MEMORANDUM

To: Saqib Shirazi, P.E., Innovative Water Technologies, Texas Water Development Board (TWDB)

FROM: Lianfa Song, Ph.D., Texas Tech

SUBJECT: Demonstration of High Recovery and Energy Efficient RO System for Small-Scale Brackish Water Desalination – August 2011

DATE: December 1, 2011

CONTRACT: 1004831107

Recent Project Activities:

During the current quarter, the following project activities have been completed:

1. Fouling tests have been conducted at a salt (NaCl) concentration of 2,500 mg/L (ppm) and crossflow velocities of 0.1 meter per second (m/sec) and 0.2 m/sec. Results of the fouling tests are presented below in Figures 1 through 4 on pages 2 and 3. Figures 1 and 2 plot pressure increase vs. recovery for various foulant concentrations at 0.1 m/sec and 0.2 m/sec. When pressure increase is plotted as a function of recovery, the relationships between crossflow velocity, foulant concentration and the onset of fouling are difficult to visualize. However, when pressure increase is plotted as a function of operating time, the impacts of foulant concentration and crossflow velocity are much easier to see. Figures 3 and 4 plot pressure increase as a function of time.

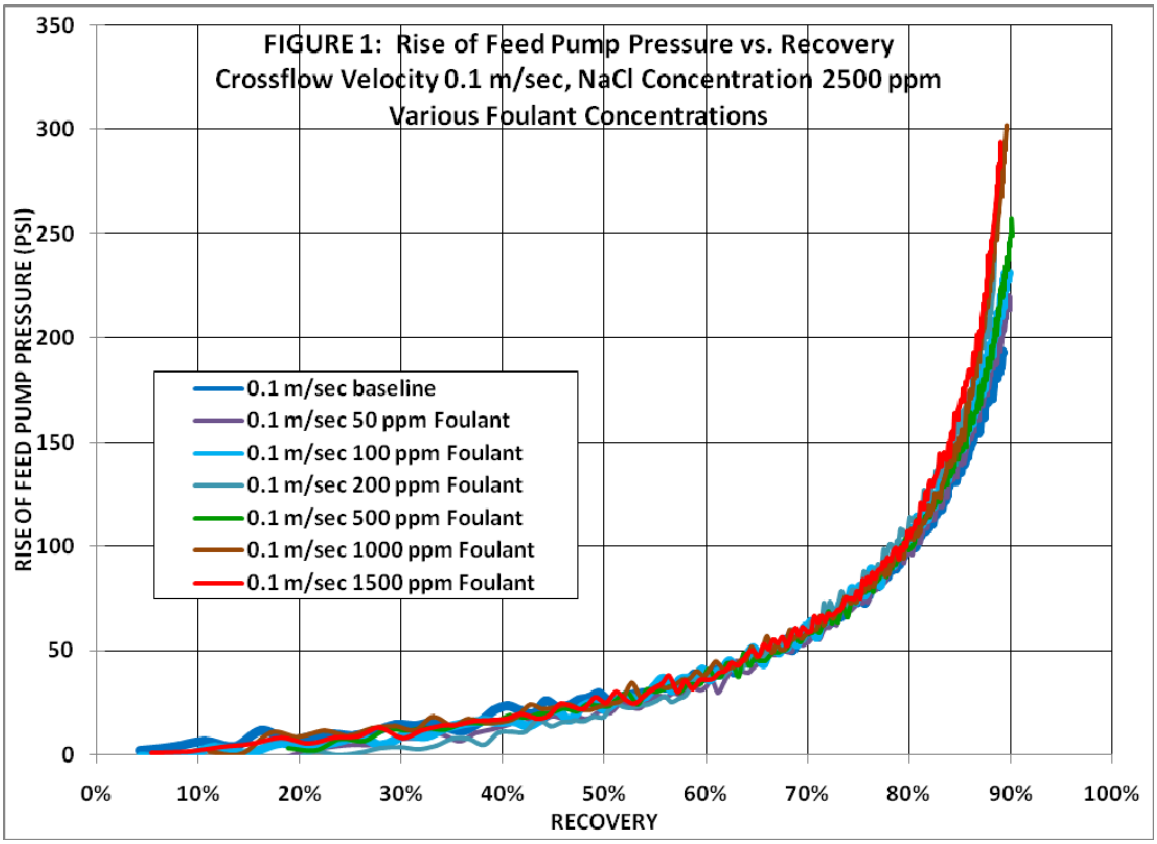
FIGURE 1: Rise of Feed Pump Pressure vs. Recovery
Crossflow Velocity 0.1 m/sec, NaCl Concentration 2500 ppm
Various Foulant Concentrations
RISE OF FEED PUMP PRESSURE (PSI)
RECOVERY
0.1 m/sec baseline
0.1 m/sec 50 ppm Foulant
0.1 m/sec 100 ppm Foulant
0.1 m/sec 200 ppm Foulant
0.1 m/sec 500 ppm Foulant
0.1 m/sec 1000 ppm Foulant
0.1 m/sec 1500 ppm Foulant
0
50
100
150
200
250
300
350
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

