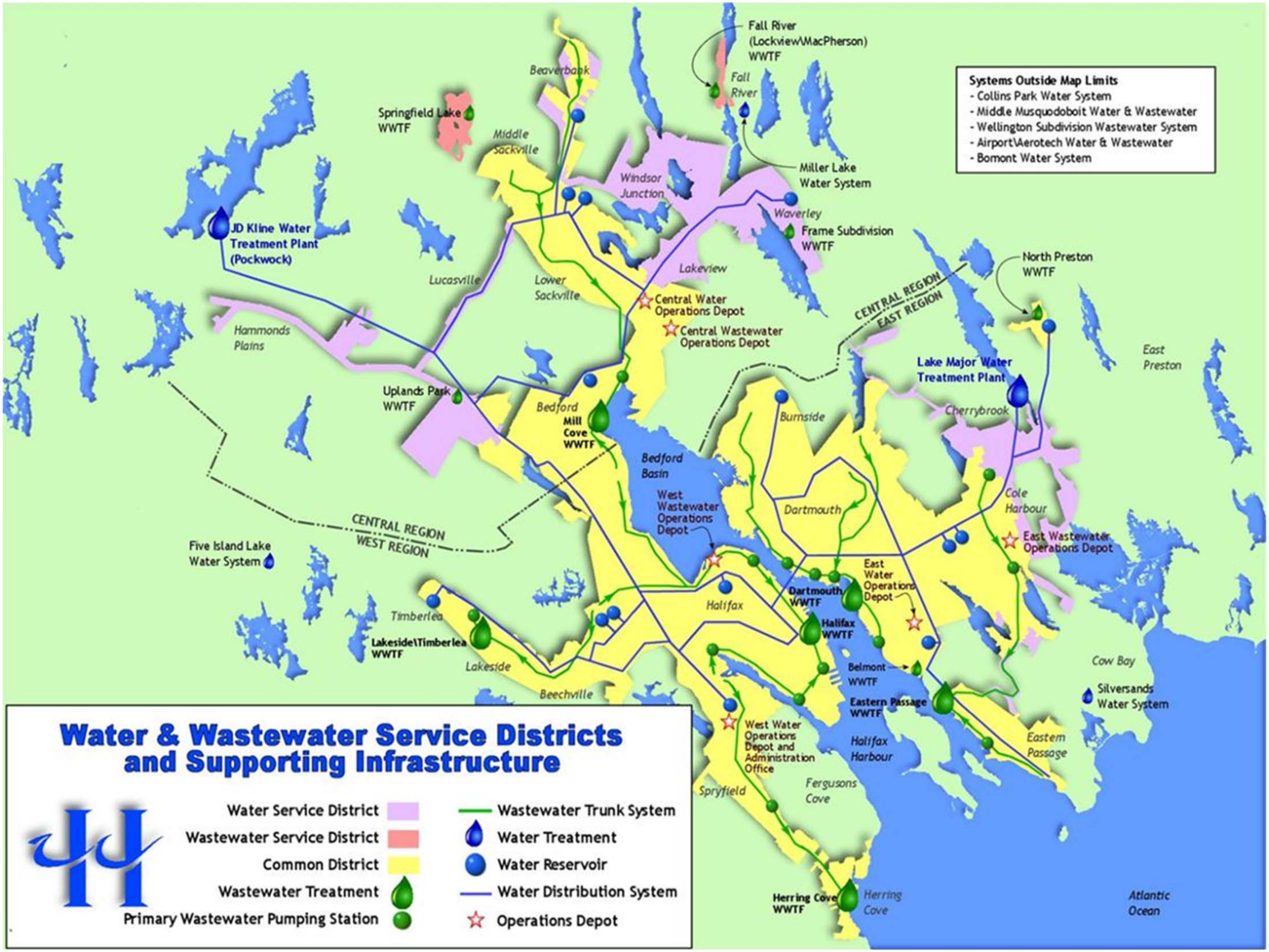
Utility Background

- 1st Regulated W/WW/SW Utility in Canada
- Halifax Regional Water Commission Act
- Regulated by NS Utility & Review Board
- Board of Directors – 100% Owned by HRM
- Self Financed – Funded by W/WW/FP Revenue

About Halifax Water

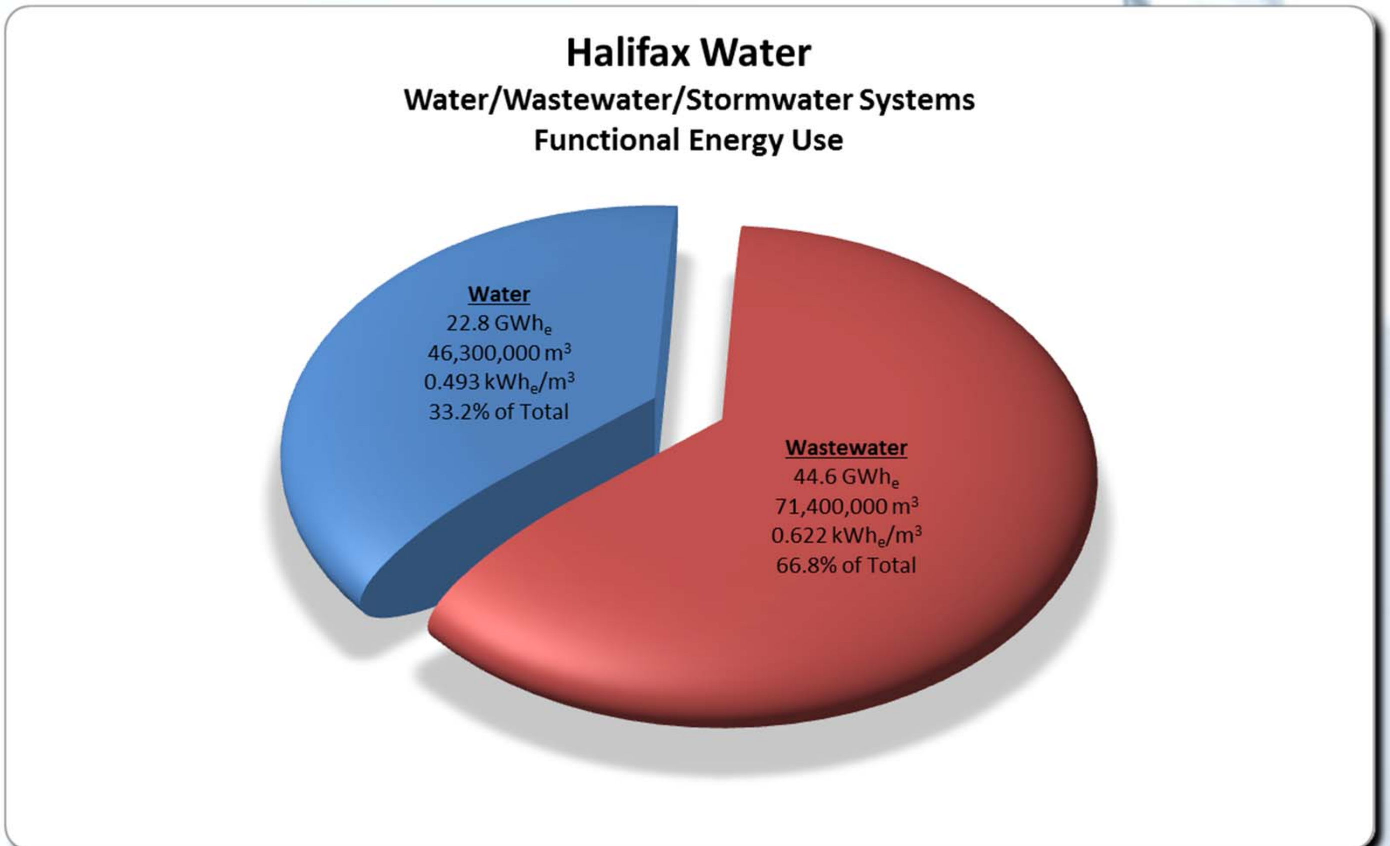
Facilities

- Water Treatment
  - 3 Large + 6 Smaller Facilities (227 MLD to 8 KLD)
  - 18 Storage Reservoirs (269 MLD Capacity)
  - Distribution System (~ 180 Pumping/Meter/PRV Stations)
  - 7,700+ Fire Hydrants
  - 80,000+ Customer Connections
- Wastewater Treatment
  - 5 Large (344 to 62 MLD) + 10 Smaller Facilities
  - Collection System (~ 180 Pumping Stations)


