Evaluation of Inter-stage Turbines for Energy Recovery in a Reverse Osmosis Membrane Process treating Brackish Groundwater

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Overview

- ❖ The City of Sarasota (City) Water Treatment Plant (WTP) treats 12 million gallons per day (MGD) using ion exchange (IE) and reverse osmosis (RO) processes (Figure 1).
- ❖ Water is gathered from 51 surficial groundwater wells located 20 miles from the plant and several brackish water wells throughout the City's service area.
- ❖ The IE process and a raw water blend produces up to 7.5 MGD, while the RO process produces around 4.5 MGD, and then is blended altogether before final disinfection.
- ❖ Inter-stage boost recovers energy from the second stage concentrate to provide additional pressure to the second stage feed. This results in lower inputted feed pressure, therefore requiring less energy.

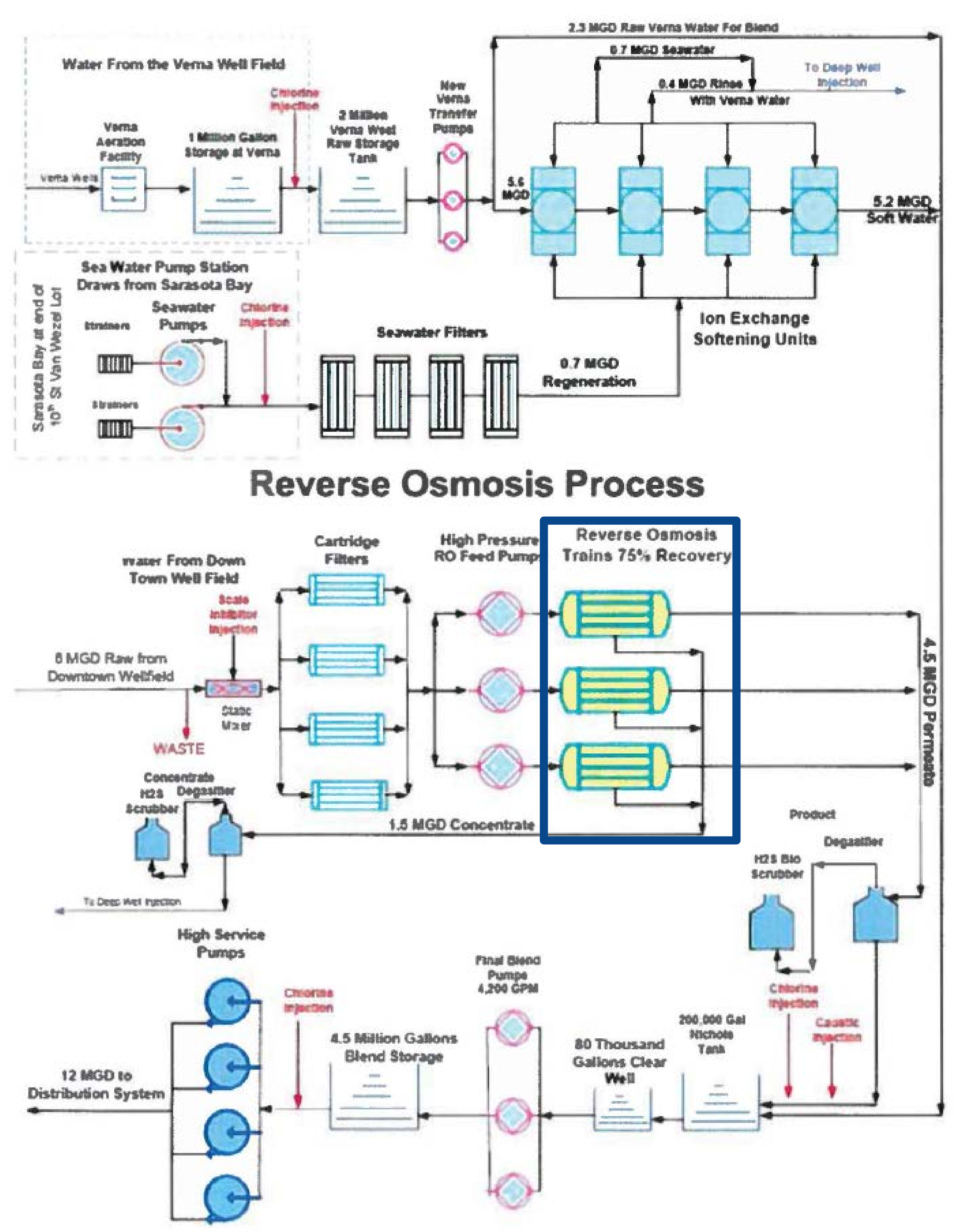

Figure 1: City's WTP Process Flow Diagram

RO System

- 75% Recovery
- 1.5 MGD Capacity per Train
- Three 2-Stage (28x14) RO Trains (A,B,C)
- Six elements in each vessel
  - Stage 1: Hydranautics CPA3
  - Stage 2: Hydranautics ESPA2