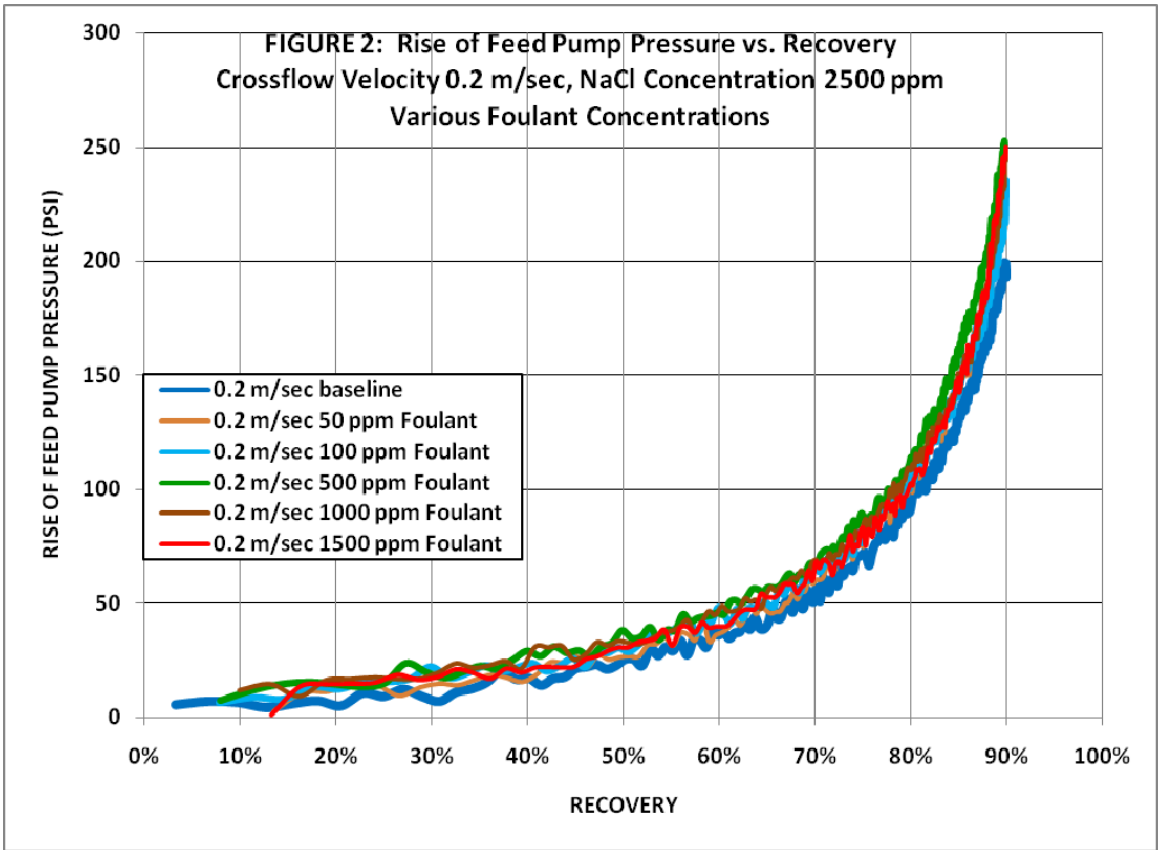
FIGURE 2: Rise of Feed Pump Pressure vs. Recovery
Crossflow Velocity 0.2 m/sec, NaCl Concentration 2500 ppm
Various Foulant Concentrations
RISE OF FEED PUMP PRESSURE (PSI)
RECOVERY
0.2 m/sec baseline
0.2 m/sec 50 ppm Foulant
0.2 m/sec 100 ppm Foulant
0.2 m/sec 500 ppm Foulant
0.2 m/sec 1000 ppm Foulant
0.2 m/sec 1500 ppm Foulant
0
50
100
150
200
250
300
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