Water & Wastewater Service Districts and Supporting Infrastructure
Water Service District
Wastewater Service District
Common District
Wastewater Treatment
Primary Wastewater Pumping Station
Wastewater Trunk System
Water Treatment
Water Reservoir
Water Distribution System
Operations Depot
Systems Outside Map Limits
- Collins Park Water System
- Middle Musquodoboit Water & Wastewater
- Wellington Subdivision Wastewater System
- Airport\Aerotech Water & Wastewater
- Bomont Water System
Fall River (Lockview\MacPherson) WWTF
Fall River
Miller Lake Water System
Beaverbank
Springfield Lake WWTF
Middle Sackville
Windsor Junction
Waverley
Frame Subdivision WWTF
JD Kline Water Treatment Plant (Pockwock)
Lucasville
Lower Sackville
Lakeview
Central Water Operations Depot
Central Wastewater Operations Depot
Hammonds Plains
North Preston WWTF
CENTRAL REGION
EAST REGION
East Preston
Lake Major Water Treatment Plant
Uplands Park WWTF
Bedford
Mill Cove WWTF
Burnside
Cherrybrook
Bedford Basin
West Wastewater Operations Depot
Dartmouth
Cole Harbour
CENTRAL REGION
WEST REGION
Five Island Lake Water System
East Wastewater Operations Depot
East Water Operations Depot
Dartmouth WWTF
Halifax
Timberlea
Lakeside\Timberlea WWTF
Halifax WWTF
Lakeside
Belmont WWTF
Cow Bay
Beechville
Eastern Passage WWTF
Silversands Water System
West Water Operations Depot and Administration Office
Halifax Harbour
Eastern Passage
Spryfield
Fergusons Cove
Herring Cove WWTF
Herring Cove
Atlantic Ocean

About Halifax Water

Energy Use



Halifax Water

Energy Management Program

Long Term Goals

- Responsible Energy Management
- Reduced Dependency on Fossil Fuels
- Reduction of Pollution & Emissions
- Energy Reduction Targets
- Development of Renewable Energy Projects

Energy Recovery From PRV Chambers Using In-Line Turbines

Energy Recovery from PRV Chambers

A Brief History

Early Investigations

- Planning/Design of Pockwock System
- **Recognized potential for energy recovery**
- Economics/Energy costs unfavourable
- Availability of Technology

Minimal Activity

- HRM Amalgamation
- Formation of Water/Wastewater Utility
- **Economics/Energy costs remain unfavourable**
- Ongoing infrastructure development

Orchard Project

- Pinehill Report
- ID of Projects
- Chain/Robie/Orchard
- **COMFIT Program**
- WRF/NSE Funding

1970's 1980's 1990's 2000's 2010's

Halifax Water

Energy Recovery from PRV Chambers

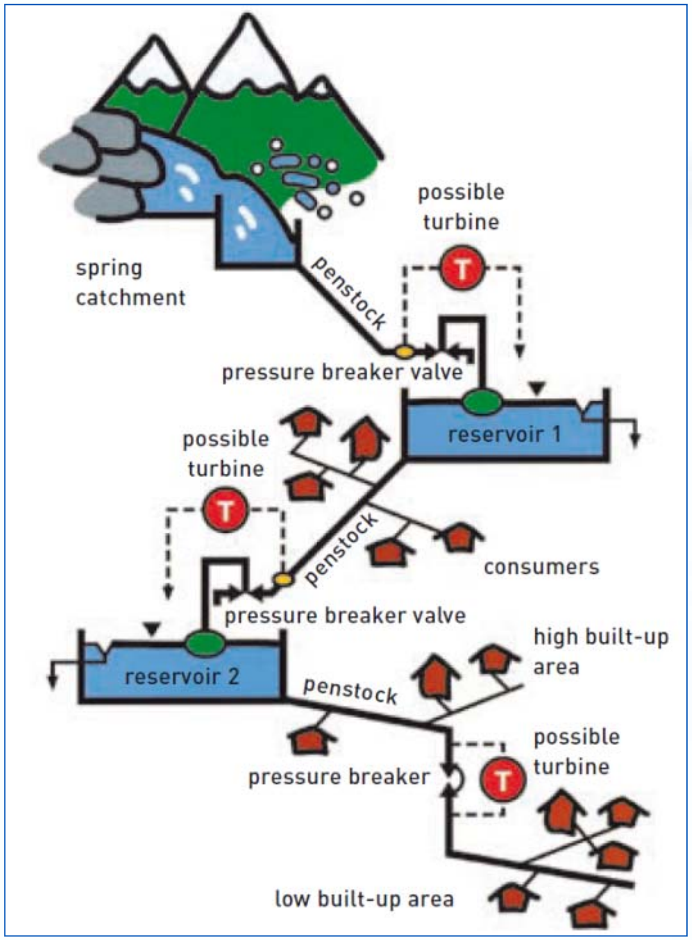
Background

- Energy recovery using turbines in an *Open* (i.e. atmospheric pressure) water system is very common.
- Energy recovery in a *Closed* (i.e. pressurized) water system is not common.
- Energy recovery from a *Closed* water transmission system involves the installation of a "turbine" to replace the normal function of a Pressure Reducing Valve (PRV) in the system.

Halifax Water

Energy Recovery from PRV Chambers

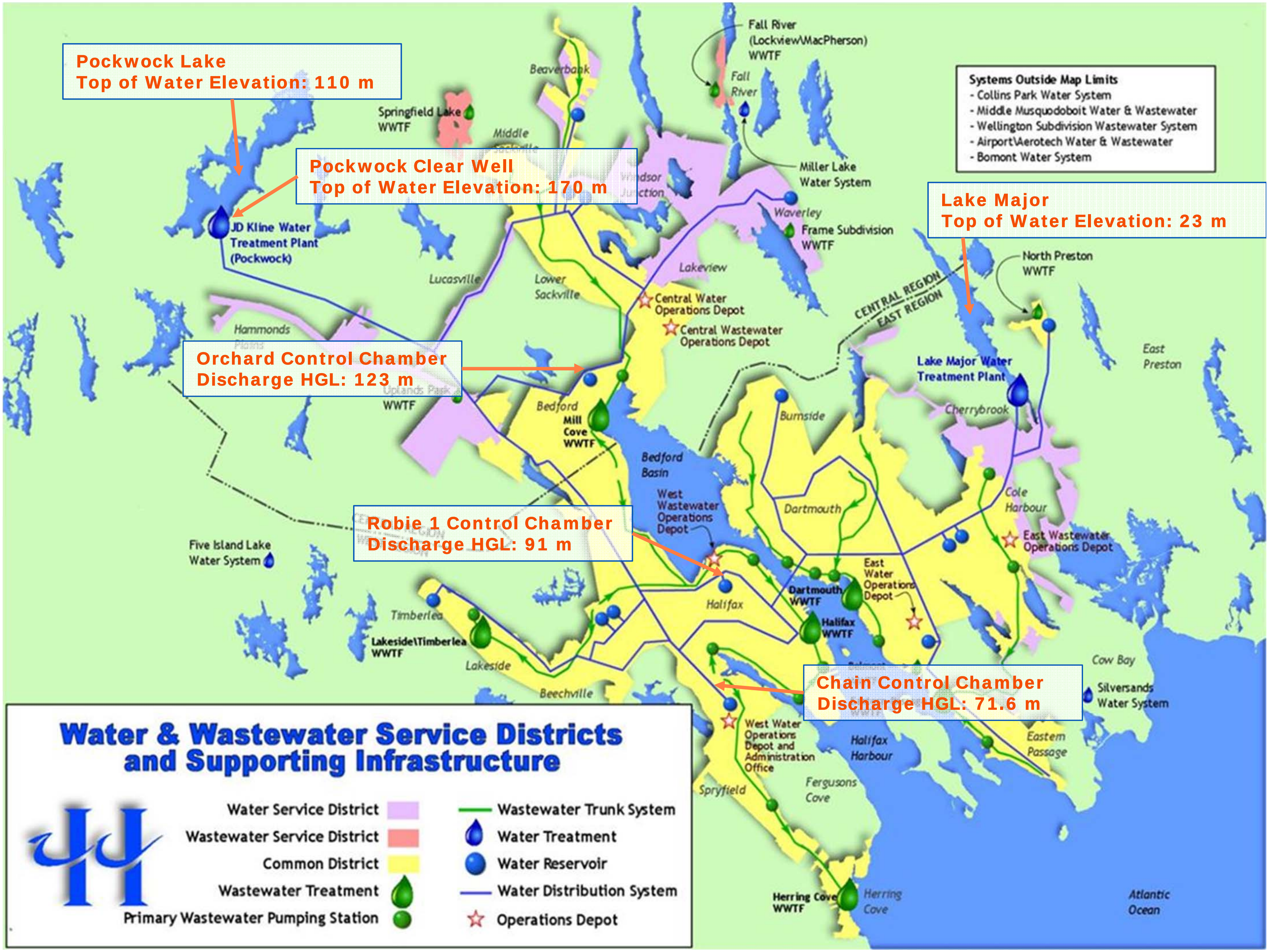
Potential Water Supply Applications



- Discharge into Reservoir
- Within the Supply Network
- Discharge to the Environment