Objective

To evaluate the cost and performance impact of installing inter-stage turbines within the City of Sarasota's brackish water reverse osmosis desalination process

Table 1: Water Quality Ion Inputs

Feed Water Ion	Concentrations (mg/L)
Ca^{2+}	279
Mg^{2+}	135
Na^{+}	294
Cl^{-}	588
K^{+}	6.60
Ba^{2+}	16.2
Sr^{2+}	21.9
HCO_3^{-}	136
SO_4^{2-}	858
SiO_2	21.9

Table 2: Operations Inputs

Train	Feed pH	Feed Temperature (°F)	Feed Pressure (psi)	Permeate Flow (MGD)
A	7.13	77.0	219	1.48
B	7.13	77.0	218	1.47
C	7.13	77.0	217	1.46

Figure 2: Train C Side View

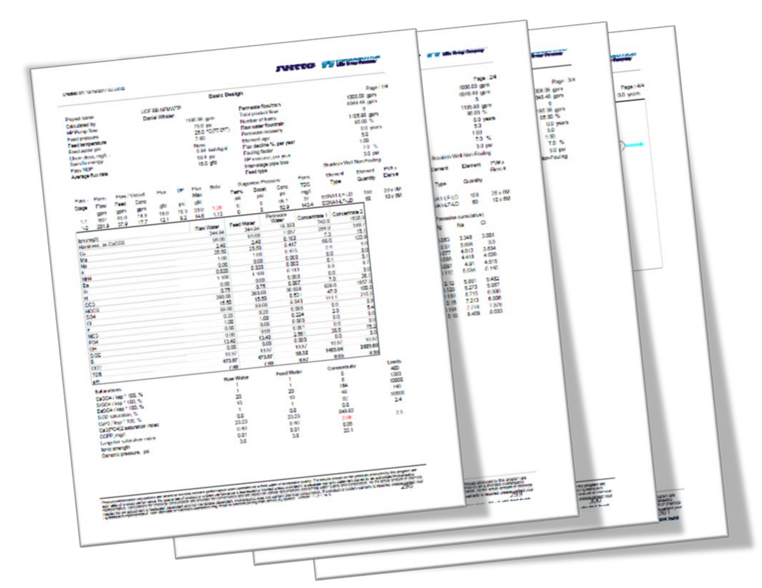

Figure 3: Hydranautics (San Diego, CA) Membrane Manufacturer Design Software

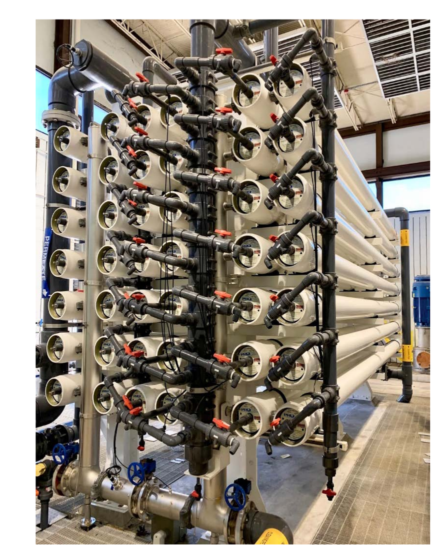

Figure 4: Train C Front Side View

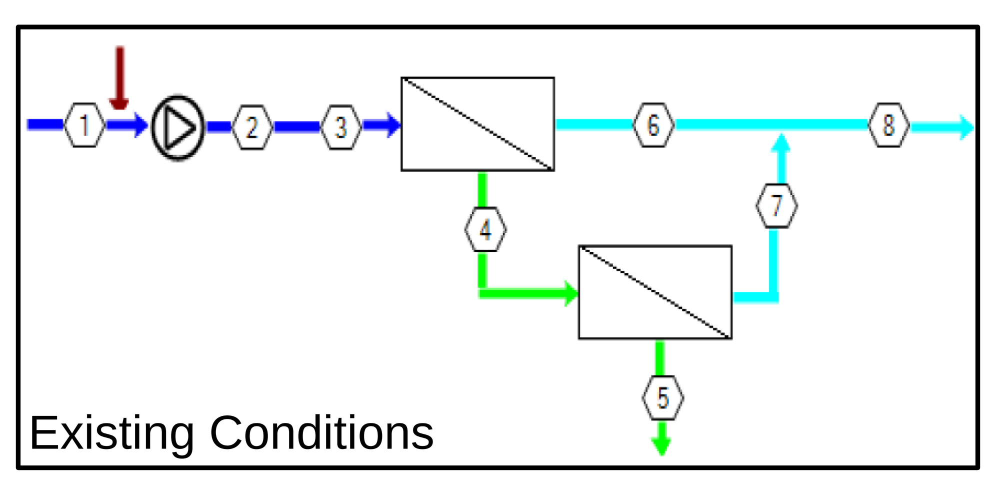

Figure 5: Hydranautics Flow Diagram in Current Conditions
1. Hexagonal numbers are pressure test points.

