Management of Produced Water in Oil & Gas Operations:
Produced Water Treatment and Re-use in Field Demonstrations of Natural Habitat Restoration

- David B. Burnett GPRI
- Department of Petroleum Engineering
- Texas A&M University
- Faculty Group: Water Resource Management in Oil & Gas Operations

- 979 845 2274
- http://www.gpri.org
- http://pumpjack.tamu.edu/

San Angelo O.C. Fisher Reservoir, April 1999

Does Produced Water have Value?

1. **Can the water be treated economically?**
   Impurities removed
   Salinity removed
   It's a lot easier than refining crude oil

2. **What can the water be used for?**
   Agriculture, watershed augmentation
   Landscaping, Livestock Watering
   Artificial Wetlands, Habitat Restoration
   Rangeland Recovery

3. **Is the water environmentally safe?**

4. **Is there a method that will allow the water's value to be realized?**
   - **Sell or trade the water**
   - **Recover the cost of treatment**
   - **Tax Incentive to help rural sustainability**

Proving that Produced Water is a Resource & not a Pollutant

- Step 1:
  - Designing Water Treatment to achieve acceptable fresh water quality.
- Step 2:
  - Developing a Water Reuse Program to utilize the water in beneficial manner.
- Step 3:
  - Monitoring to Ensure Environment is not harmed.
- Step 4:
  - Realizing Water as Value for the Community

Outline of This Presentation

- Summary of the Texas A&M Program
- Description of Produced Water Treatment Technology
- Outline of Program to use Treated Water to Restore Native Rangelands & Wildlife Habitat
- Monitoring to Ensure Environmental Compliance
- Discussion of Incentives for Operators who Manufacture Fresh Water

Produced Water Treatment and Reuse Program –Collaborators & Co-Sponsors

- ***<u>Texas Water Resources Institute (TWRI),</u>***
- **Department of Pet Eng,**
- **Rangeland Ecology Management**
- **Environmental Toxicology**
- **Department of Soils Science**
- **A&M Extension Agency**

<u>Global Petroleum Research Institute (GPRI),</u>

Chemical Engineering Separation Sciences Laboratory

Department of Rural Sociology

Department of Wildlife & Fisheries

Hydrology

<u>Ground Water Protection Council (GWPC)</u>

Current Regulatory Practices in Areas

Texas

- Texas Railroad Commission
  - "Land Farming"
  - "Surface Deposition on Land farms"
- Texas Natural Resources Conservation Commission
  - Environmental impact statement
- EPA
  - To be determined.

Other Areas

to be determined

The Four Major Project Areas

- Step 1:
  - Water Treatment Project to develop portable filtration Units.
- Step 2:
  - Water Reuse Project to utilize the water in beneficial manner.
- Step 3:
  - Monitoring to Ensure Environment is not harmed.
- Step 4:
  - Realizing Water as Value for the Community

Step 1: Oil Field Brine Treatment

1. Design a process module with the capability to de-oil, desalinate and convert oilfield produced brine to fresh water.

   Prove the design in laboratory tests

   Build a prototype unit for field treatment

   Incorporate Process Stream Monitoring - Remote

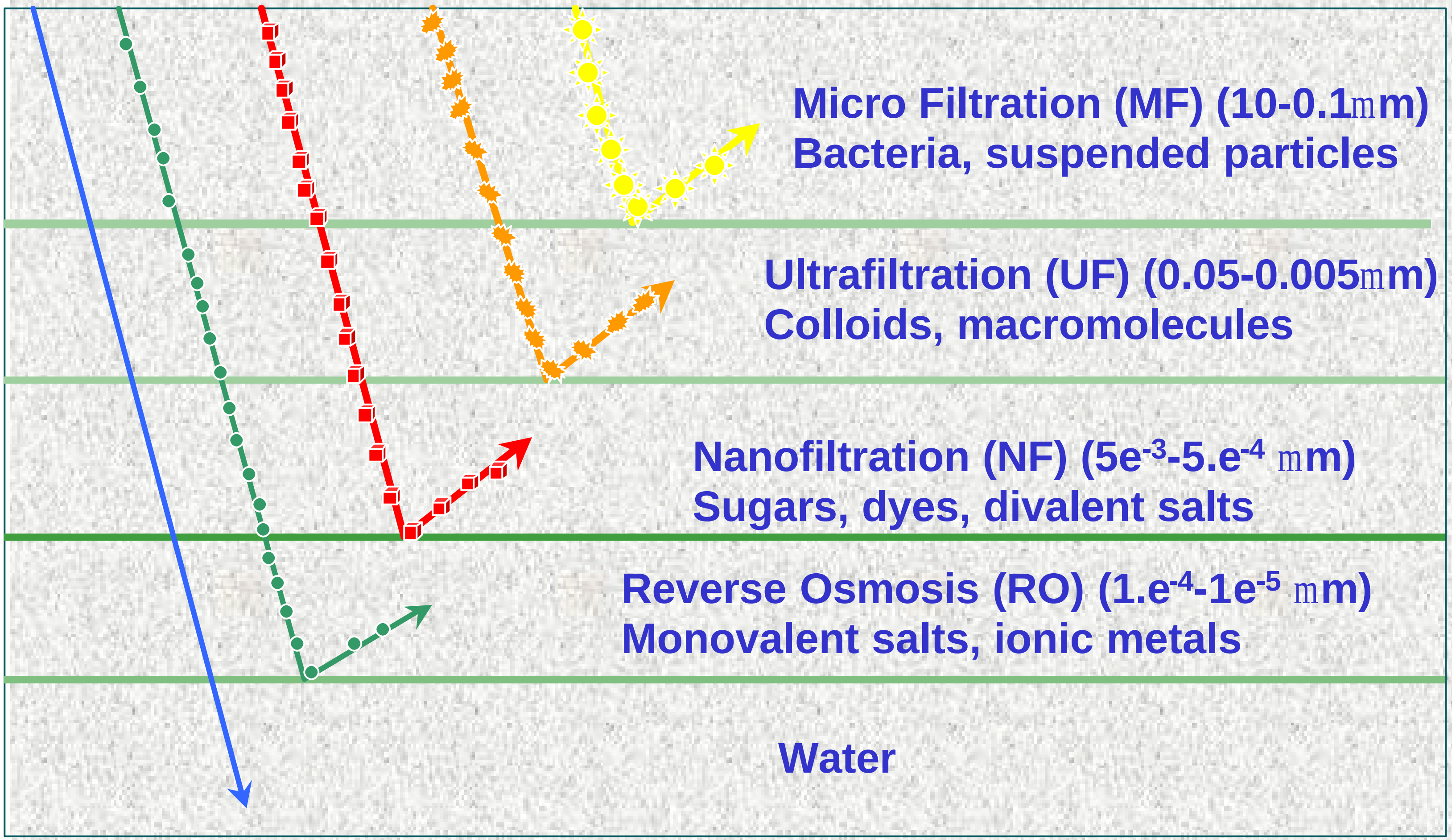
2. Incorporate this GPRI project into the overall program currently being conducted at Texas A&M University

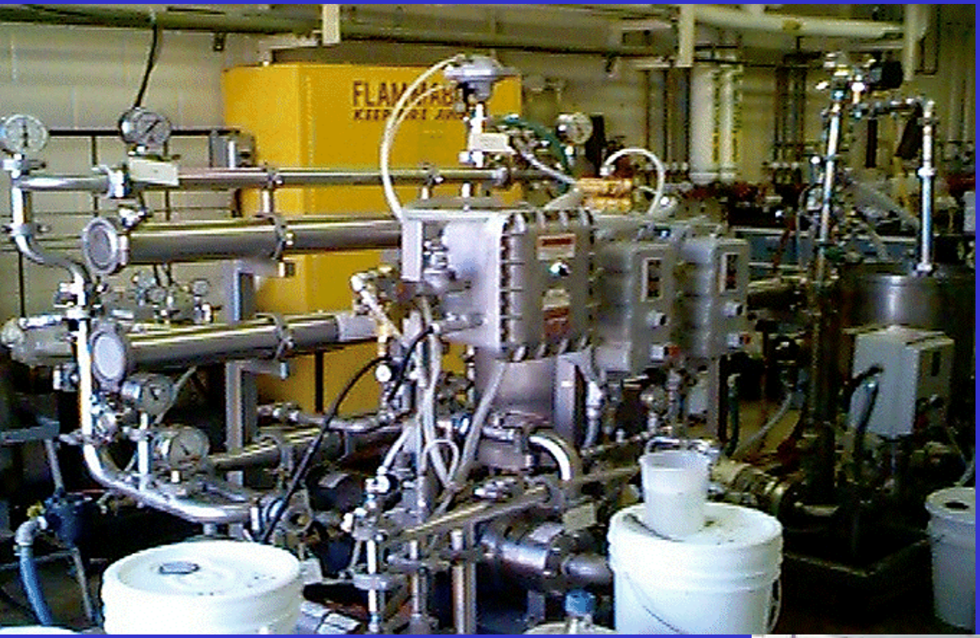
Produced Water Treatment: Tasks

- To design for oilfield applications. Plan for portability. Design for compatibility with field facilities.

  - Accommodate variation in input stream characteristics
  - Take advantage of continued disposal of waste stream from conversion units.
  - Design for relatively small fresh water output for use nearby.
  - Plan for automated operation. Reliability and safety issues are critical.
  - Utilize existing infrastructure, power, fluid distribution.
  - Work with local, state and federal agencies to incorporate new technology into permitted operations.