"Anywhere there is significant and sustained flow with a significant and sustained pressure differential"

Halifax Water


Pockwock Lake
Top of Water Elevation: 110 m
Pockwock Clear Well
Top of Water Elevation: 170 m
Lake Major
Top of Water Elevation: 23 m
Orchard Control Chamber
Discharge HGL: 123 m
Robie 1 Control Chamber
Discharge HGL: 91 m
Chain Control Chamber
Discharge HGL: 71.6 m
Systems Outside Map Limits
- Collins Park Water System
- Middle Musquodoboit Water & Wastewater
- Wellington Subdivision Wastewater System
- Airport\Aerotech Water & Wastewater
- Bomont Water System
Fall River (Lockview\MacPherson) WWTF
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Water Service District
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Wastewater Trunk System
Water Treatment
Water Reservoir
Water Distribution System
Operations Depot

Energy Recovery from PRV Chambers

Why Do It?

"Pressure Reduction = Wasted Energy"

- Gravity Based Systems
  - Naturally available head
  - Excess Energy Available (usually!)
- Pumped Systems – Energy added to satisfy:
  - Static Head Requirements; and/or
  - System Pressure Requirements.

Energy Recovery from PRV Chambers

Traditional Pressure Reduction

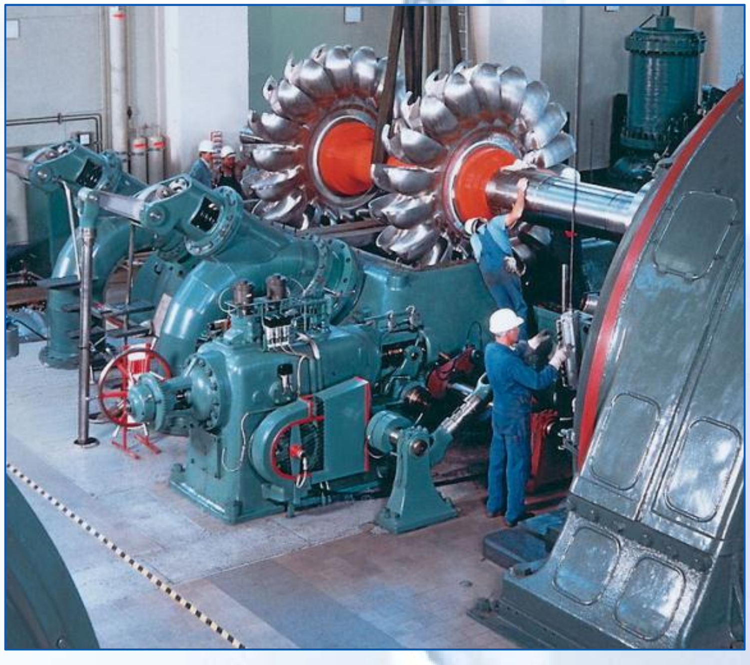
ROSS MODEL - 40WR
Pressure Reducing Valve

GLOBE FLAT SEAT STYLE

Energy Recovery from PRV Chambers

Available Technologies

- ***Pelton Turbines***
  - High Head, Low Flow Applications
  - Variable Flow
  - Radial Nozzle Entry
  - Good Efficiency
  - Built In Flow/Surge Regulation
  - Open Discharge (Usually)
  - Prone to Nozzle Plugging



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Energy Recovery from PRV Chambers

Available Technologies

- ***Turgo Turbines***
  - Medium Head Applications
  - Variable Flow
  - Side Nozzle Entry
  - Good Efficiency
  - Open Discharge
  - Prone to Nozzle Plugging

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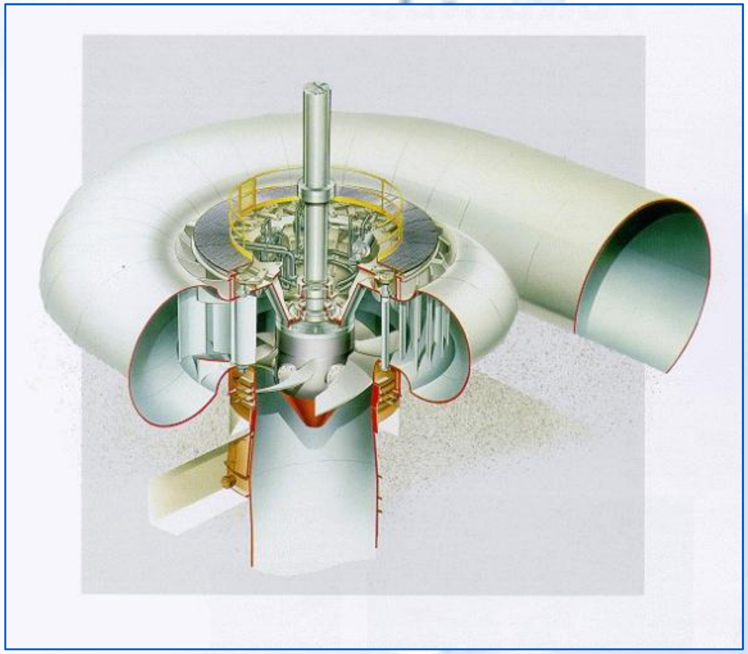
Energy Recovery from PRV Chambers

Available Technologies

- ***Kaplan Turbine***
  - Medium Head Applications
  - Side Entry Nozzle
  - Efficiencies ~87%
  - Open Discharge



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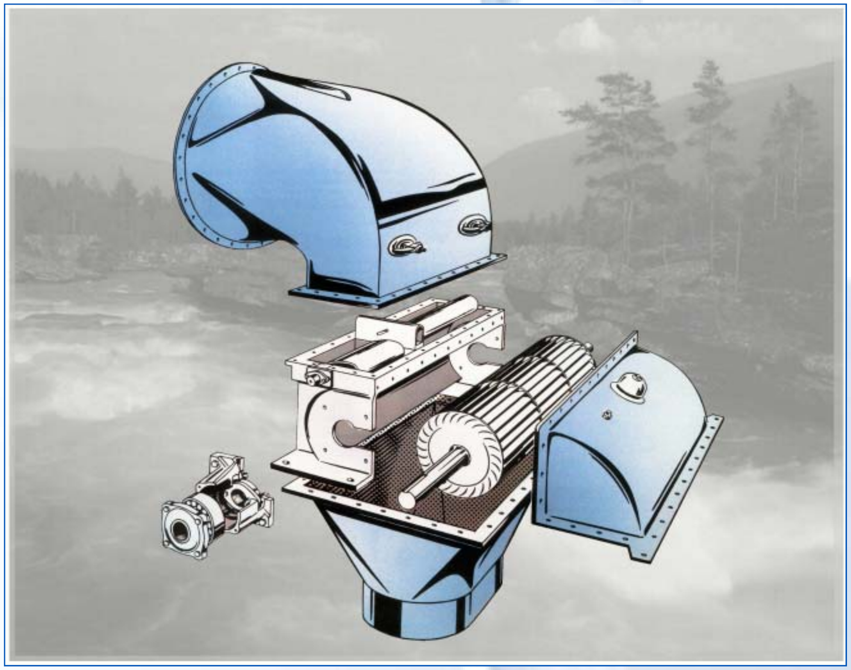
Energy Recovery from PRV Chambers

Available Technologies

- ***Cross Flow Turbine***
  - Simple Construction
  - Good Efficiency over Varying Flows
  - Good Run-of-River Performance
  - Open Discharge



Energy Recovery from PRV Chambers

Available Technologies

- ***Francis Turbine***
  - Reaction Turbine
  - Most Common Hydro Turbine
  - Small to Very Large
  - Moderate Flow Variability
  - Atmospheric Discharge