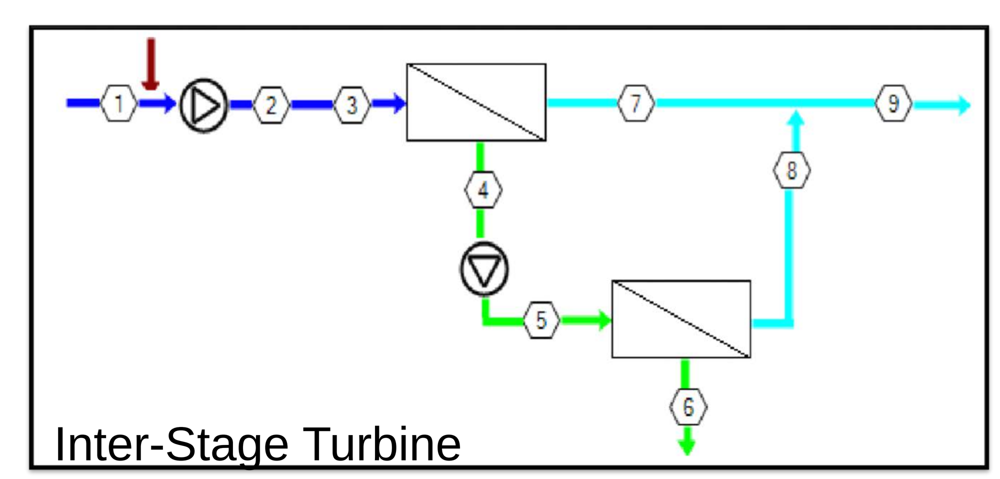

Figure 6: Hydranautics Flow Diagram with Booster Pump
1. Hexagonal numbers are pressure test points.

Table 3: Average Water Quality Outputs

Ion	Conc. (mg/L)
Ca^{2+}	2.23
Mg^{2+}	1.08
Na^{+}	11.2
Cl^{-}	15.7
K^{+}	0.310
Ba^{2+}	0.129
Sr^{2+}	0.175
HCO_3^{-}	8.26
SO_4^{2-}	5.80
SiO_2	0.529

Table 4: Average Train Operations Outputs

Stage 2 Feed Pressure (psi)	177
Specific Energy (kWh/kgal)	2.61
Power Cost ($/yr)	112,000

Table 5: Average Water Quality Outputs

Ion	Conc. (mg/L)
Ca^{2+}	1.94
Mg^{2+}	0.940
Na^{+}	9.79
Cl^{-}	13.8
K^{+}	0.271
Ba^{2+}	0.113
Sr^{2+}	0.153
HCO_3^{-}	7.22
SO_4^{2-}	5.06
SiO_2	0.462

Table 6: Average Train Operations Outputs

Stage 2 Feed Pressure (psi)	258
Specific Energy (kWh/kgal)	2.82
Power Cost ($/yr)	121,000

Results

Table 7: Economical-Energy Analysis of Inputting Inter-stage Turbines

Item	Results Trains A, B, and C
Permeate Flow (MGD)	1.47
Recovered Pressure (psi)	92.7
Δ Specific Energy (kWh/kgal)	0.205
Power Cost Savings ($/yr)	8,700

Table 8: Cost Analysis of the Practicality of Inter-stage Turbines

Total Cost ($)	Life Span (yr)	Power Saved ($/yr)	Power Saved for Life Span ($)	Overall Savings ($)
234,000	5	26,100	131,000	-103,000
234,000	10	26,100	261,000	27,200

1. Break point ≈ 8.96 years
2. A 20-year life span will save $288,000.

Conclusions

- ❖ Investing in three inter-stage turbines, for a life expectancy of 20 years, will save the City $14,400 annually.
- ❖ In a present-worth economic analysis, it will take approximately 9 years to recover the inter-stage turbine investment.
- ❖ Implementing inter-stage turbines would also balance the water flux, therefore reducing pressure loss, and increasing permeate water quality.

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