Filtration and Reverse Osmosis: Definitions

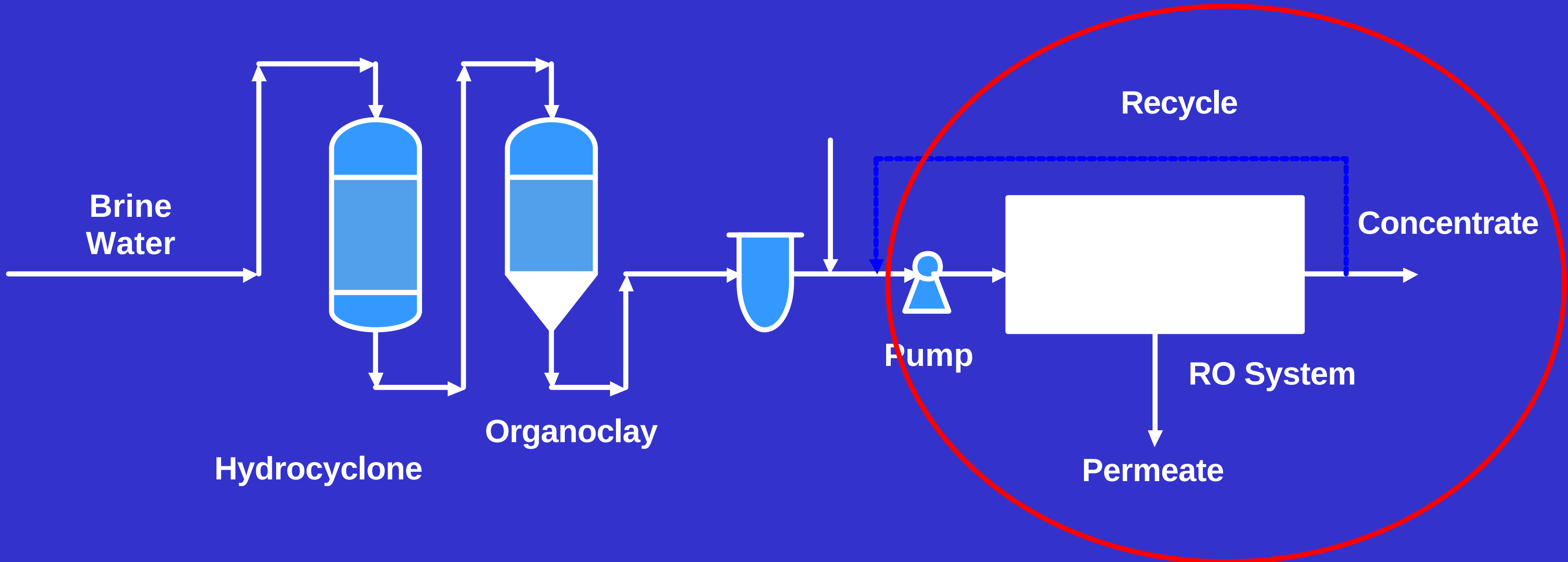




Facilities: Produced Water Treatment Program

Separation Sciences Lab Texas A&M University

Brine Desalination Process



Recent Test Results with New Membrane Filters

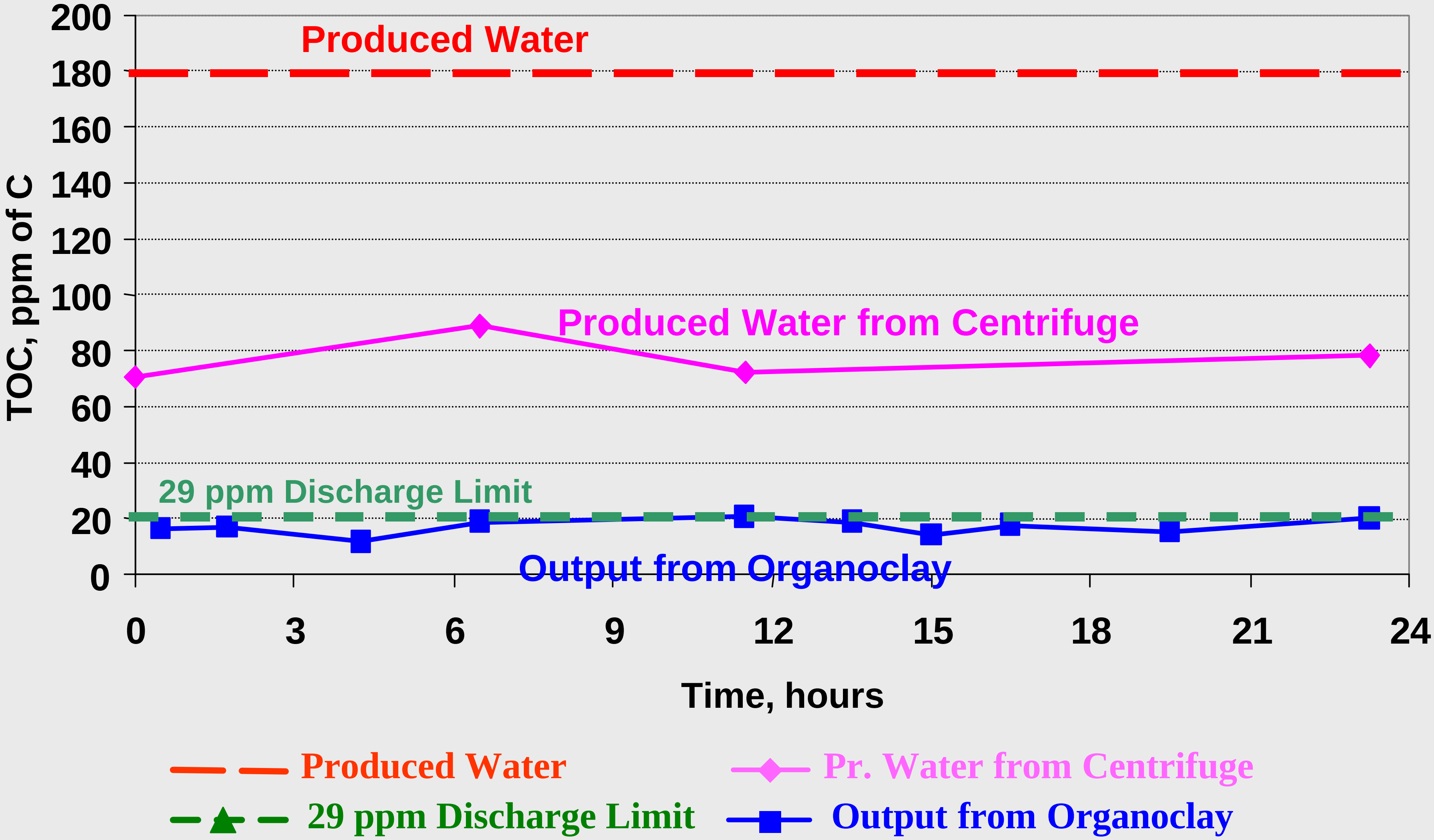
Oil Rejection

Desalination

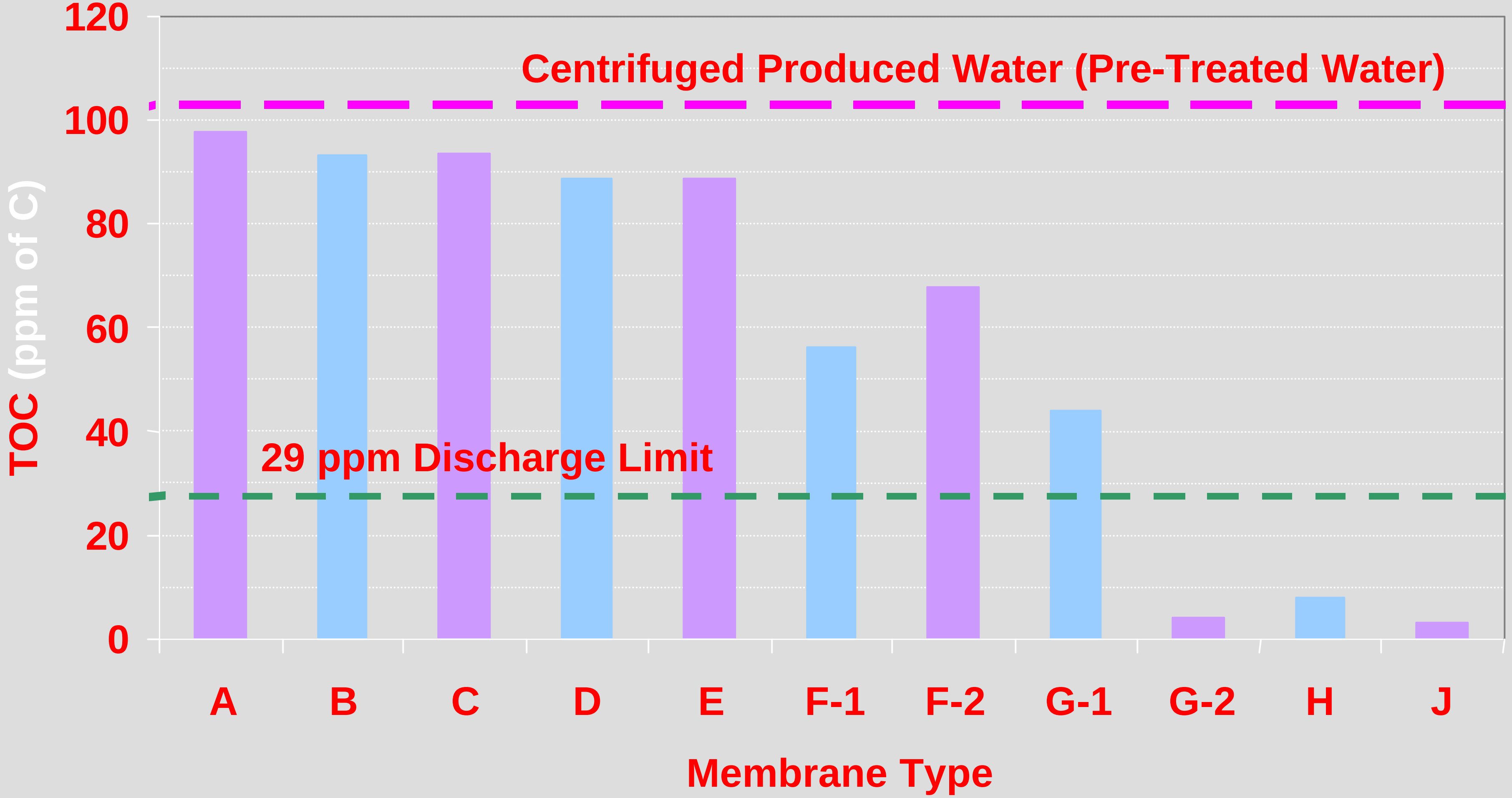
Flux

Efficiency

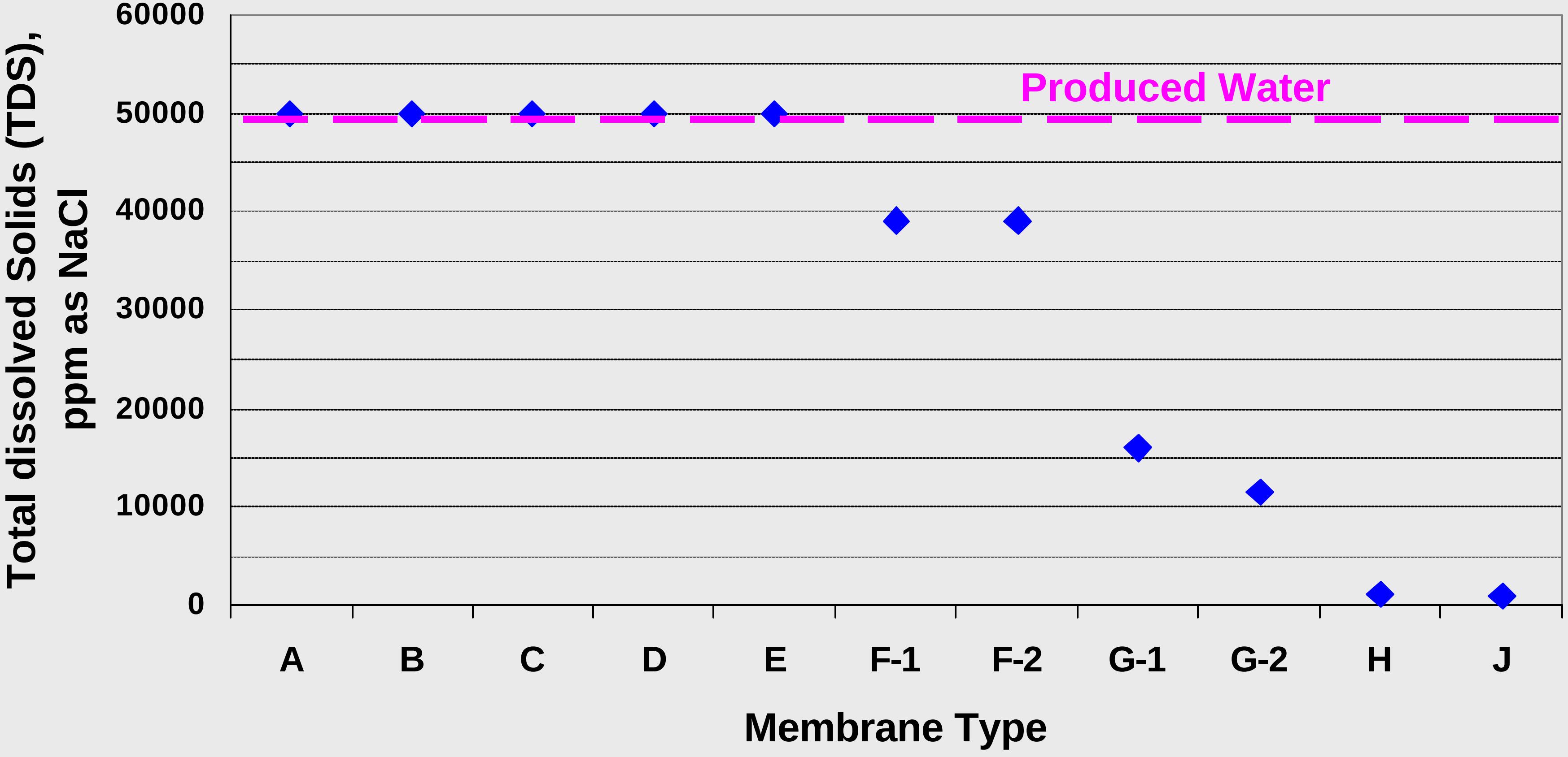
Reduction in TOC by Centrifuge and Organoclay