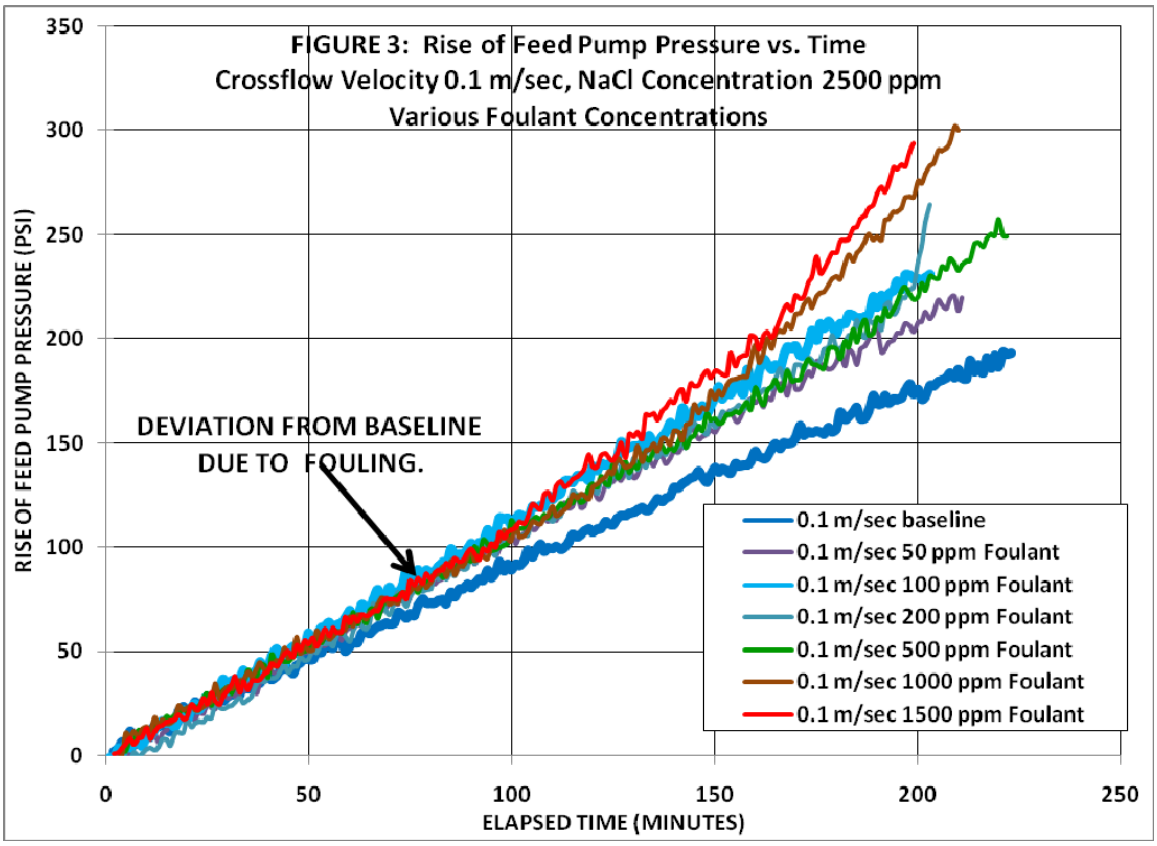
FIGURE 3: Rise of Feed Pump Pressure vs. Time
Crossflow Velocity 0.1 m/sec, NaCl Concentration 2500 ppm
Various Foulant Concentrations
RISE OF FEED PUMP PRESSURE (PSI)
ELAPSED TIME (MINUTES)
DEVIATION FROM BASELINE
DUE TO FOULING.
0.1 m/sec baseline
0.1 m/sec 50 ppm Foulant
0.1 m/sec 100 ppm Foulant
0.1 m/sec 200 ppm Foulant
0.1 m/sec 500 ppm Foulant
0.1 m/sec 1000 ppm Foulant
0.1 m/sec 1500 ppm Foulant
0
50
100
150
200
250
300
350