Energy Recovery from PRV Chambers

Available Technologies

- ***Pump as Turbine***
  - Limited Flow Variability
  - Typically Small Applications
  - Simple Construction
  - Readily Available Technology (low cost)
  - Open/Closed Discharge

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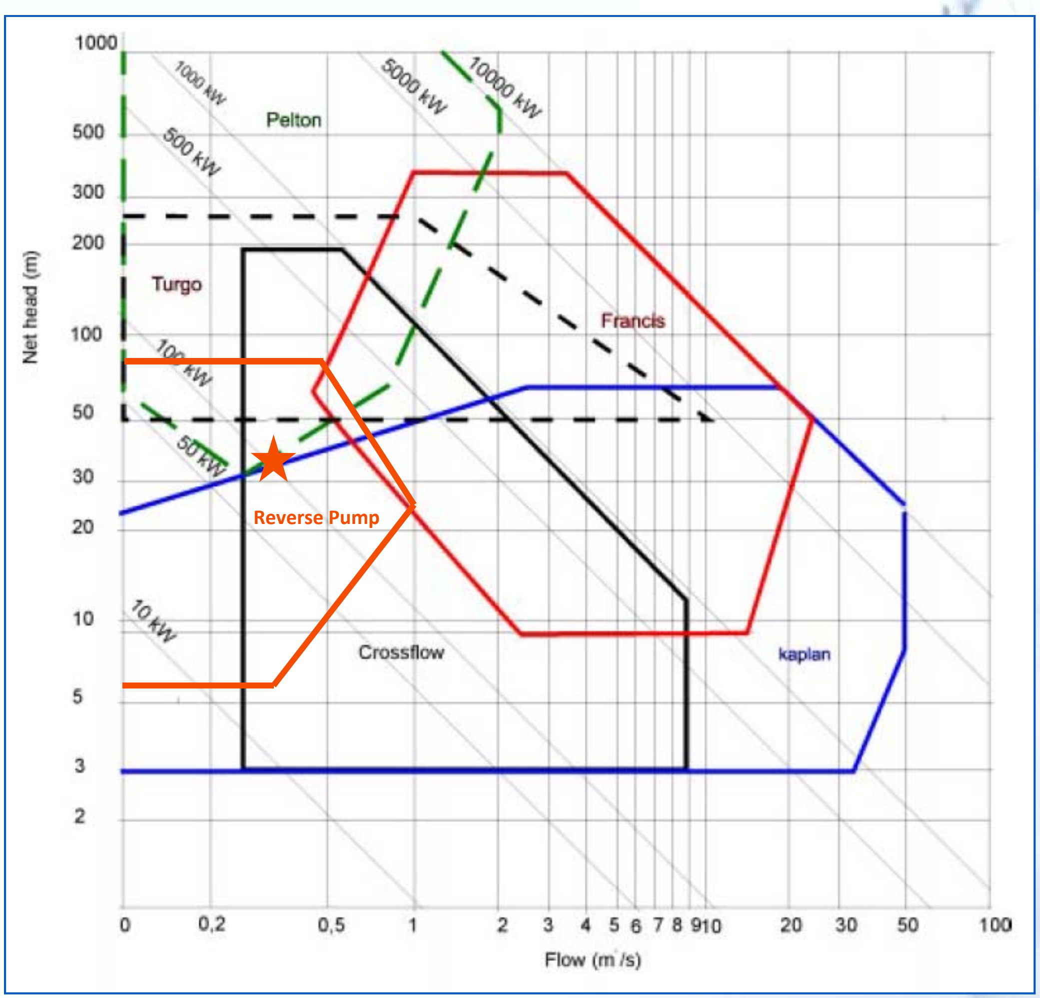
Energy Recovery from PRV Chambers

Available Technologies



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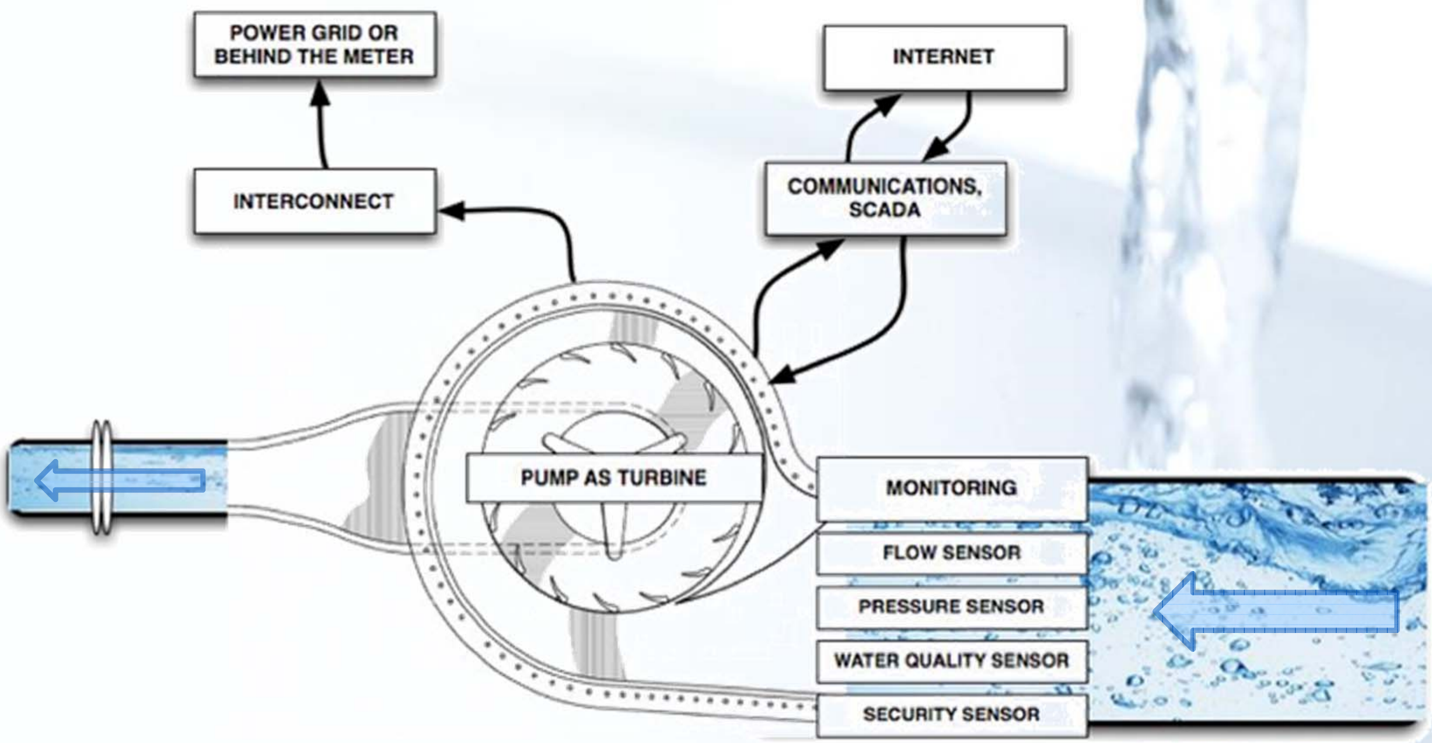
Energy Recovery from PRV Chambers

”Reverse Pump” or “Pump as Turbine” (PaT)