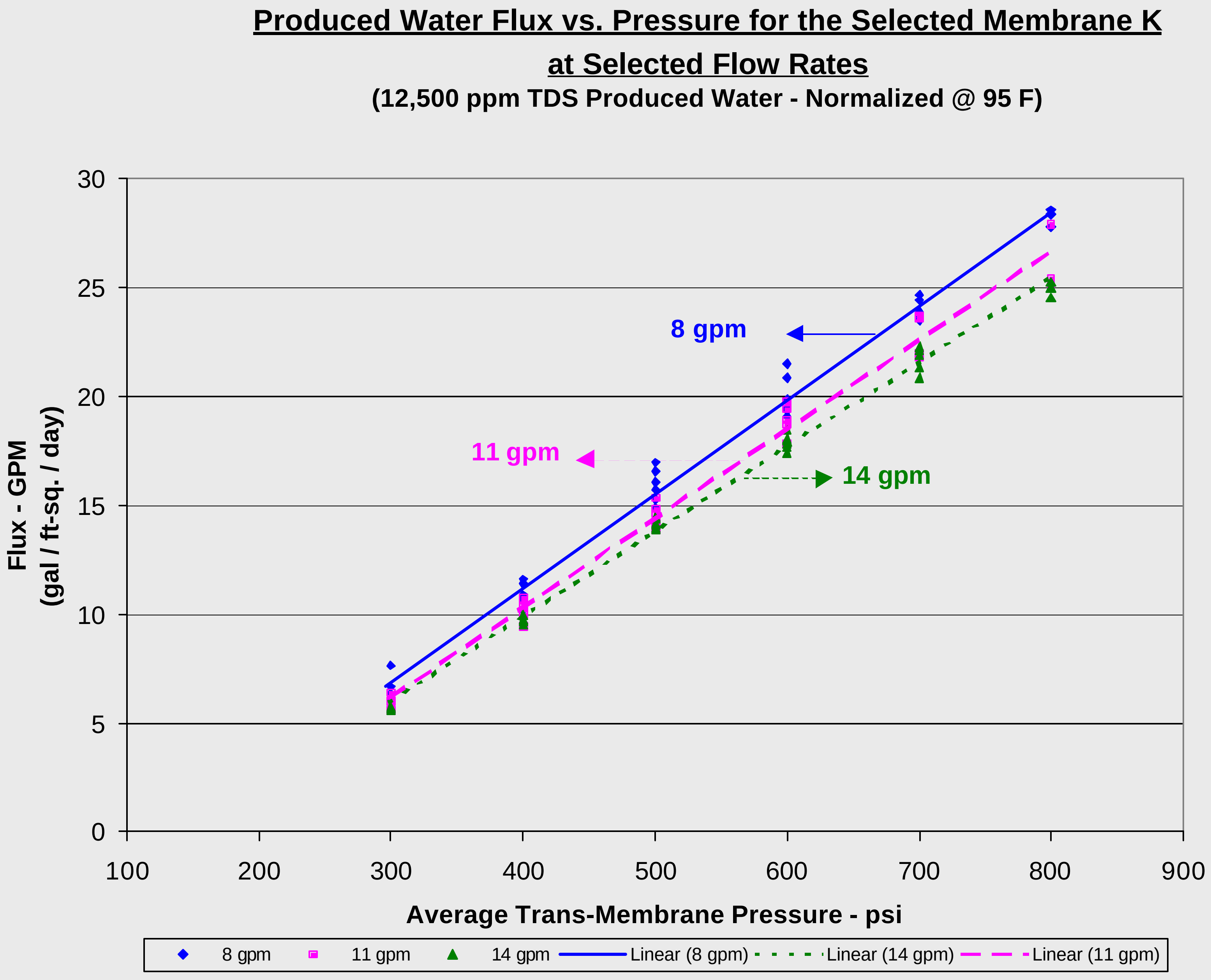
Reduction in TOC by Membranes

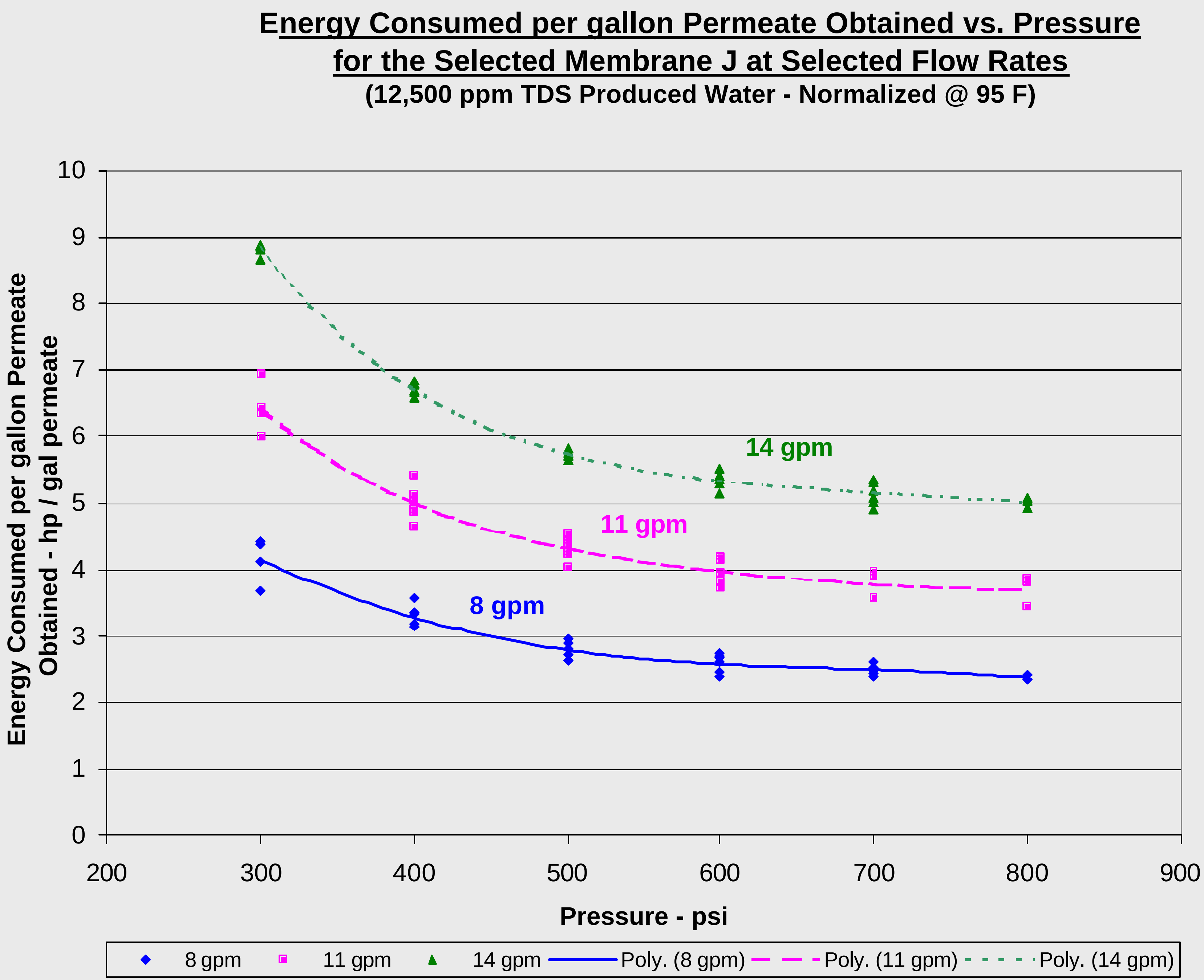


Salt Rejection by Membranes

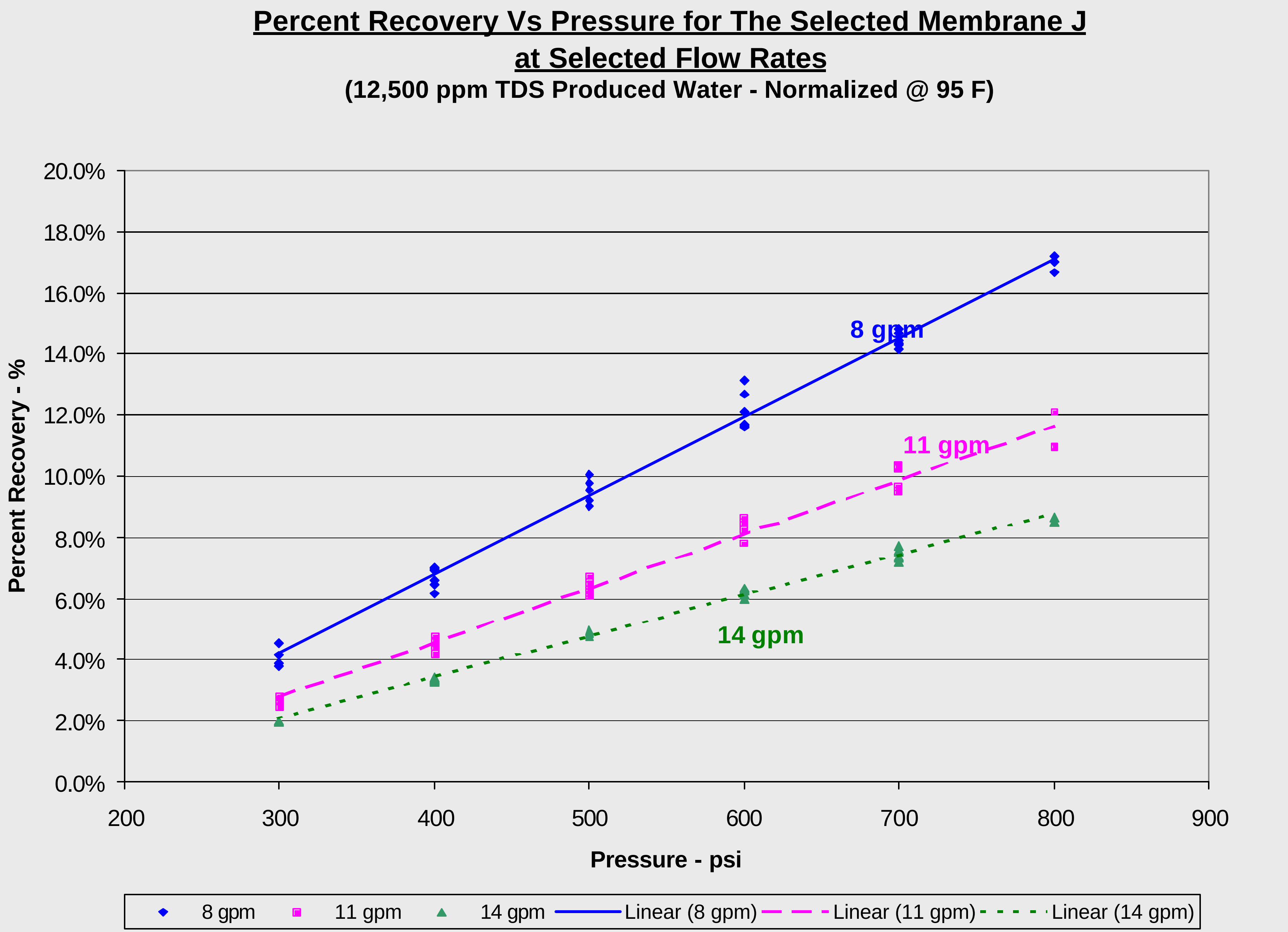


- **Total dissolved Solids (TDS) in Permeate (Salt Concentration)**

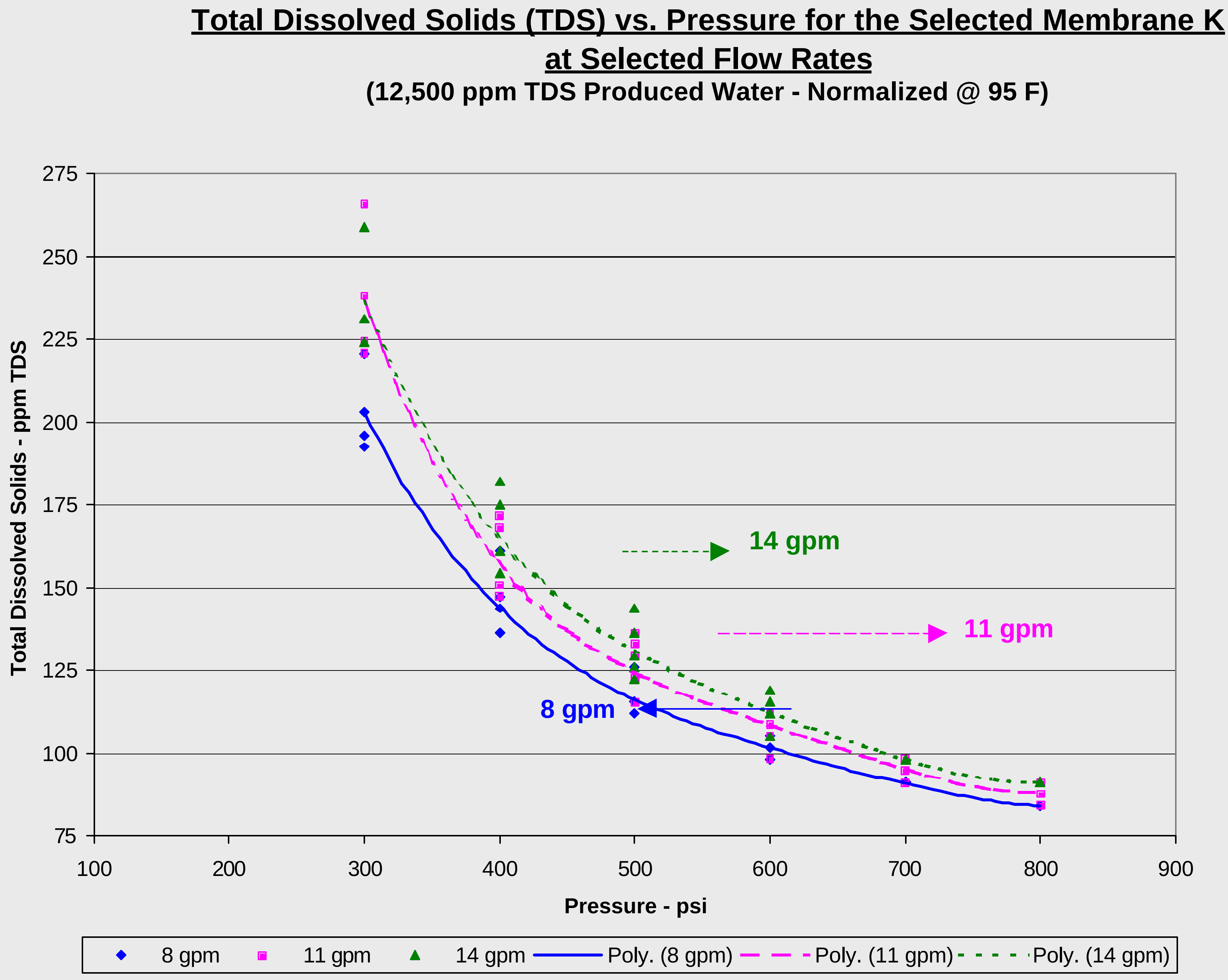

Produced Water Flux vs. Pressure for the Selected Membrane K
at Selected Flow Rates
(12,500 ppm TDS Produced Water - Normalized @ 95 F)
Flux - GPM
(gal / ft-sq. / day)
30
25
20
15
10
5
0
100
200
300
400
500
600
700
800
900
Average Trans-Membrane Pressure - psi
8 gpm
11 gpm
14 gpm
8 gpm
11 gpm
14 gpm
Linear (8 gpm)
Linear (14 gpm)
Linear (11 gpm)



Energy Consumed per gallon Permeate Obtained vs. Pressure
for the Selected Membrane J at Selected Flow Rates
(12,500 ppm TDS Produced Water - Normalized @ 95 F)
Energy Consumed per gallon Permeate Obtained - hp / gal permeate
Pressure - psi
0
1
2
3
4
5
6
7
8
9
10
200
300
400
500
600
700
800
900
14 gpm
11 gpm
8 gpm
8 gpm
11 gpm
14 gpm
Poly. (8 gpm)
Poly. (11 gpm)
Poly. (14 gpm)