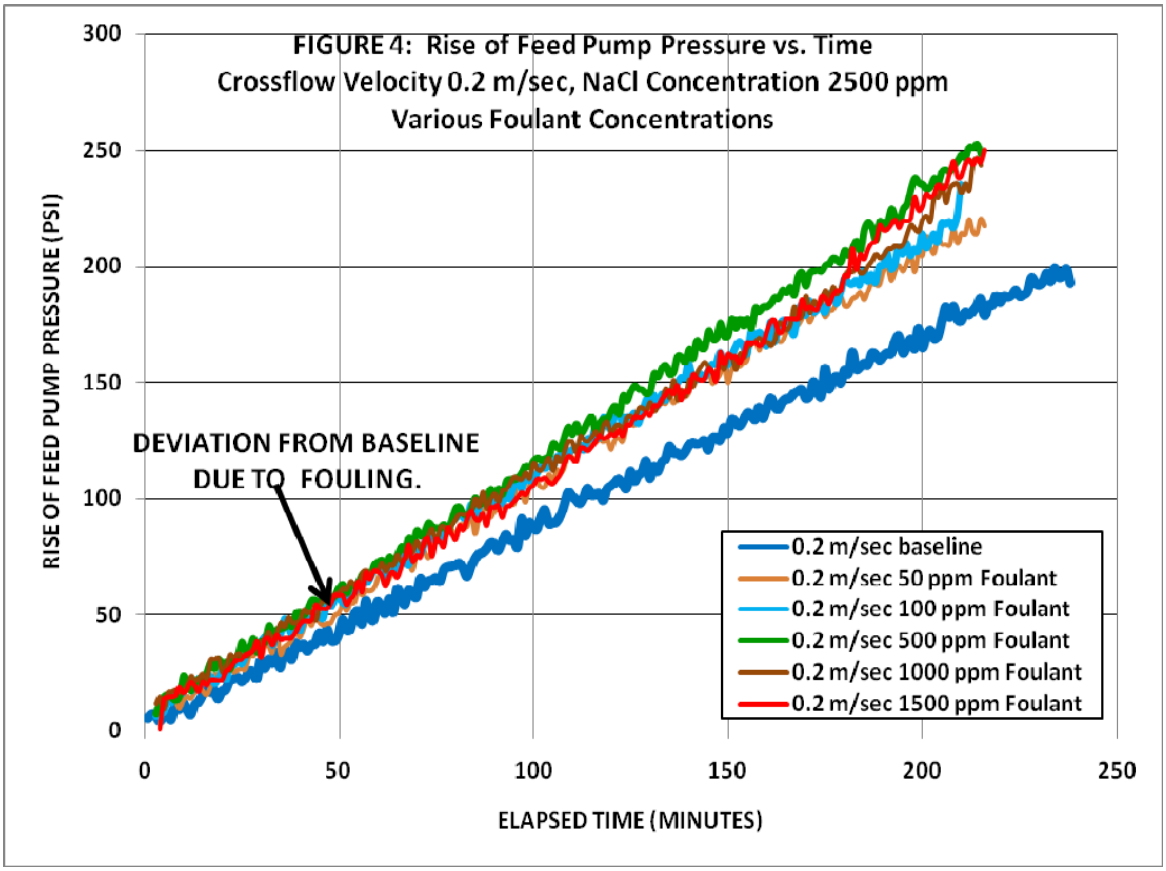
FIGURE 4: Rise of Feed Pump Pressure vs. Time
Crossflow Velocity 0.2 m/sec, NaCl Concentration 2500 ppm
Various Foulant Concentrations
RISE OF FEED PUMP PRESSURE (PSI)
ELAPSED TIME (MINUTES)
DEVIATION FROM BASELINE
DUE TO FOULING.
0.2 m/sec baseline
0.2 m/sec 50 ppm Foulant
0.2 m/sec 100 ppm Foulant
0.2 m/sec 500 ppm Foulant
0.2 m/sec 1000 ppm Foulant
0.2 m/sec 1500 ppm Foulant
0
50
100
150
200
250
300