Energy Recovery from PRV Chambers

Known PaT Suppliers

FLOWSERVE

SULZER

CORNELL

KSB

Energy Recovery from PRV Chambers

Orchard Site Considerations

J.D. Kline WSP
- Elevation = ~170 m
- Flows = ~3,600 m^3/hr

WSP vs. Orchard
Elevation Difference ~ 93 m

Pockwock vs. Orchard
Elevation Difference ~ 35 m

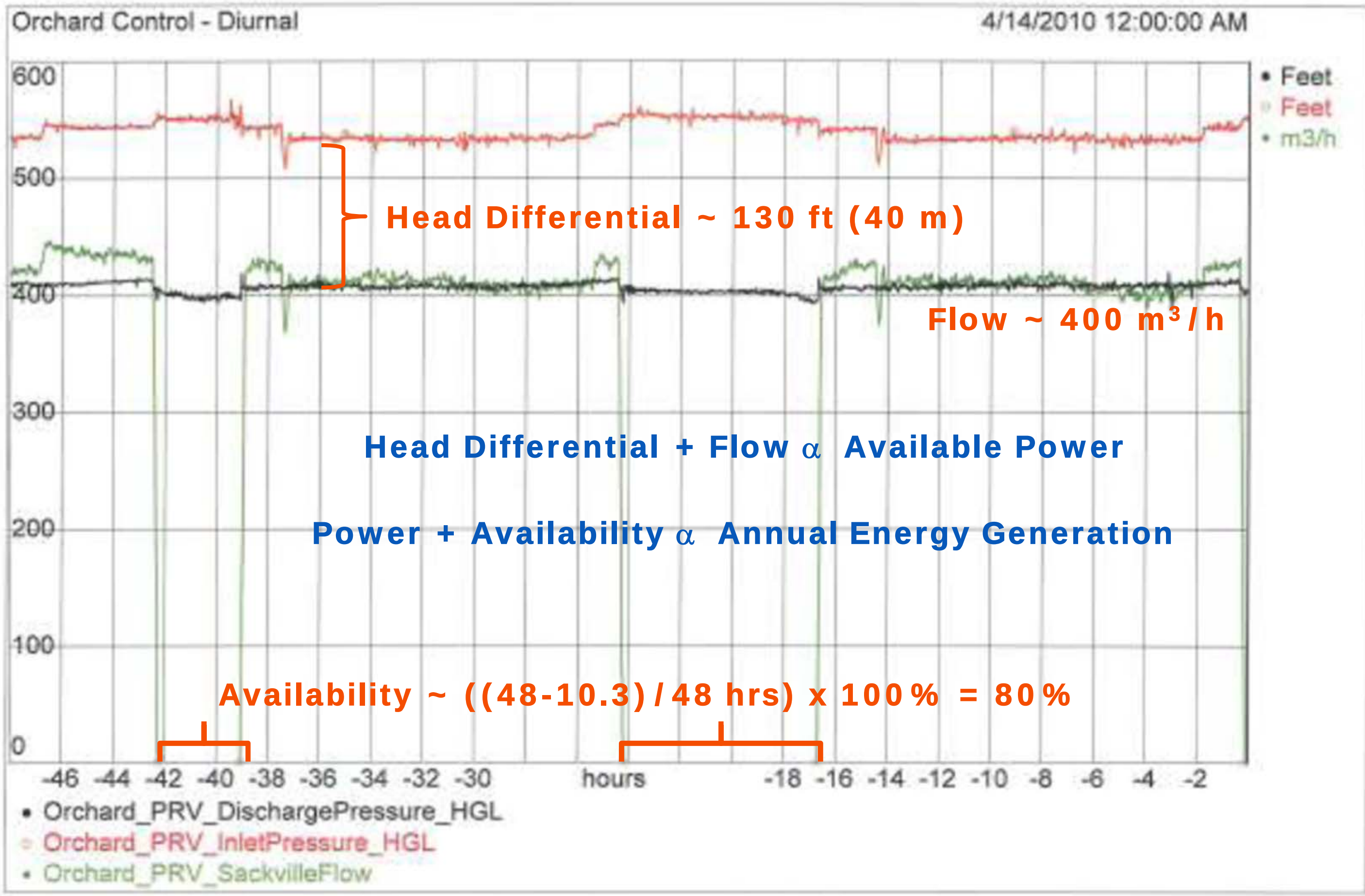
Pockwock Lake + Pumping Station
- Elevation = ~110 m

Orchard PRV Chamber
- Elevation = ~75 m (Gravity Fed)
- Average Capacity = ~33.5 kW
- Flows = ~400 m^3/hr (1,700 USGPM)

Halifax Water

Energy Recovery from PRV Chambers

Orchard System Hydraulics



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Energy Recovery from PRV Chambers

Orchard Power Calculations

- Formula: $P_e = \Delta Z \cdot Q \cdot \rho \cdot g \cdot \eta t \cdot \eta e \cdot \eta f \cdot 1/1000$

  $E_e = P_e \cdot 8760 \cdot R_a$

  Where:
  P_e = Power (kW)
  ΔZ = Head (m)
  Q = Flow (m^3/sec)
  ρ = Density of water (1000 kg/m^3)
  g = Acceleration due to gravity (9.81 m/sec^2)
  η_t = Turbine efficiency ($75\% \leq \eta_t \leq 85\%$)
  η_e = Generator efficiency ($\geq 92\%$)
  η_f = Transformer efficiency ($\geq$ 97%)
  E_e = Energy (kWh)
  R_a = Availability Ratio (Up time/Total time)

  Overall Efficiencies Typically 70 – 75%

Halifax Water

Energy Recovery from PRV Chambers

Orchard Power Calculations

Known Data: Head (ΔZ) = 40 m
Flow (Q) = 0.112 m^3/sec
Density of water = 1000 kg/m^3
Overall Efficiency (η) = 73 %
- Turbine Efficiency (η_t) = 78 %
- Generator Efficiency (η_e) = 93 %

P_e = (40 m · 1000 kg/m^3 · 0.112 m^3/sec · 9.81 m/sec^2 · 73%)/1000
= 32 kW

E_e = 32 kW · 8760 hrs/yr · 0.80
= 225,000 kWh/yr

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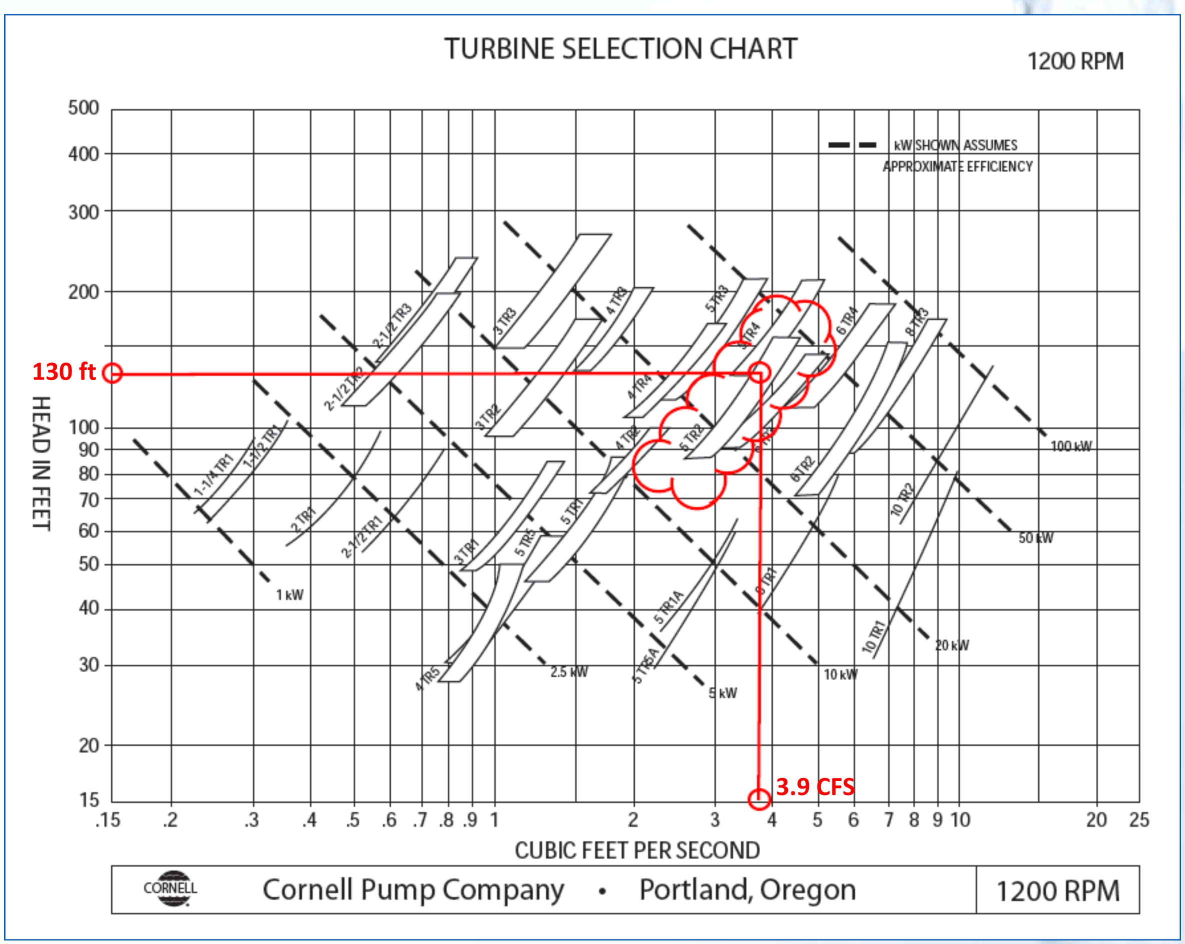
Energy Recovery from PRV Chambers