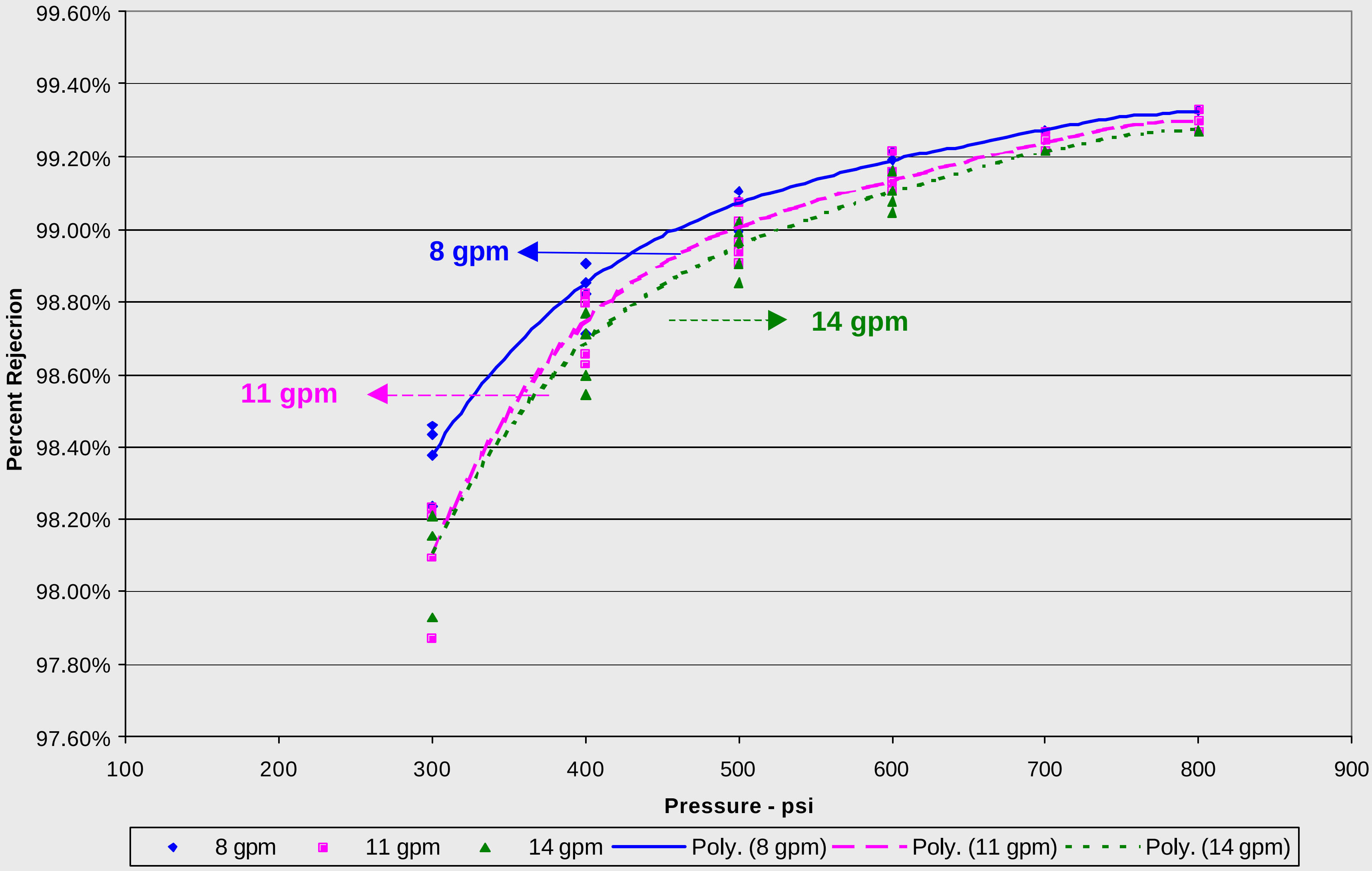
Percent Recovery Vs Pressure for The Selected Membrane J
at Selected Flow Rates
(12,500 ppm TDS Produced Water - Normalized @ 95 F)
Percent Recovery - %
20.0%
18.0%
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
200
300
400
500
600
700
800
900
Pressure - psi
8 gpm
11 gpm
14 gpm
8 gpm
11 gpm
14 gpm
Linear (8 gpm)
Linear (11 gpm)
Linear (14 gpm)

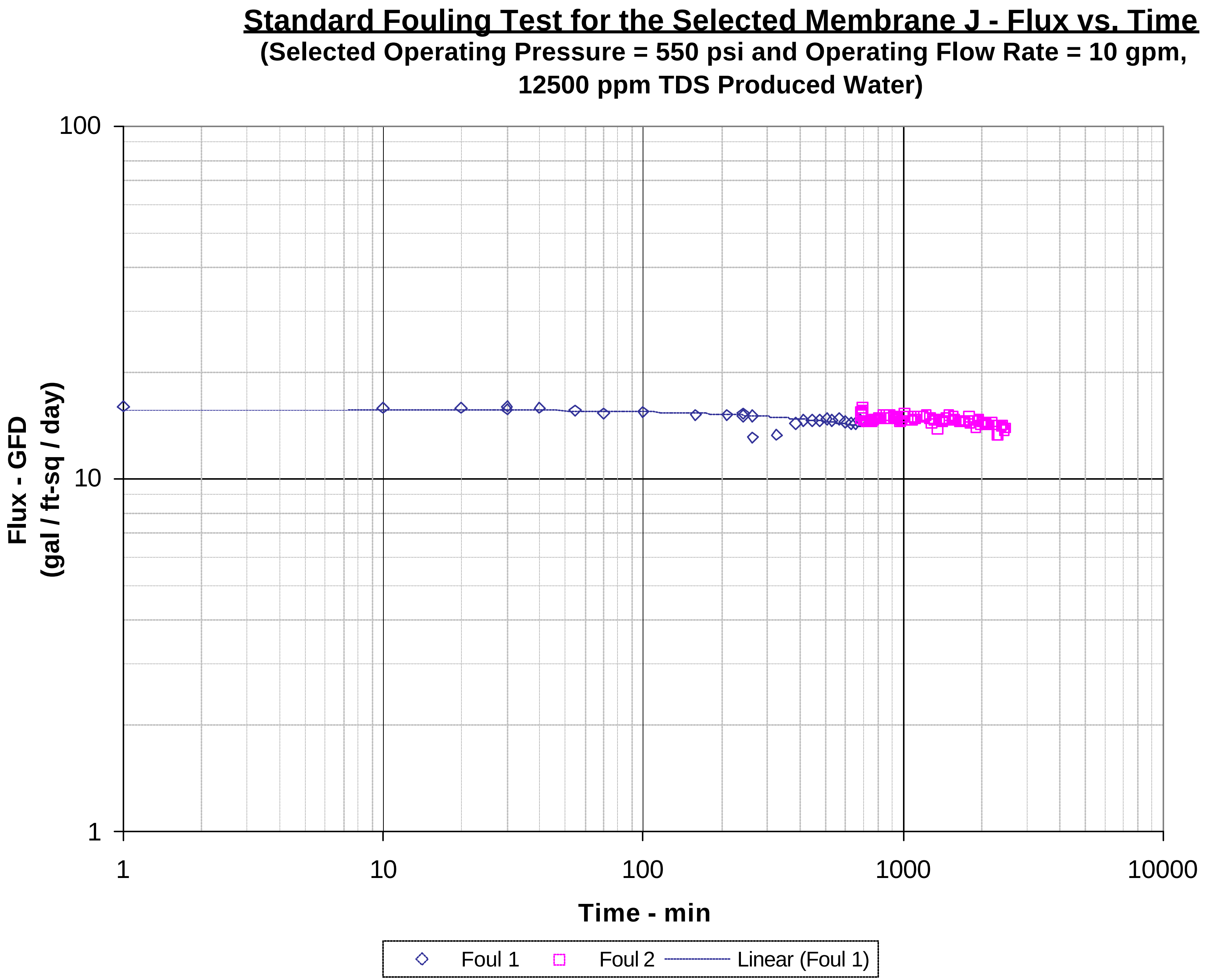


Total Dissolved Solids (TDS) vs. Pressure for the Selected Membrane K at Selected Flow Rates
(12,500 ppm TDS Produced Water - Normalized @ 95 F)
Total Dissolved Solids - ppm TDS
275
250
225
200
175
150
125
100
75
100
200
300
400
500
600
700
800
900
Pressure - psi
14 gpm
11 gpm
8 gpm
8 gpm
11 gpm
14 gpm
Poly. (8 gpm)
Poly. (11 gpm)
Poly. (14 gpm)