Because pressure readings were extremely "noisy", 4-minute averaging of pressure readings was used. The onset of fouling at both crossflow velocities is marked by a deviation from the baseline (no foulant present) pressure over time. Although deviation from baseline appears to occur slightly earlier in the tests at the higher crossflow velocity (0.2 m/sec), the severity of the deviation and the apparent effects of fouling are much worse after a period of about 3 hours in tests at the lower crossflow velocity (0.1 m/sec). This agrees with what one would expect regarding the impact of crossflow velocity on fouling severity.

The effect of foulant concentration at the lower crossflow velocity becomes significant after about 2 hours, while the effect of foulant concentration at the higher crossflow velocity becomes significant after about 3 hours.

Feed pressure increases at 0.1 m/sec crossflow velocity appear to be larger for the test solution containing 100 ppm foulant than for the solution containing 500 ppm foulant. One explanation for this anomalous behavior might be increased contact between foulant particles at the higher concentration creating even larger particles and preventing the foulant from entering the void spaces within the membranes. The same behavior is observed for test solutions containing 500 ppm foulant at a crossflow velocity of 0.2 m/sec.

2. A research paper describing preliminary results of energy consumption studies on the experimental RO system has been prepared in draft form and is currently undergoing revision prior to journal submission. The paper presents results for tests conducted at three NaCl concentrations: 1,000 ppm, 2,500 ppm and 5,000 ppm; several feed and permeate flowrates ranging from 0.4 gallons per minute (gpm) to 1.0 gpm; and several recirculation flowrates ranging from 2.0 gpm to 5.0 gpm.

3. The energy consumption of the experimental RO process has been compared to energy consumption of conventional large-scale RO published in the literature. Comparisons made between the experimental process and conventional large-scale RO have been included in the draft research paper being prepared for publication.

Issues Encountered:

1. The introduction of foulant into the RO system impacts the ability of the variable flow drive system to maintain target feed flowrates. This impact, as expected, increases as the foulant concentration increases, but is significant at all foulant concentrations. When test solutions contain only dissolved NaCl, the measured permeate flowrate, which should equal the target feed flowrate, is within +/- 10% of the target flowrate. When foulant is introduced, the measured permeate flowrate varies within a much wider range, i.e., +/- 20% of the target feed flowrate.

Items to be Addressed and Anticipated Project Activities:

1. Duplicate tests will be conducted as necessary to determine repeatability of test results.

2. Results of energy consumption studies will be finalized and prepared for publication. Additional tests will be conducted as necessary to address data gaps.

3. Results of fouling tests shall be prepared in draft form for publication. Additional tests will be conducted as necessary to address data gaps.