Orchard Turbine Selection



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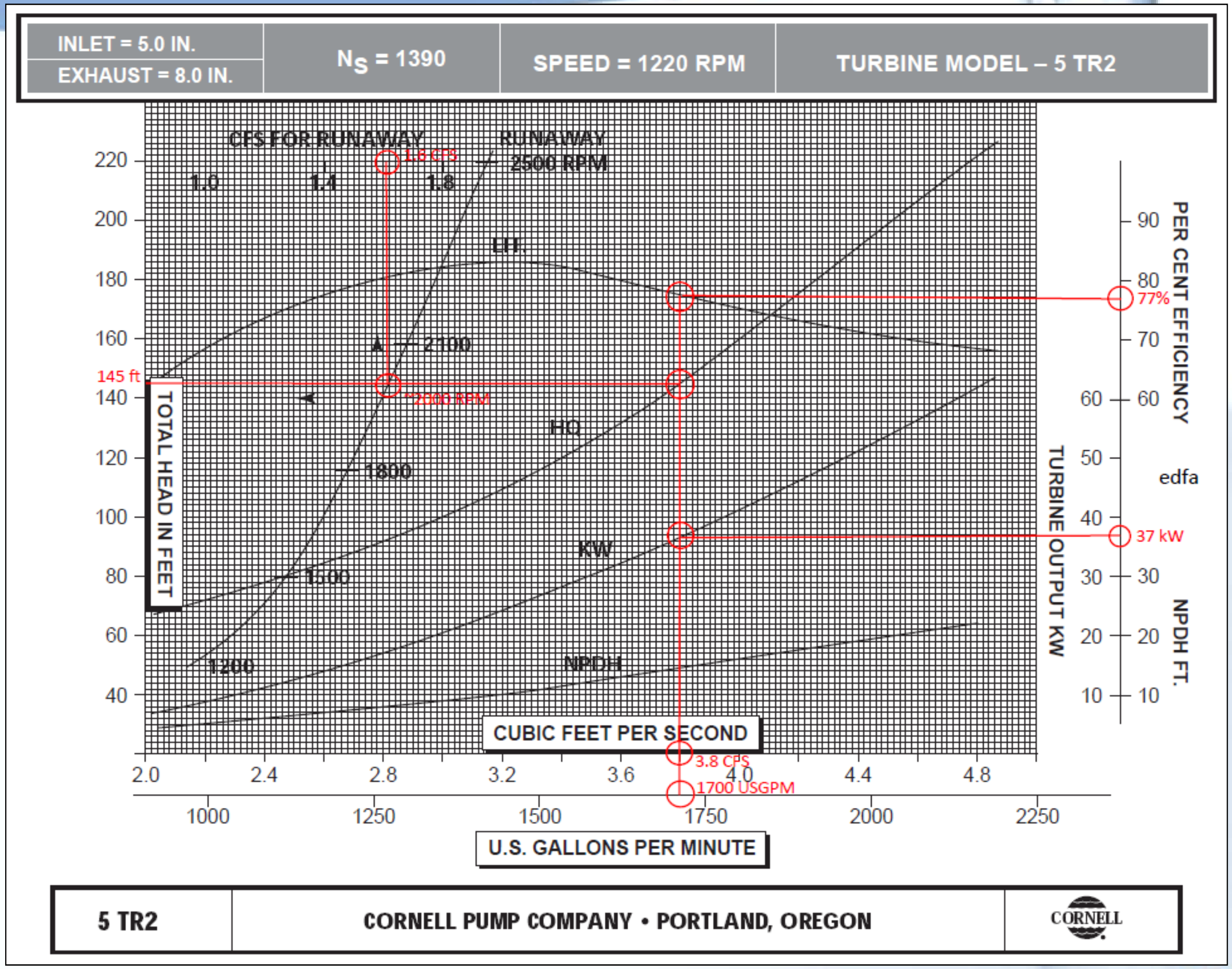
Energy Recovery from PRV Chambers

Orchard Predicted Turbine Performance



Energy Recovery from PRV Chambers

Orchard Project Economics

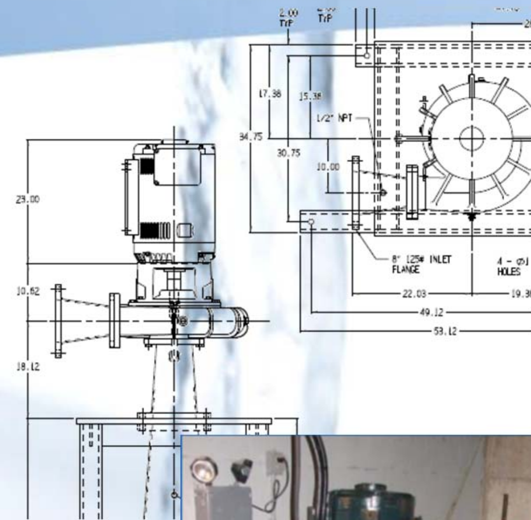
- COMFIT Project ~ $0.14/kWh
- Capacity ~ 32 kW / 225,000 kWh/yr *
- Revenue ~ $31,500/yr *
- Project Cost ~ $468,000
- Part Funded by WRF + NS DOE $200,000
- NPV ~ $350,000
- IRR ~ 11.4% **
- SPB ~ 8.6 Years **

* Estimated

** Based on HW Contribution Only

Energy Recovery from PRV Chambers

Orchard Technical Highlights



- Cornell Model 5TR2 Turbine
- Marathon Induction Generator
- NSF/ANSI 61 Certified
- Fully Instrumented & Monitored (SCADA)
- Failsafe (Beckwith Protective Relay)
- Integral Surge Relief (Cla-Val)
- Variable Rate Inlet Control Valve (Bray/Rotork)
- Manual Isolation Valves (AVK)
- Mechanical Seal (John Crane Type 1)
- Interconnection 600 VAC – 25 KVAC

Energy Recovery from PRV Chambers

Research & Development Perspective

Major Questions to be Answered:

- Water Quality Impacts? *None found.*
- Up/Down Stream Pressure Transients? *Small Upstream.*
- Flow Control? *No Issues.*
- Loss of Grid Connection? *No Impact.*
- Turbine Shutdown? *No Impact.*
- Turbine Runaway? *Upstream PT due to Flow Reduction.*
- Surge Relief? *Necessary, automated Turbine Bypass.*
- Vibration? *No Issues Except for Emergency Shutdowns.*

Energy Recovery from PRV Chambers
Orchard Chamber

Halifax Water

Energy Recovery from PRV Chambers

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Halifax Water

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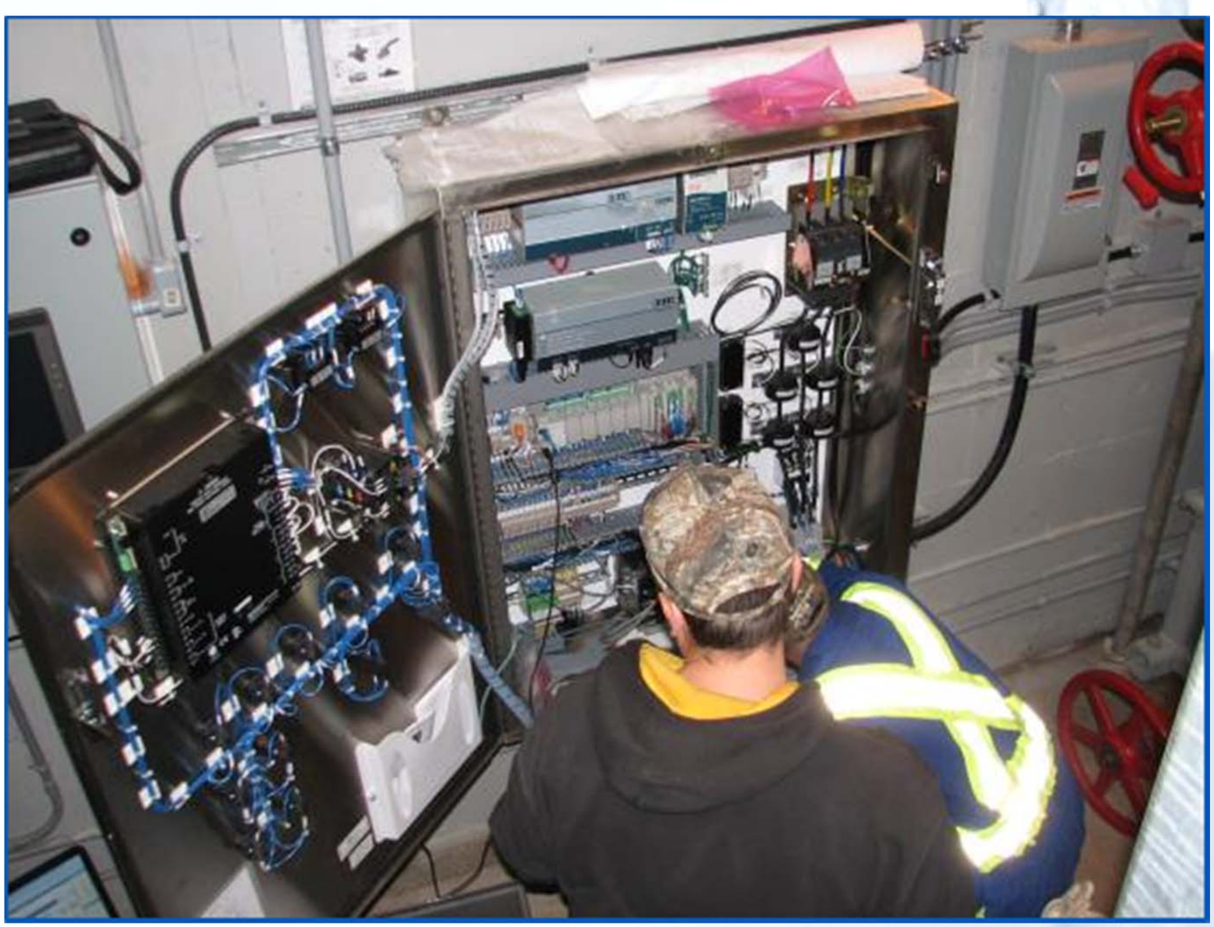
Orchard Chamber