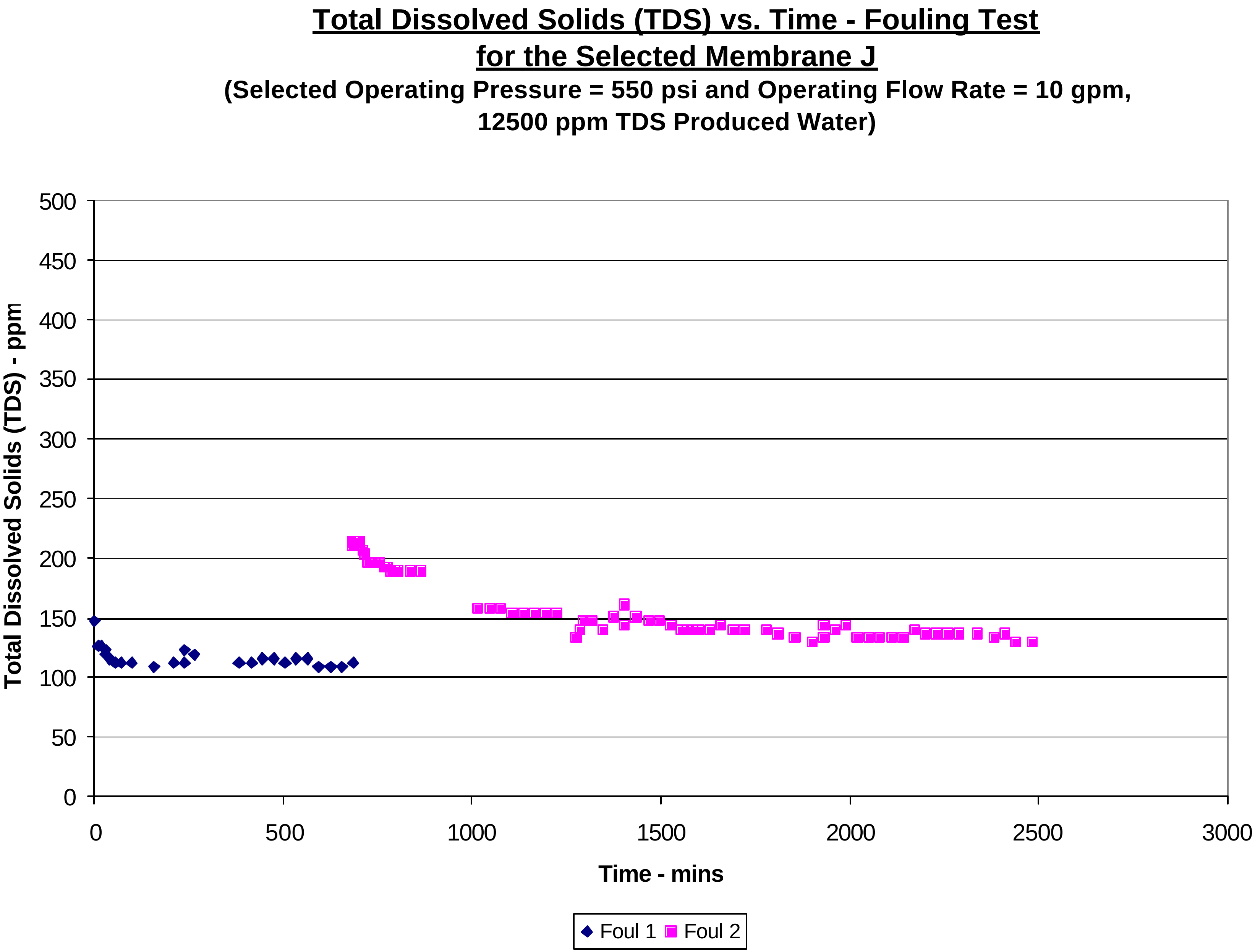
Percent Salt (TDS) Rejection vs. Pressure for the Selected Membrane K at Selected Flow Rates

(12,500 ppm TDS Produced Water - Normalized @ 95 F)





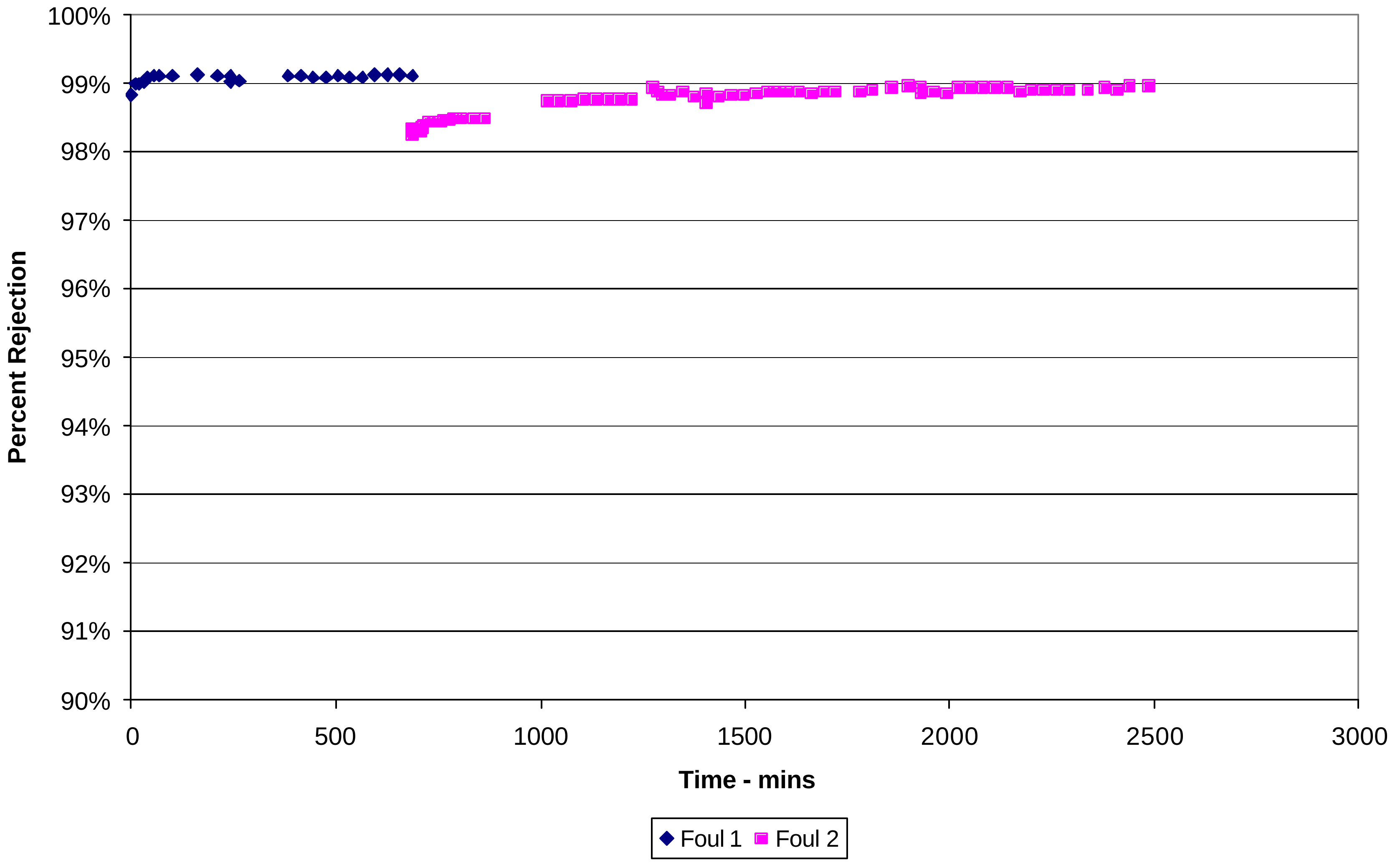
Standard Fouling Test for the Selected Membrane J - Flux vs. Time
(Selected Operating Pressure = 550 psi and Operating Flow Rate = 10 gpm,
12500 ppm TDS Produced Water)
Flux - GFD
(gal / ft-sq / day)
100
10
1
1
10
100
1000
10000
Time - min
Foul 1
Foul 2
Linear (Foul 1)

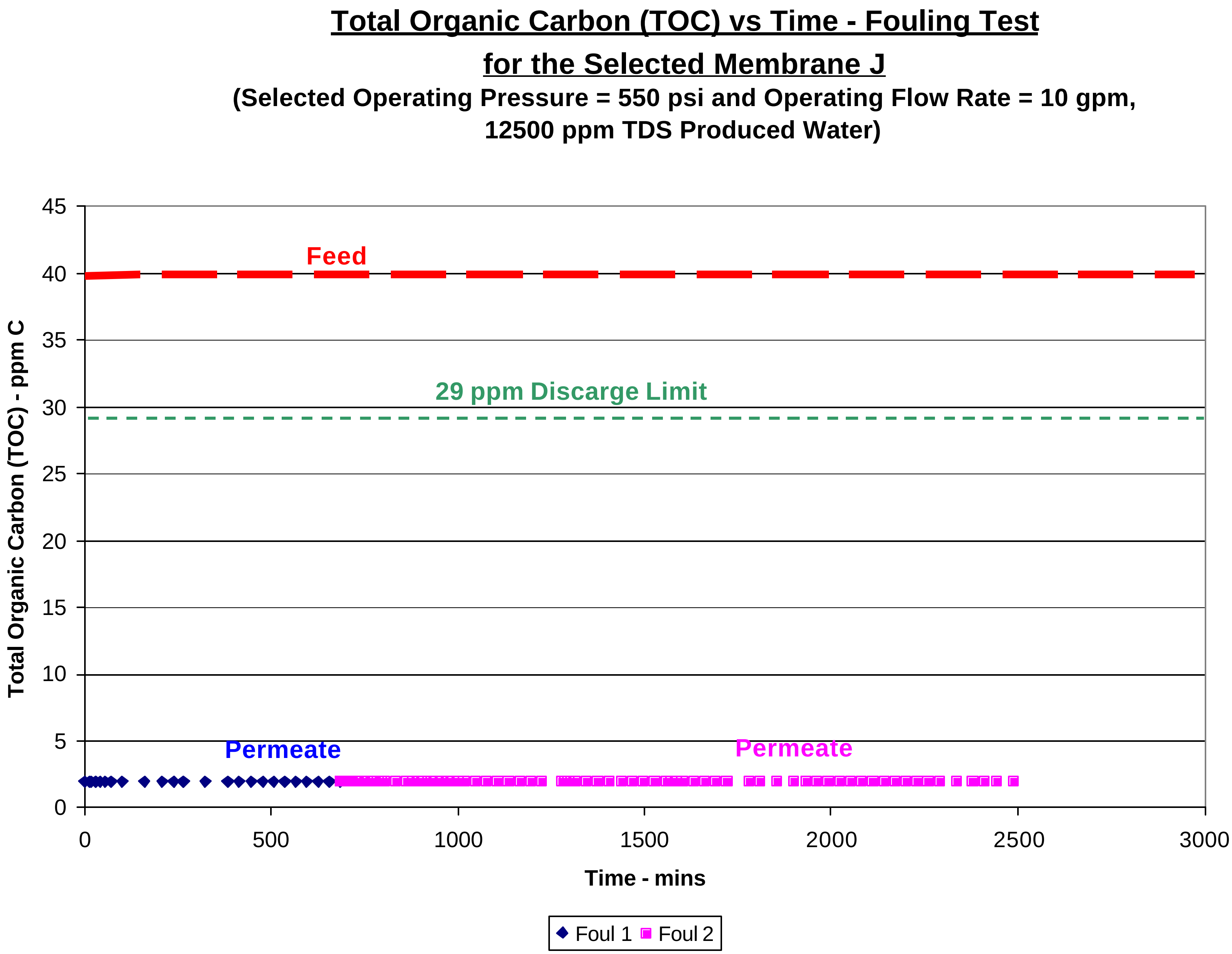


Total Dissolved Solids (TDS) vs. Time - Fouling Test
for the Selected Membrane J
(Selected Operating Pressure = 550 psi and Operating Flow Rate = 10 gpm,
12500 ppm TDS Produced Water)
Total Dissolved Solids (TDS) - ppm
500
450
400
350
300
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
Time - mins
Foul 1
Foul 2

Percent Salt (TDS) Rejection vs. Time for Foling Test for the Selected Membrane J

(Selected Operating Pressure = 550 psi and Operating Flow Rate = 10 gpm, 12500 ppm TDS Produced Water)





Total Organic Carbon (TOC) vs Time - Fouling Test
for the Selected Membrane J
(Selected Operating Pressure = 550 psi and Operating Flow Rate = 10 gpm,
12500 ppm TDS Produced Water)
Feed
29 ppm Discarge Limit
Permeate
Permeate
Total Organic Carbon (TOC) - ppm C
Time - mins
0
5
10
15
20
25
30
35
40
45
0
500
1000
1500
2000
2500
3000
Foul 1
Foul 2

Our Progress

Oilfield Produced Water
200 ppm TOC
42,500 ppm TDS

Partially Treated Water
80 ppm TOC
42,500 ppm TDS

Final Product (Treated Water)
< 8 ppm TOC
< 1,000 ppm TDS

Cost to Treat Yates Field Brine

Total Water Treatment Costs based on Unit Life					
Flow rate (Produced Water)		14500	gpd	10.0694	gpm
Treated Water (Permeate) Flow rate		2500	gpd	1.736	gpm
Years		3	5	7	10
Capital Cost of Treated Water ($/gal)		0.0429	0.0258	0.0184	0.0129
Operation Cost ($/gal)		0.0231	0.0231	0.0231	0.0231
Total Water Cost ($/gal)		0.0660	0.0489	0.0415	0.0360
Total Water Cost ($/1000 gal)		66.03	48.86	41.50	35.99
Total Water Cost ($/day)		165.08	122.16	103.76	89.96
Total Water Cost ($/yr)		60253.79	44587.12	37872.84	32837.12

Objectives of Step 2 of the Water Reuse Project

1. **Water Reuse**

   To design and operate sites for restoration of range land and habitat .

2. **To Monitor the Field Operations**

   Performance of filtration Units
   Growth of Soils/grasses and plant re-establishment
   Wildlife for change in Chromosomal Damage

Portable filtration unit donated to Texas A&M by Koch Micromembrane Filtration Services Inc.

Step 2: Rangeland & Grassland Rehabilitation

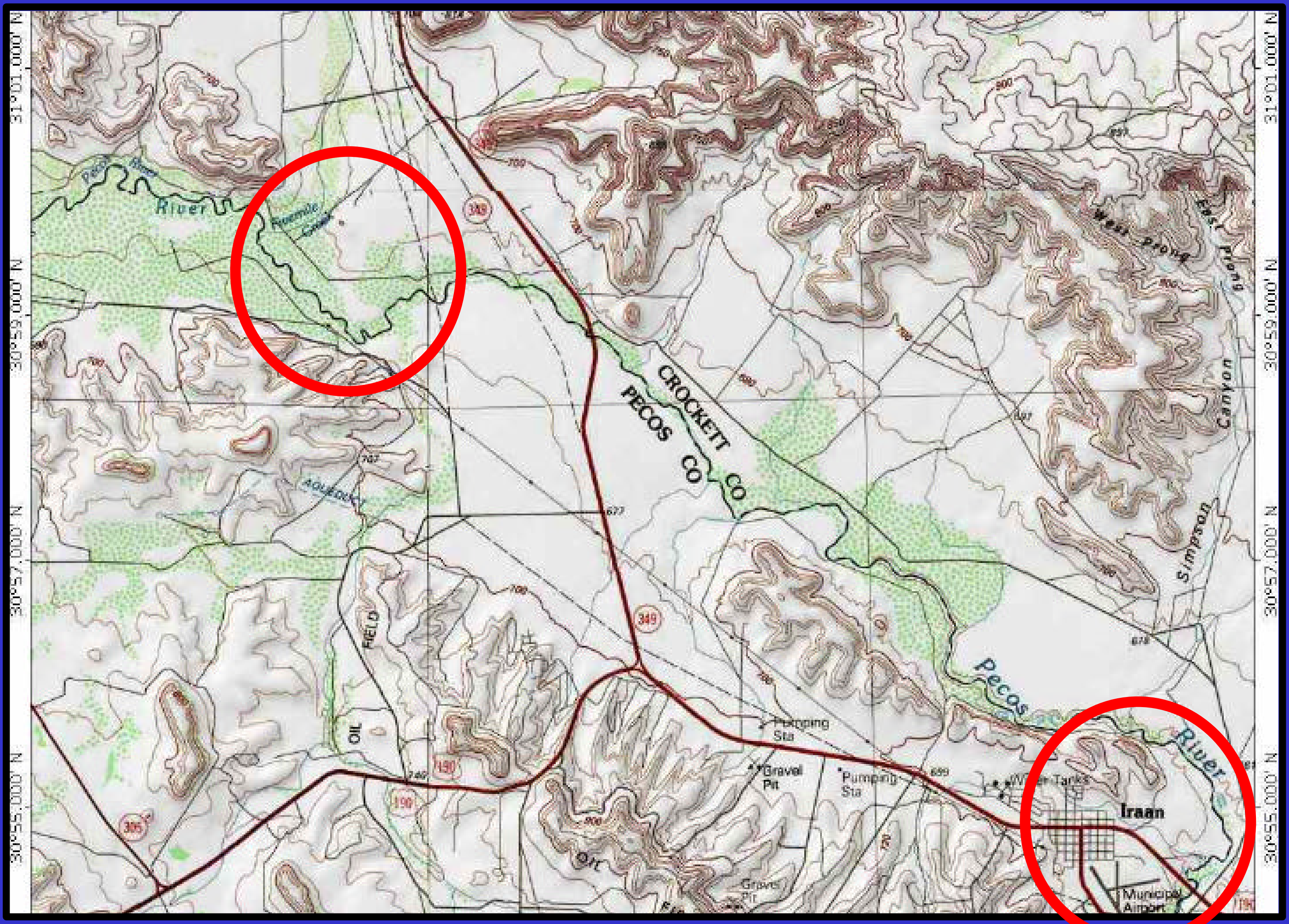
A&M Agriculture Extension Service and Research has special expertise in rangeland management.

Microenvironment Creation for Site Remediation:

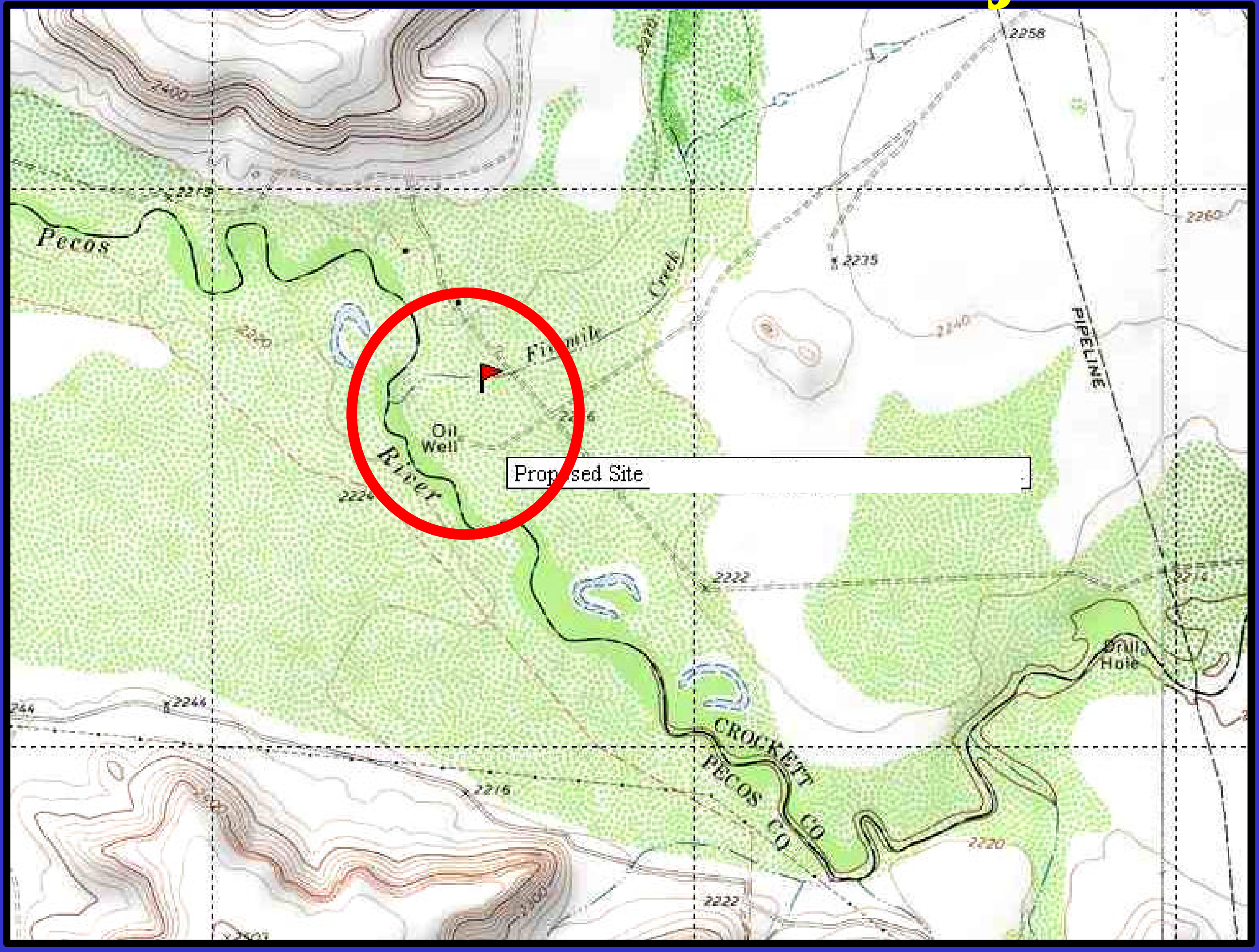
- 2 to 3 acre sites used for field demonstrations
- 1 inch water per month avg. for 24 months
- Monitor EC soil readings, monitor plant growth
- Reestablishing native grasses from seed bank
- Providing nutrients for wildlife and natural grass re establish.