Halifax Water

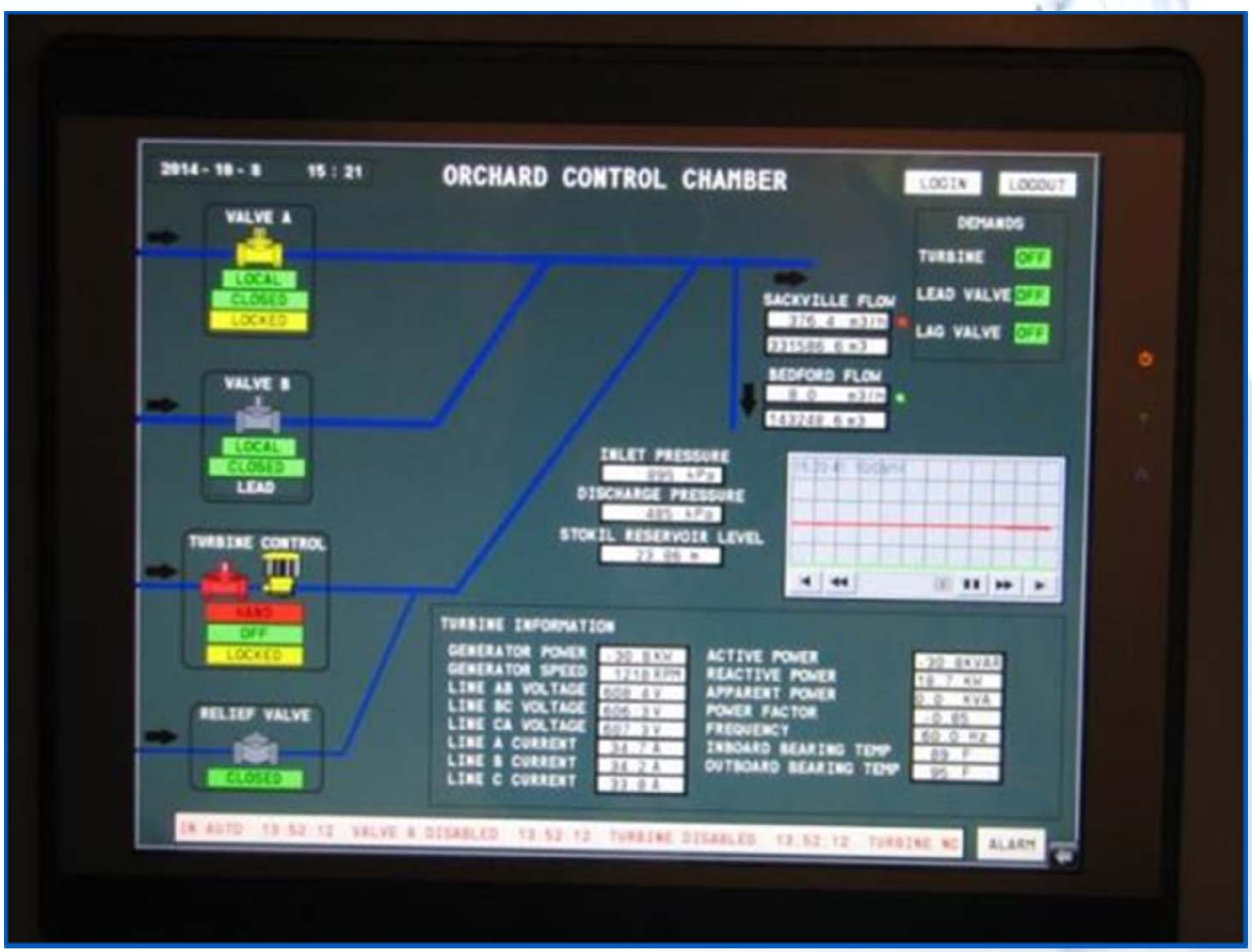
Energy Recovery from PRV Chambers

Orchard Chamber



Energy Recovery from PRV Chambers

Orchard Chamber



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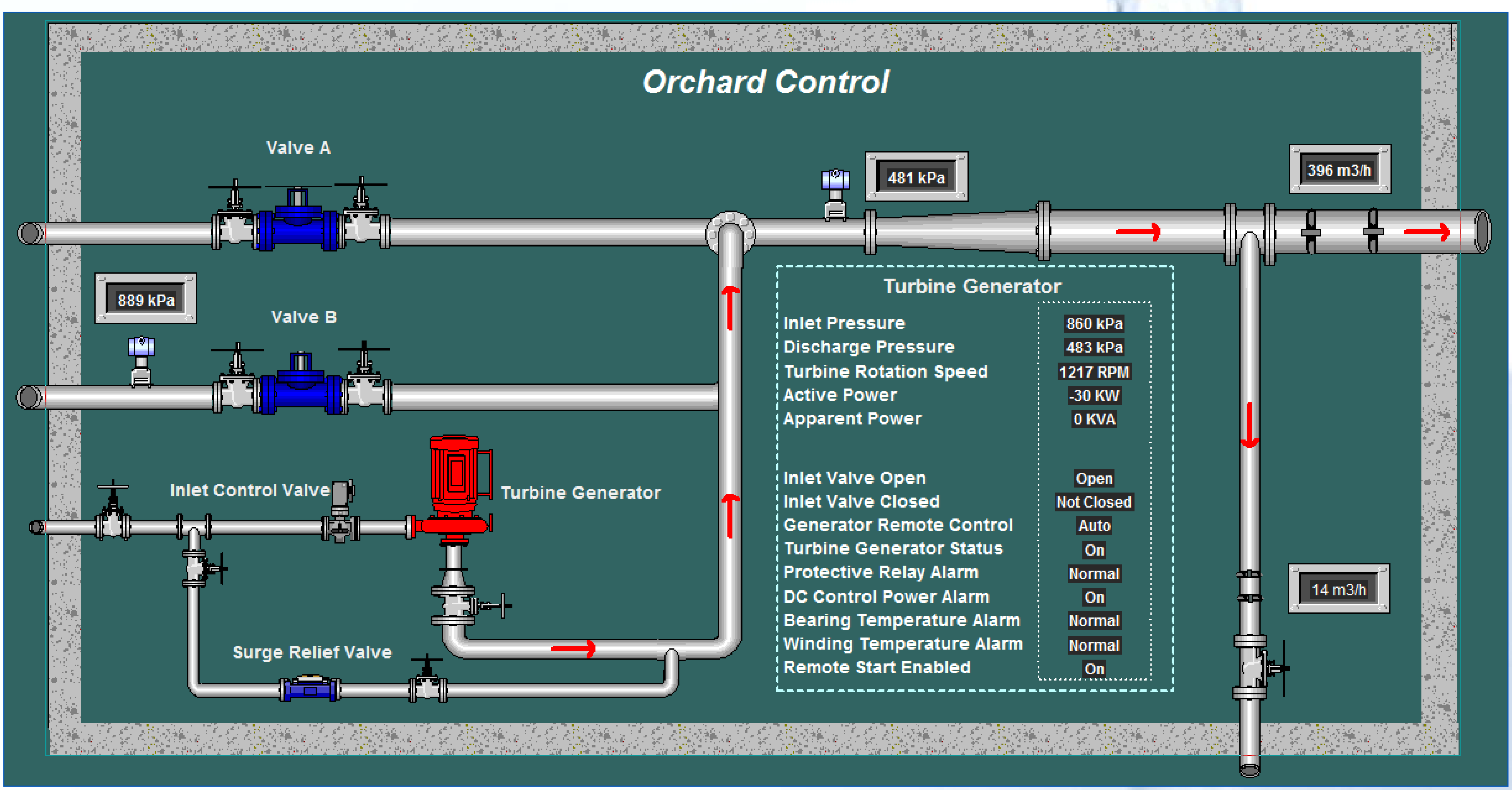
Energy Recovery from PRV Chambers