A&M Team: October, 2001, Chevron McElroy Field, Upton Co. TX.

Community of Iraan & Marathon's Yates Ranch Site



Site of Yates Ranch Project



Yates Ranch and Pecos River

Mason Wildlife Management Area Test Plot

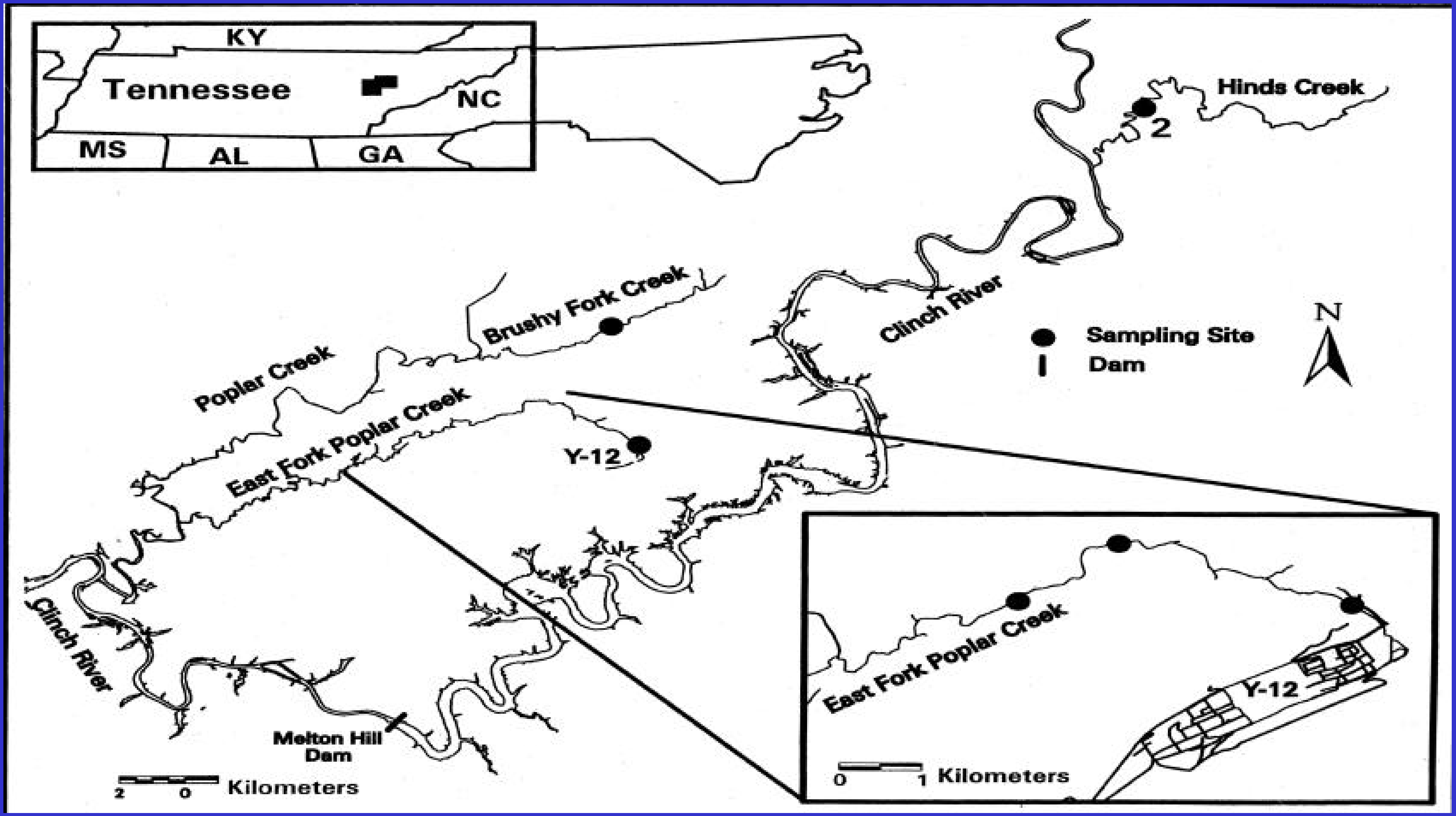

COUNTY
2B

Water Runoff Collector, to Sampler

Step 3: Environmental Monitoring :

1. To Ensure Fresh Water Quality
2. To Measure Filtration Unit Performance
3. To Measure Impact on Soils/ Native Grasses
4. To measure Wildlife for Changes in Chromosomal Damage

Example: Environmental Monitoring Site, Tennessee

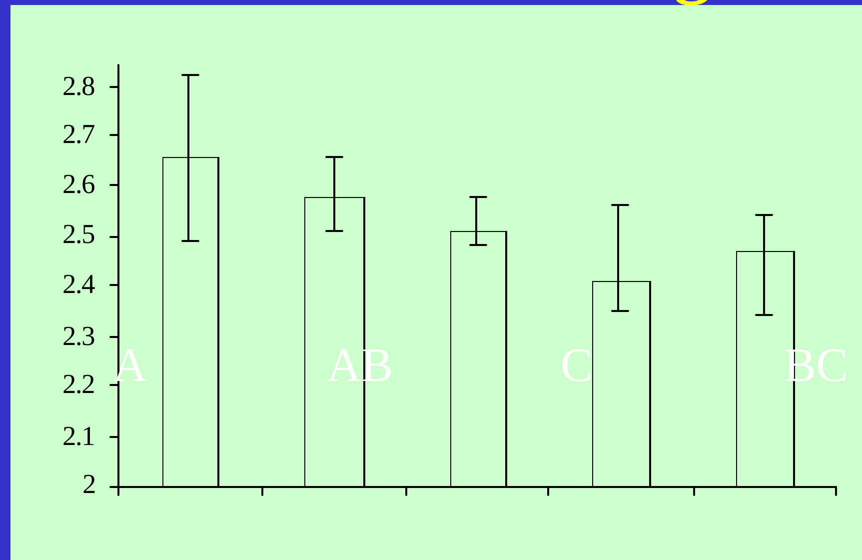


Flow Cytometry DNA Biotyping for Chromosomal Damage

Number of SSB/10^5 bp

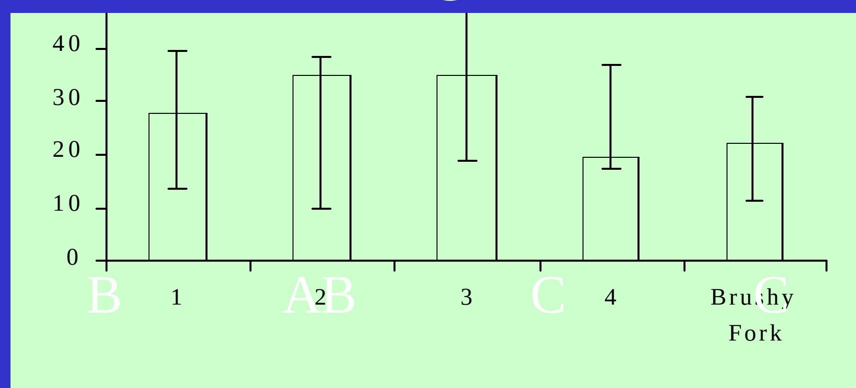
Coefficient of Variation (DNA Content)

A



B. Number of Single-Strand Breaks

A



EFPC Sites

Permits for Field Project: Texas

- RRC Land Treatment Permit – Current Restrictions:
  - Isolated from Ground Water
  - Not subject to flooding
  - Not subjected to erosion
  - Minimize release of pollutants to off-site water, lands or air.
- Texas Natural Resources Codes
  - Announcements in Newspaper –"Commercial Surface Disposal Facility Permit".
  - Public Meeting (subject to Commission's requirements)
- Liability
  - Not defined.

Step 4: Realizing Water to Value for the Community

1. Creation of a Community- Industry Dialog

2. Developing a model for water use and its value to the community.

3. Identifying Incentives for Producers to Treat Water and Provide it for Community Needs

Step 4: The Value of Rangeland and Habitat Restoration

Step 4: Intervention for Rural Community Development

Rural Communities at Risk: Roma Texas

Technology Acceptance – Market Mechanisms & Incentives

- Rangeland and Habitat Restoration
  - The model: Mason Texas Wildlife Management Area
- Creation of “Water Banks” for Community/Industry Venture
  - The model: Wichita Kansas /Jet Blue Airline Venture
- Tax Credits as Incentives to Operators
  - Model: PGA Championship Golf Course Balcones Aquifer Recharge Zone
  - Model: New Mexico Pecos Watershed Augmentation Plan

  - “Tax Enterprise Zones” for Community / Industry Development

Example: Community Needs: Statistics for San Angelo Texas

Population	93,000
Water Usage	20 MM gal.
Average Annual rainfall	18.3 in.
Rainfall 2002	2.2 in.
Condition of O. C. Fisher	9% of capacity (up from 4% in April, 2000)
Monthly oil production, six county area (7/97)	1.7 MM bbl
Daily water disposal (est. based on WOR = 1)	71 MM gal.

June 10, 2002, 12:40AM

Houston Chronicle

Houston Chronicle

HIGH AND DRY

Adventure travel itineraries may run aground if drought conditions persist

By HARRY SHATTUCK

The worst drought in 50 years has put adventure travel off-limits in some areas of the Southwest.

Outfitters are adjusting rafting itineraries in New Mexico, Colorado and Utah -- favorite destinations for many Houston-area vacationers -- because of low water flow.

Also in New Mexico, the Santa Fe and Carson national forests are closed to the public because of fire potential in the kindling-dry forests, requiring hikers, bikers and picnickers to look elsewhere.

The Challenge to Treat Oil Field Brine

- Adapt interdisciplinary skills to oil field operations
- Develop Automated Small Scale Transportable Units
- Relate Environmental and Regulatory Issues to
- Develop Integrated Approach to main areas of work:

  Engineering Program Development

  Field Trial Demonstration segment

  Technical Management and Administration

Thank you!

Rio Grande Valley Agriculture: Restored Irrigation Pump House

David B. Burnett

GPRI

Texas A&M University

409 845 2274

Burnett@GPRI.org

Presentation Available at: http://www.gpri.org