Orchard Chamber



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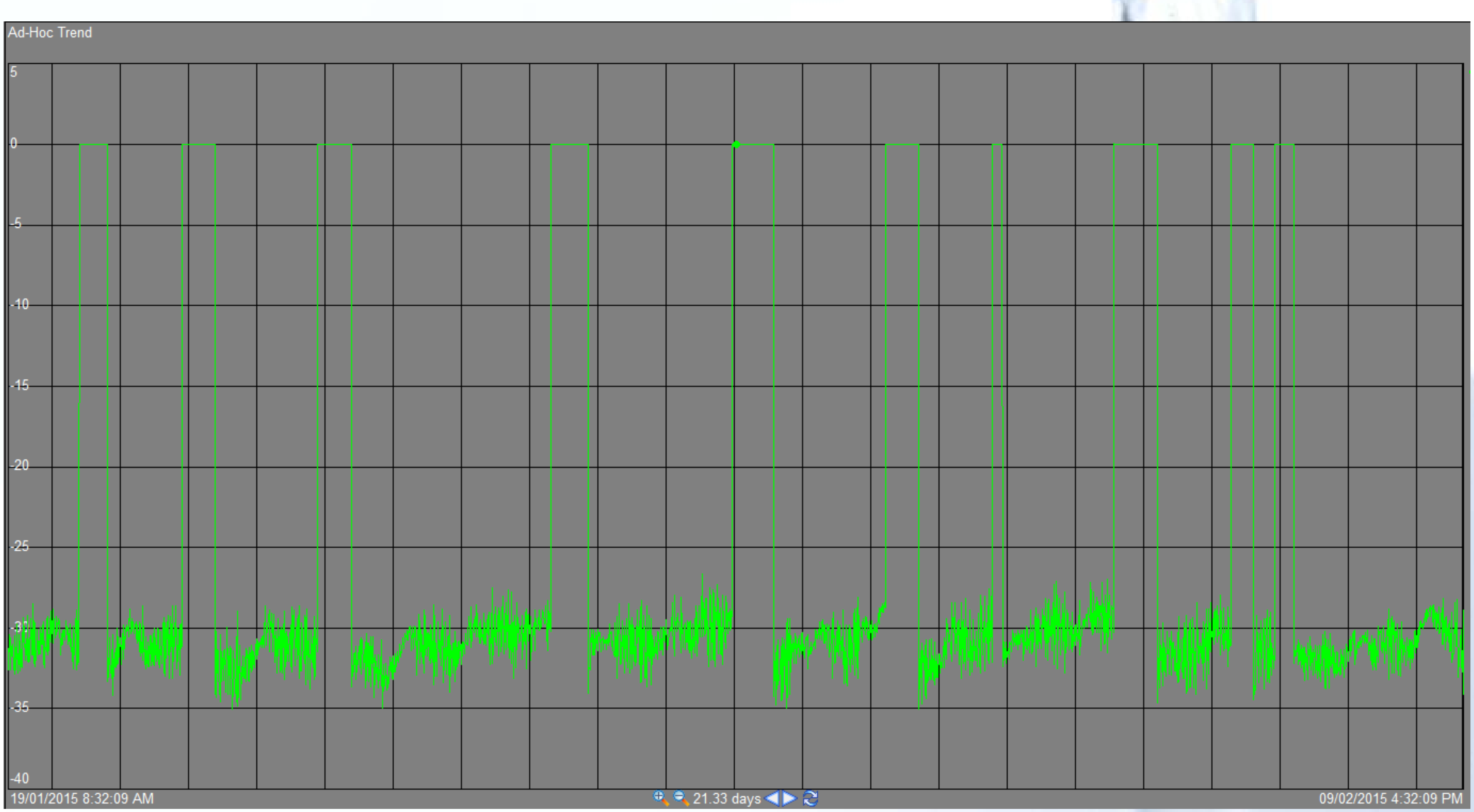
Energy Recovery from PRV Chambers

Orchard Chamber

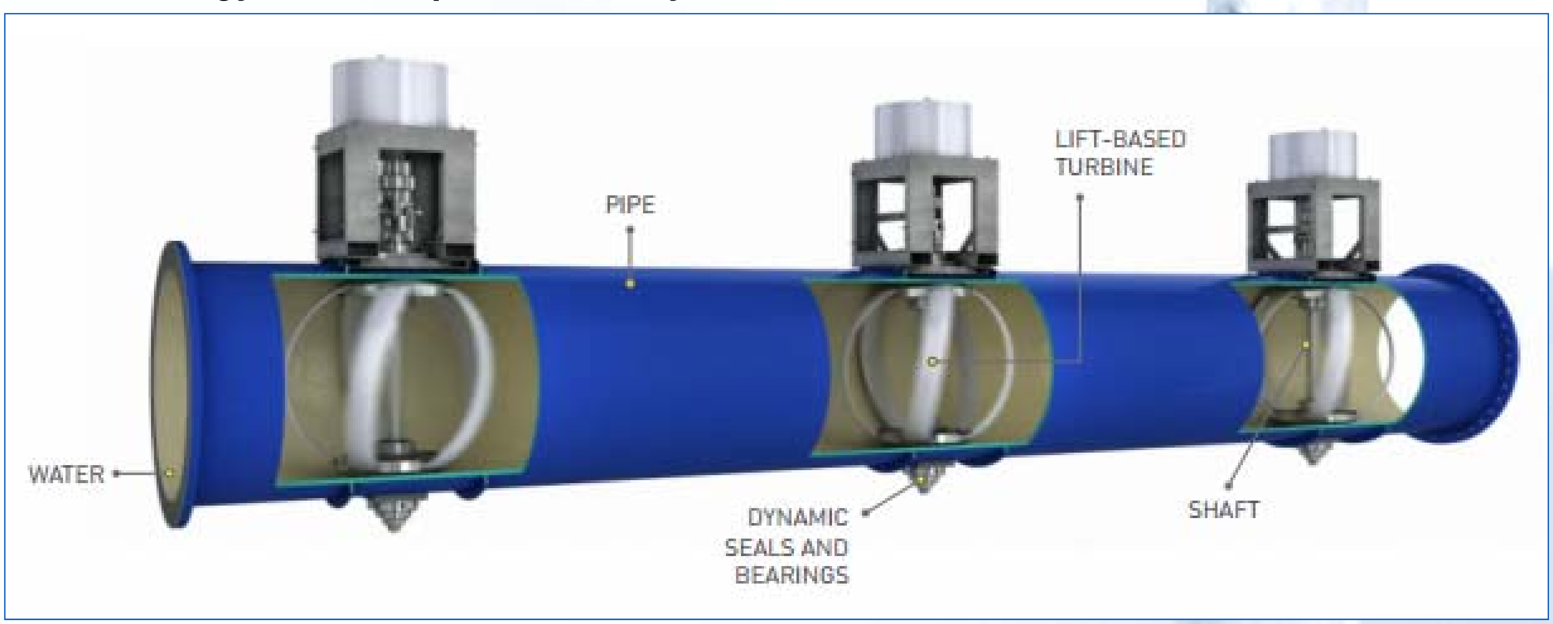


Halifax Water

Energy Recovery from Water Systems

Alternative Technologies

Lucid Energy – LucidPipe™ Power System



http://www.lucidenergy.com/

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Questions?

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